VULNERABILITY, ADAPTATION TO AND COPING WITH DROUGHT: THE CASE OF COMMERCIAL AND SUBSISTENCE RAIN FED FARMING IN THE EASTERN CAPE

Jordaan, A.J. (Editor)

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Vulnerability, Adaptation to and Coping with Drought: The Case of Commercial and Subsistence Rain Fed Farming in the Eastern Cape

Volume I

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by

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Executive Summary

Introduction

Dry periods and droughts remain the major climatological factor with devastating impacts on the livelihoods of most rural people in Africa. The agricultural sector specifically incurs millions of Rand in losses every year. Economic growth in South Africa is severely hampered with every disastrous drought, even given the low contribution of agriculture to GDP in an industrialised economy.

The pro-active approach towards drought management emphasizes the need for coordination and collaboration among all role players. This includes coordination among monitoring agencies in terms of reliable early warning information, communicated in a comprehensible way to decision-makers, farmers, agricultural businesses and all who have an interest in agriculture. Collaboration at national and provincial level among the Department of Agriculture, Forestry and Fisheries (DAFF) at national level, provincial Departments of Agriculture, National and Provincial Disaster Management Centres (NDMC and PDMC), the Department of Water Affairs and Sanitation (DWS), the South African Weather Service (SAWS) and others is essential in this regard.

Most people in agriculture acknowledge climatic extremes, and the fact that the country and society will experience future dry periods, as a given. It is just a matter of when and how severe. The challenge though, is to prevent dry periods from developing into disaster droughts. Important, however, is the vulnerability and the resilience of the agricultural sector and of individual farmers as key factors in drought prevention and mitigation. Several scientists highlight the critical role of vulnerability and resilience in drought risk management. One cannot assess drought risk by assessing solely precipitation, evaporation and transpiration. These are variables used for the hazard assessment and not for total drought risk. Hazard assessment is only one component of the risk assessment equation and that is clearly illustrated in this report.

Vulnerability and resilience are key factors to any disaster risk assessment and should always be assessed in relation to a specific hazard - drought in this case. Scientists have already acknowledged the integration of social, environmental or ecological and economic factors in watershed management since the 1980s. Currently, much research focuses on climate change and future climate scenarios, yet very little work is undertaken on the vulnerability to climate change of the agricultural sector and its communities and more specifically in the extensive livestock sector. The lack of vulnerability and resilience assessments at regional level are major gaps in climate risk assessment. Any drought strategy should support efforts to increase resilience against droughts amongst all role players in agriculture.

The South African National Disaster Management Framework (NDMF) is clear on the need for disaster risk assessments as one of the key performance areas for any disaster risk reduction strategy

- drought in this case. This research provides clear guidelines for future drought risk assessments at a regional scale. The difference between commercial farmers and communal farmers in terms of drought vulnerability is clearly illustrated. Communal farmers, for example, experience normal dry periods as droughts simply because of the lack of adaptive and coping capacity, imperfect markets and additionally as the result of ill-defined property right systems, which lead to increased land degradation and over-grazing. The climate affecting them is the same as that for the rest of commercial farmers, yet this research clearly shows the difference in vulnerability and coping capacity between communal and commercial farmers.

This poses a challenge to institutions responsible for disaster management with regard to the declaration of drought disasters and resultant drought responses from Government. This research highlights the most important indicators for drought declaration that also consider the inherent vulnerability of the communal and subsistence farming system in South Africa. This research provides clear guidelines for drought classification and disaster drought declaration. The National Drought Task Team already accepts the drought indicators proposed in this research as the new guidelines for drought classification and declaration in South Africa.

Contextualization of the Research

The research addresses a serious issue in agricultural risk and disaster management in South Africa. The results of the research provide the basis for a national drought management strategy and provide improved indicators for drought classification and declaration. Provinces currently manage drought disaster declaration and drought response and each province applies different guidelines, which are influenced by politicians and pressure groups. This research provides a set of quantitative measures for drought classification and disaster declaration. The difference in vulnerability and drought resilience between commercial and subsistence farmers is also highlighted, with recommendations made on criteria indicators for drought declaration to each sector.

Study Area

The Eastern Cape is one of the regions most suitable to compare drought vulnerability, adaptation, coping and resilience of commercial and communal subsistence farmers because of the historical demarcation of communal areas. Large areas in the Eastern Cape are still managed by tribal authorities with mainly common property right systems. These areas are entwined with well-planned commercial farms with well-defined individual or private property right systems. The Eastern Cape also covers different rainfall zones with annual precipitation of 1000 mm in the eastern coastal zones to less than 350 mm per annum in the western part of the province. Three districts with the largest diversity were selected as study areas, namely Cacadu, OR Tambo and Joe Gqabi.

Research Objectives

As per the memorandum of agreement the main objective of the research was to propose adaptation and coping strategies to drought risk, based on drought risk assessment for the rain fed farming sector. This included both commercial and communal subsistence farmers and considered risk as a function of hazard, economic/social/ecological vulnerability, adaptation and coping capacity or of resilience. In support of the main objective the following sub-objectives were formulated:

- *Determination of drought hazard assessment by calculating the standard precipitation Index (SPI) and standard precipitation evaporation index (SPEI) for each quaternary catchment in the designated area, with that providing the basis for calculating drought probability, intensity and severity for each catchment;*
- *Determination of economic, social and environmental vulnerability to drought in the designated area;*
- *Determination of current adaptation and coping capacities to drought risk and identification of factors that contribute to drought resilience;*
- *Developing a drought risk profile for the study area;*
- *Developing drought loss functions for the livestock sector and selected rain fed crops in the research area;*
- *Proposing adaptation and coping mechanisms for the commercial livestock sector as well as to communal livestock farmers to future drought risks; and*
- *Proposing a set of indicators for disaster drought classification and declaration*

Research Outcomes

The main outcome of the research is a better understanding of drought and its corresponding vulnerabilities, coping mechanisms and adaptation strategies in the commercial and small-scale communal farming sectors. The following specific outcomes were achieved:

- *Hazard assessment per quaternary catchment in the designated area, this including SPI, drought probability, intensity and severity based on meteorological data (Chapter 3;*
- *Identification and measurement of vulnerability indicators to drought for the rain fed commercial and small-scale communal farming sectors (Chapters 3, 5, 6 and 7);*
- *Calculation of drought risk based on hazard, vulnerability, adaptation and coping mechanisms for each quaternary catchment in the designated area (Volume II Chapter 5);*
- *Identification of adaptation strategies and coping mechanisms for drought in both commercial and small-scale sectors (Volume II Chapter 6);*
- *Provision of a web-based information tool for drought risk management in the selected area, which extension officers, farmers and other role players could use for drought risk planning (See dimtecrisk.ufs.ac.za/wrc_ec, Annexure 4A)*

- *Transfer of knowledge regarding drought risk assessment, vulnerabilities, adaptation and coping strategies to extension officers and farmers (Annexure 1A);*
- *Completion of postgraduate studies for students (Annexure 1A); with a*
- *Major impact possibly being the stimulus to develop a national and uniform drought strategy and plan for South Africa (Volume II, Chapters 9 & 10).*

Reporting

The research report consists of two volumes: Volume I deals with the literature study and hazard assessment. Volume II consists of the risk assessment, vulnerability and coping capacity assessment for communal and commercial farmers, loss functions and proposed drought plans. Volume II ends with the final conclusion and recommendations. Both volumes are structured into different chapters according to the project deliverables and research objectives. Chapters follow each other in a logical manner according to the risk assessment methodology, but each chapter can be read as an entity with an executive summary and list of references for the specific chapter. Chapters are structured as follows:

- *Vol. I, Chapter 1* *Introduction*
- *Vol. I, Chapter 2:* *Description of Study Area*
- *Vol. I, Chapter 3:* *Literature Review*
- *Vol. I, Chapter 4:* *Hazard Assessment*
- *Vol. II, Chapter 5:* *Drought Risk Assessment*
- *Vol. II, Chapter 6:* *Vulnerability Assessment; Communal Farmers*
- *Vol. II, Chapter 7:* *Resilience Assessment; Commercial Farmers*
- *Vol. II, Chapter 8:* *Drought Loss Functions*
- *Vol. II, Chapter 9:* *Drought Indicators for South Africa*
- *Vol. II, Chapter 10:* *Framework for Drought Management Plan*
- *Vol. II, Chapter 11:* *Conclusions and Recommendations*

Following below are executive summaries for each of the chapters.

Introduction

The research background, rationale, objectives and deliverable are reported on in the first chapter. This chapter also provides the research methodology applied during the four years of research as well as aspects regarding the management of the projects. A report on some of the alternative outcomes such as capacity building and knowledge dissemination is captured in an appendix to Chapter 1.

Description of Study Area

Chapter 2 only deals with the identification and description of the study area. The selection of a suitable study area was important in that the study area should allow for the comparison of vulnerabilities and coping mechanisms to drought between the livestock commercial farming system and communal small-scale and subsistence farming under similar climatic conditions.

The districts OR Tambo, Cacadu and Joe Qgabi were considered to be good study areas since commercial farms and communal land are entwined, especially near the former Ciskei and Transkei areas. This chapter elaborates on the demarcation of the study area and describes drought related features such as climate, agricultural systems, land use, environment, and the socio-economic profile of the selected districts.

The research methodology described in Chapter 1 only covers methodology applied to complete the description of study area. The primary source of information was a literature study of available documentation (i) on the web as well as (ii) offices of the Eastern Cape Department of Agriculture and Rural Development in Bisho, East London and Port Elizabeth, (iii) the National Department of Rural Development and Land Reform in East London and Pretoria, (iv) the South African Weather Service (SAWS) in Port Elizabeth, (v) Statistics South Africa (StatsSA) and (vi) District Municipalities.

Individuals consulted include, inter alia, (i) the Director General of the Department of Agriculture and Rural Development in the Eastern Cape, (ii) the Assistant Director of the National Department Rural Development, Eastern Cape region, (iii) Regional Directors, Eastern Cape Department of Agriculture and Rural Development, (iv) officials from the South African Weather Service (SAWS) in Port Elizabeth, (v) farmer representatives from Eastern Cape Agri as well as (vi) middle management officials working for the Department of Agriculture and Rural Development. GIS specialists provided the GIS data, including shape files from (i) the Department of Agriculture and Rural Development, (ii) the National Department of Rural Development, and (iii) the Department of Geography at the University of the Free State.

Transect drives were also undertaken through parts of the study area unfamiliar to the project leader. Information reported in this chapter was selected, summarized and analysed based on its relevance to drought risk. Economic, social and environmental vulnerability and capacity to deal with exogenous shocks are, together with meteorological influences, the most important factors contributing to drought risk. This chapter therefore focuses on the indicators relevant for drought risk.

Literature Review

A thorough literature review provided for a better understanding of what was done locally and internationally on drought risk, vulnerability, resilience and coping capacities. It also served as a guide to identifying relevant methodologies used by other researchers for similar projects.

Drought risk is a function of the frequency and the severity of drought as well as the vulnerability, susceptibility, resilience and the impact of drought or dry conditions. One of the main challenges in drought risk assessment is the identification of indicators and the weighting of these indicators in relation to each other. Indicators for social, economic and environmental vulnerability as well as coping capacity and adaptation were identified and evaluated in the context of their relevancy to the livestock and crop production sector in the proposed study area.

The literature review in this chapter analysed the different methods of risk assessment and focused on theoretical models for vulnerability and resilience. The concept of resilience is especially highlighted in that the answer for drought risk reduction is embedded in a resilient system.

Hazard Assessment

This chapter focused on the drought hazard (H), i.e. the meteorological variables in the drought risk assessment equation. Historical meteorological data are analysed for all 260 quaternary catchments in the selected three districts namely Joe Gqabi, OR Tambo and Cacadu. A website http//dimtecrisk.ufs.ac.za/wrc_ec was developed as an interactive tool for analysing data "on the fly". The large volumes of data available made it impossible to present all data in hard copy in a single report. Reliable time series of meteorological data remains one of the challenges. For the analysis, a base period from 1950 to 1999 (50 years) was utilised for quaternary catchments and a base period from 1900 to 1998 for point data. Reliable data could be obtained for a few point stations, stretching from 1900 to 2010. These data were used to estimate alpha and beta parameters of the gamma distribution, which are used to calculate the cumulative probabilities of precipitation events.

The analysis of precipitation shows a slight decrease in precipitation in the higher rainfall zones and a slight increase in the lower rainfall zones. The number of rainy days in the high rainfall zones, on the other hand, shows a declining trend while it remain constant in the lower rainfall zones; an indication of potentially higher rainfall intensity in the higher rainfall zones. Changes in both annual precipitation and the number of rainy changes are, however, statistically not significant with p values being too high. The average temperature and evapotranspiration have a positive trend; they also are statistically not significant with the exception of a number of catchments where a significant positive trend in temperature was detected. Drought frequency and intensity were calculated for each catchment based on historical data and were used for calculating drought risk.

Drought Risk Assessment

The calculation of drought risk in the selected study areas is explained and illustrated in Chapter 4. The framework for indicator selection in this research is the Community Capitals Framework. Indicators, which were grouped as part of each capital for both vulnerability and coping capacity. All indicators as well as the seven capitals were weighted according their contribution, or importance, to drought risk. Weightings of the seven capitals are (i) human = 0,12, (ii) social = 0,04, (iii) cultural = 0,10, (iv) financial = 0,27, (v) infrastructure = 0,08, (vi) environmental = 0,35, and (vii) political = 0,04.

Weighting was done arbitrarily after inputs from experts, experienced commercial farmers and communal farmers. The research team finally allocated weights arbitrarily according to these expert inputs. For better accuracy the weighting process was repeated after two months and adjusted accordingly.

The results show a higher than expected hazard risk for the higher rainfall OR Tambo district. Vulnerability is also the highest in OR Tambo due mainly to serious land degradation and human, social and cultural factors. Resiliency, on the other hand, is also lower in OR Tambo, but not as dramatic as vulnerability, due to the potential of the natural resources, soil and water availability. Drought risk, however, is the highest in OR Tambo. One would have expected drought risk to be the highest in the arid Karoo region, but it was not the case due to low coping capacity and high vulnerability of farmers in OR Tambo district. Drought risk was the lowest in catchments with available water for irrigation where farmers have the opportunity for diversification and stocking of fodder banks.

Drought Vulnerability: Communal Farmers

The focus in Volume II Chapter 5 is on the analysis of drought vulnerability amongst communal farmers. Understanding farmers' vulnerability to drought is complicated, yet very necessary for planning preparedness, mitigation and response policies and programs. Vulnerability highlighted the various burdens of drought losses that farmers experienced in different locations. The Eastern Cape (EC) regularly experienced drought, with government relief programs mostly too late. Drought relief, however, does not provide insight into peoples' vulnerability; it does not reduce risk or improve resiliency against drought. This chapter identified and highlighted the factors that render communal farmers vulnerable to drought.

Mixed methods of qualitative and quantitative approaches were used to analyse drought vulnerability. In order to familiarize researchers with the study area, transect trips were carried out through the study area. These provided valuable insights to the different agricultural systems in the study area. During these transect tours several vulnerability indicators were identified, such as overgrazing, soil erosion, land degradation, cultural practices and the availability of natural resources.

An indicator method, based on a combination of the Bogardi Birkmann & Cordona (BBC) framework and the Community Capitals framework (CCF), was used to assess farmers' vulnerability and resilience to drought. Five environmental indicators, eleven social indicators and seven economic indicators were identified and subjected to the assessment process.

Farmers in Cacadu district reported problems with surface and ground water supply. In OR Tambo, it was observed that overgrazing, soil erosion and land degradation contributed mostly to drought vulnerability. Farmers from Joe Gqabi reported moderate vulnerability to drought. Economically, farmers from the three districts perceived the lack of safety nets, dependency on agriculture (lack of diversification) and level of debt as contributing more to vulnerability than the other factors. OR Tambo district had the highest economic vulnerability index, followed by Joe Gqabi and Cacadu with *estimated high indices. With regard to social vulnerability, the results revealed an extremely high social vulnerability index for farmers in OR Tambo district, high vulnerability for farmers in Joe Gqabi and moderate vulnerability for farmers in Cacadu. According to their perceptions, farmers viewed psychological stress, cultural values and practices and the lack of preparedness strategies as contributing the most to social vulnerability to drought.*

Overall, vulnerability to drought was estimated to be very high for farmers from OR Tambo district, followed by Joe Gqabi, with Cacadu having the lowest vulnerability index. On the other hand, the results also indicated that farmers from these three districts are not completely vulnerable to drought. They have some coping mechanisms of which indigenous knowledge allowed them to continue with farming in spite of previous droughts. The study concluded that whilst dry periods are frequent in the three districts, there are social, economic and environmental factors that contribute to vulnerability as well as coping capacity.

Drought Resilience; Commercial Farmers

This chapter contains the results for drought resilience with the focus on commercial farmers. The Community Capitals Framework (CCF7) was used as a framework to explain drought resilience and it explained the resilience of the commercial farming sector in contrast to the vulnerability of communal farmers. The capitals analysed in the CCF7 framework were (i) human, (ii) social, (iii) cultural, (iv) financial, (V) infrastructure, (vi) environmental, and (vii) political. Identification of the indicators serve as a good source for future planning of beneficiary selection for land reform as well as for the development of extension programs in support to all new entrants. The communal farmers can also learn from the results in order to increase their own drought resilience.

The results clearly showed the importance of all capitals as elements of resilience building. Commercial farmers regarded experience gained through mentorship and good extension services at the beginning of their farmer careers as extremely important in their success today. The importance of private land ownership and well-planned farms with infrastructure such as camp systems and water articulation systems were equally important. The CCF7 was used for the calculation of drought risk. Each of the capitals consisted of several indicators. These indicators, as well as the capitals, were weighted and indexed for use in the drought risk equation.

Drought Loss Functions

Calculations of Mean Annual Loss (MAL) and the development of loss functions are particularly important to the insurance industry since they provide an indication of what is needed during the good years for coverage during dry years. Drought insurance has been too costly and risky for insurance companies until now. Insurers and re-insurers, however, should investigate the possibility of index insurance where the SPI could be used as an index for drought loss payments. The exposure and probability of dry periods are relatively easy to calculate and are expressed as SPI values. Actuaries *should be able to calculate the exposure to the insurers once the MAL and loss function is known. Farmers instead, could use the MAL as a guideline on what they could afford in terms of premiums.*

The only sectors with reliable data for the development of loss functions were the mohair and wool sectors. Mohair farmers reported that mohair production during dry years could not be compared to other years since farmers provided additional feeding during dry years because of expected higher than normal prices. South Africa remains the largest mohair producer in the world and therefore determines global mohair prices. Wool prices, on the other hand, are determined by production in Australia and not in South Africa. We therefore decided to analyse the wool production system and develop loss functions for wool production. Loss functions were developed based on production output at district and farm level.

This study found no correlation between annual precipitation and wool yield and we therefore rejected the null hypothesis that drought impacted on wool production without considering the additional inputs during dry years. We also tested a potential lag effect, but the results also showed no correlation. These results were in contrast to what farmers believed and to the initial assumption of the research team. This result highlighted the importance of the wool production system as a resilient system to droughts and dry periods. Considering climate change scenarios of warmer weather and an increase in the intensity and frequency of dry periods and droughts, wool sheep farming seems to be a resilient system with good potential as an adaptation strategy. Wool farmers, in fact, reported excellent income levels even during dry years, but mention predators as the biggest threat to small stock farming and not droughts and dry periods.

Development of loss functions for maize production was challenging in the absence of reliable historical data. The research team could obtain historical farm level maize production data only from 2006, but that was not sufficient to develop a robust drought loss function for maize. In desperation the SAPWAT program was adjusted for use for dry land conditions. The potential of the SAPWAT model as a decision support tool for dry land crop production became evident during the research. After a few adjustments to the SAPWAT3 software, loss functions were calculated for maize production in different catchments. The results demonstrated the use of the SAPWAT model for dry land application, but more research is required for the development of a new dry land SAPWAT model. More work is still required to ground-truth the results and to adapt the model fully for dry land applications.

Drought Indicators for South Africa

Drought classification and the application of drought indicators are essential elements in drought management and drought monitoring. Drought classification is normally based on certain indicator thresholds and provides a framework for drought management. The drought classification, indicator selection and indicator thresholds discussed in this chapter are the result of research completed as *part of this project as well as inputs from the National Drought Task Team expert sub-committee for drought indicators development.*

Drought was categorized into five categories namely (i) D0 – Dry, (ii) D1 – Moderately dry, (iii) D2 – Severe drought, (iv) D3 – Extreme drought, and (v) D4 – Exceptional drought. Indicators were classified as primary indicators, which are easy to monitor on a daily basis, and secondary indicators, which focus more on drought impacts. Primary indicators were categorized as meteorological indicators, agricultural indicators, which are remotely sensed, and hydrological indicators. Thresholds were proposed for all the indicators, but the difference between different sectors such as small-scale communal farmers and commercial farmers were also highlighted.

This chapter provides a guide for drought indicators for future drought management in South Africa. The proposed indicators are in line with international best practice. Two of the leading countries in the world on drought management, the USA and Mexico, utilised similar indicators for drought monitoring and drought declaration. The USA expanded the number of indicators to more than 20 and is therefore in a position to better monitor the impacts of drought at all levels. Ten primary indicators are proposed for South Africa as a result of this research. This should be expanded in future. The National Drought Task Team of South Africa accepted the proposed indicators as a good start and the Department of Agriculture, Forestry and Fisheries (DAFF) and the National Disaster Management Centre (NDMC) should formalise the use of these indicators for all of South Africa.

Framework for Provincial Drought Management Plan

South Africa (SA) has a well-developed economy with a strong agricultural sector and the citizens in SA are largely protected from the most critical effects of drought such as water and food shortages. However, the 2015/2016 drought created awareness of the critical effects of a prolonged drought and the danger of not maintaining water infrastructure properly. Whereas the agricultural sector suffered the most as a result of drought in the past, densely populated urban areas are expected to also suffer water shortages in future droughts if South Africa does not plan properly for the next drought.

The drought plan template proposed in this chapter was based on the National Disaster Management Framework and consists of the 4 Key Performance Areas (KPAs) namely:

- *KPA 1: Integrated institutional capacity for drought management*
- *KPA 2: Drought risk assessment*
- *KPA 3: Drought risk reduction*
- *KPA 4: Response and recovery*

The 3 Enablers are the following:

- *Enabler 1: Information management and communication*
- *Enabler 2: Education, training, public awareness and research*

- *Enabler 3: Funding*

It is possible to use the drought plan template proposed in this chapter as a template for all three levels of governance namely district, provincial and national. Development of a drought plan, however, should follow a process of consultation with all stakeholders. Also important, however, is the alignment of national guidelines at all levels of governance. The drought classification, indicators and drought relief measures should be standardised for all government levels.

The implementation of a drought strategy should follow 10 steps, as follows:

1. *Appoint a drought Task Team*
2. *State the purpose and objectives of the drought plan*
3. *Seek stakeholder participation and resolve areas of conflict or duplication*
4. *Inventorise resources and identify groups at risk (risk assessment)*
5. *Establish and write the drought plan*
6. *Identify research needs and fill institutional gaps*
7. *Integrate science and policy*
8. *Publicize the drought plan*
9. *Develop education and awareness programs*
10. *Evaluate and revise drought plan.*

The drought plan template proposed in this chapter is just one of the phases in the development of a provincial or national drought management strategy.

Recommendations for Drought Resilience

The focus of the final chapter is on recommendations for increased resilience against drought. Drought risk reduction strategies are proposed for the different affected sectors, namely communal farmers, land reform farmers and commercial farmers. Recommendations for the supportive role players such as government and municipalities as landowners are also provided in separate tables.

The Community Capitals Framework (CCF7) serves as basis of the recommendations for resilience building. Factors contributing toward high vulnerability were identified and grouped under the CCF7 framework.

Knowledge Dissemination

Knowledge dissemination was one of the major outcomes of the research. The method of action research provided the opportunity to share results with farmers and extension officers during the research period and thereby created a "feedback loop" that assisted the research team to continually evaluate results and findings.

One hundred and thirty nine extension officers, 285 communal farmers and 8 mentors participated in 12 workshops in the three districts. Workshops were interactive with the research team that provided training and feedback on research progress during morning sessions and information gathering during afternoon sessions. The research results have already been shared with commercial farming leaders and AGBiZ leadership at the 2016 AgriSA annual meeting.

Research results were presented as conference presentations at 12 international and 5 national conferences. Two papers have already been published in peer-reviewed journals, three papers are currently under final review and three more papers are in final stages of preparation.

Capacity Building

Eight postgraduate students participated in the project. Two students have already obtained their Masters degrees. Two Master students obtained full time job appointments and should hand in their final thesis during 2017. One PhD candidate should finalise his thesis during 2017 with another PhD candidate plans completion of his research in 2018. The remaining two students enrolled for studies at other Universities owing to personal circumstances.

Capacity building was also targeted at extension officers and farmers. As already alluded to,139 extension officers, 285 communal farmers and 8 mentors participated in 12 workshops where they received training of drought risk management.

Conclusion: Project Impact

The research has provided a better understanding of the complexity of drought risk. Integration of the community capitals and the BBC framework provided a new framework for drought risk assessment and planning for resilience. The issues that contributed to high drought vulnerability amongst communal farmers were highlighted and recommendations were made to address these challenges. The factors contributing to drought resilience were also identified and farmers can learn from these outcomes. Recommendations were also made based on "best practice".

The project has already provided the framework for drought classification in South Africa. The National Drought Task Team has already accepted the proposed classification and indicator thresholds for drought classification. The project also provided a framework for the development of a national, provincial and local drought management plan. The difference between the communal farming sector and commercial sector was a main conclusion of the research and authorities have taken note of the fact that dry periods are already droughts for communal farmers and that this therefore necessitates the requirement of different thresholds for drought declaration for different sectors.

The research also highlighted several areas for future research.

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Abbreviations

ADPC	Asian Disaster Preparedness Centre
ADRC	Asian Disaster Reduction Centre
AIDS	Acquired Immune-Deficiency Syndrome
ANTA	Australian National Training Authority
ARC	Agricultural Research Council
BBC	Birkman, Bogardi & Cardona
CBS	Columbia Broadcasting System
CDI	Combined Degradation Index
CDM	Cacadu District Municipality
CoBRA	Community-Based Resilience Analysis
CWRM	Commission on Water Resource Management
DAFF	Department of Agriculture, Forestry and Fisheries
DARD	Department of Agriculture and Rural Development
DBSA	Development Bank of South Africa
DFID	Department for International Development
DWA	Department of Water Affairs
EC	Eastern Cape
ECLAC	Economic Commission and Caribbean for Latin America
ECSECC	Eastern Cape Socio-Economic Consultative Council
EW	Early Warning
EWS	Early Warning System
FAO	Food and Agriculture Organisation
FEWS	Famine Early Warning System
FS	Free State
GGP	Gross Geographic Product
GVA	Gross Value Added

HIV	Human Immune-Deficiency Virus
IBRTP	Index-based Risk Transfer Products
IDP	Integrated Development Plan
IFPRI	International Food Policy Research Institute
IFRC	International Federation of Red Cross
IPCC	Intergovernmental Panel on Climate Change
ISDR	International Strategy for Disaster Reduction
JGDM	Joe Gqabi District Municipality
KG	Kilogram
KZN	KwaZulu-Natal
LM	Local Municipality
LSU	Large Stock Unit
LTAS	Long Term Adaptation Scenarios
MAI	Moisture Anomaly Index
MAL	Mean Annual Loss
MDGs	Millennium Development Goals
NCEC	National Crop Estimate Committee
NDMC	National Disaster Management Centre
NDMC (US)	National Drought Mitigation Centre (US)
NDMF	National Disaster Management Framework
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organisation
NRLD	National Report on Land Degradation
ORTDM	OR Tambo District Municipality
PDMC	Provincial Disaster Management Centre
PDSI	Palmer Drought Severity Index
QRA	Quantitative Risk Analysis

SASSA	South Africa Social Security Agency
SAWS	South African Weather Service
SDI	Soil Degradation Index
SOER	State of the Environmental Report
SPEI	Standard Precipitation Evaporation Index
SPI	Standard Precipitation Index
SSU	Small Stock Unit
UN	United Nations
UNGA	United Nations General Assembly
UNDP	United National Development Programmes
UNEP	United Nations Environment Programme
UNISDR	United Nations International Strategy for Disaster Reduction
UNSSO	United Nations Sudano-Sahelian Office
US	United States of America
USAID	United States Agency for International Development
VDI	Veld Degradation Index
WC	Western Cape
WFP	World Food Programme
WHO	World Health Organisation
WRC	Water Research Commission

Glossary of Terms

The different concepts and definitions used in this report are discussed and explained in the following section: In order to remain in line with international concepts and definitions, the main sources for definitions were the United Nations General Assembly (UNGA) 2016 and the United Nations International Strategy for Disaster Reduction (UNISDR) 2004. Definitions are discussed in alphabetical order.

Acceptable Risk (Knutson *et al.,* 1998; UNISDR, 2004)	The level of loss a society or community considers acceptable risk given existing social, economic, political, cultural, technical and environmental conditions. Also refers to acceptable risk as a level of vulnerability that is considered to be "*acceptable,"* balancing factors such as cost, equity, public input, and the probability of drought.
Affected (UN General Assembly, 2016)	People who are affected, either directly or indirectly, by a hazardous event. Directly affected are those who have suffered injury, illness or other health effects; who were evacuated, displaced, relocated or have suffered direct damage to their livelihoods, economic, physical, social, cultural and environmental assets. Indirectly affected are people who have suffered consequences, other than or in addition to direct effects, over time, due to disruption or changes in economy, critical infrastructure, basic services, commerce or work, or social, health and psychological consequences. *Annotation: People can be affected directly or indirectly. Affected people may experience short term or long term consequences to their lives, livelihoods or health and to their economic, physical, social, cultural and environmental assets. In addition, people who are missing or dead may be considered as directly affected.*
Biodiversity (UNDP, 2008)	Refers to the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes to which they belong; this includes diversity within species, among species and within ecosystems
Capacity (UN General Assembly, 2016)	The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience. *Annotation: Capacity may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management.* ***Coping capacity** is the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.* ***Capacity assessment** is the process by which the capacity of a group, organization or society is reviewed against desired goals, where existing capacities are identified for maintenance or strengthening and capacity gaps are identified for further action.*

	Capacity development *is the process by which people, organizations and society systematically stimulate and develop their capacities over time to achieve social and economic goals. It is a concept that extends the term of capacity building to encompass all aspects of creating and sustaining capacity growth over time. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems and the wider enabling environment.*
Capacity Building (UNISDR, 2004)	Efforts aimed to develop human skills or societal infrastructures within a community or organization needed to reduce the level of risk. In extended understanding, capacity building also includes development of institutional, financial, political and other resources, such as technology at different levels and sectors of the society.
Climate Change (UNISDR, 2004)	The climate of a place or region is changed if over an extended period (typically decades or longer) there is a statistically significant change in measurements of either the mean state or variability of the climate for that place or region. Changes in climate may be due to natural processes or to persistent anthropogenic changes in atmosphere or in land use (UNISDR, 2004). The definition of climate change used in the United Nations Framework Convention on Climate Change (UNFCCC) is more restricted, as it includes only those changes, which are attributable directly or indirectly to human activity (UNFCCC, 2008). According to the UNDP (2008) climate change refers to deviations from natural climatic variability observed over time that are attributed directly or indirectly to human activity and that alter the composition of the global atmosphere. Both the UNFCCC and the UNDP use the definition that attributes climate change to human activity. In the context of this study the UNFCCC and UNDP definitions hold.
Contingency Planning (UN General Assembly, 2016)	A management process that analyses disaster risks and establishes arrangements in advance to enable timely, effective and appropriate responses. *Annotation: Contingency planning results in organized and coordinated courses of action with clearly identified institutional roles and resources, information processes and operational arrangements for specific actors at times of need. Based on scenarios of possible emergency conditions or hazardous events, it allows key actors to envision, anticipate and solve problems that can arise during disasters. Contingency planning is an important part of overall preparedness. Contingency plans need to be regularly updated and exercised.*
Coping Capacity (UN General Assembly, 2016)	The ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.
Desertification (UNDP, 2008).	The process of land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.
Disaster (UN General Assembly, 2016)	A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

	Annotations: The effect of the disaster can be immediate and localized, but is often widespread and could last for a long period of time. The effect may test or exceed the capacity of a community or society to cope using its own resources, and therefore may require assistance from external sources, which could include neighbouring jurisdictions, or those at the national or international levels. ***Emergency** is sometimes used interchangeably with the term disaster, as, for example, in the context of biological and technological hazards or health emergencies, which, however, can also relate to hazardous events that do not result in the serious disruption of the functioning of a community or society.* ***Disaster damage** occurs during and immediately after the disaster. This is usually measured in physical units (e.g., square meters of housing, kilometres of roads, etc.), and describes the total or partial destruction of physical assets, the disruption of basic services and damages to sources of livelihood in the affected area.* ***Disaster impact** is the total effect, including negative effects (e.g., economic losses) and positive effects (e.g., economic gains), of a hazardous event or a disaster. The term includes economic, human and environmental impacts, and may include death, injuries, disease and other negative effects on human physical, mental and social well-being.* *For the purpose of the scope of the Sendai Framework for Disaster Risk Reduction 2015-2030 (para. 15), the following terms are also considered:* *• Small-scale disaster: a type of disaster only affecting local communities which require assistance beyond the affected community.* *• Large-scale disaster: a type of disaster affecting a society which requires national or international assistance.* *• Frequent and infrequent disasters: depend on the probability of occurrence and the return period of a given hazard and its impacts. The impact of frequent disasters could be cumulative, or become chronic for a community or a society.* *• A slow-onset disaster is defined as one that emerges gradually over time. Slow-onset disasters could be associated with, e.g., drought, desertification, sea-level rise, epidemic disease.* *• A sudden-onset disaster is one triggered by a hazardous event that emerges quickly or unexpectedly. Sudden-onset disasters could be associated with, e.g., earthquake, volcanic eruption, flash flood, chemical explosion, critical infrastructure failure, transport accident.*
Disaster Management (UN General Assembly, 2016)	The organization, planning and application of measures preparing for, responding to and recovering from disasters. *Annotation: Disaster management may not completely avert or eliminate the threats; it focuses on creating and implementing preparedness and other plans to decrease the impact of disasters and “build back better”. Failure to create and apply a plan could lead to damage to life, assets and lost revenue.* ***Emergency management** is also used, sometimes interchangeably with the term disaster management, particularly in the context of biological and technological hazards and for*

	health emergencies. While there is a large degree of overlap, an emergency can also relate to hazardous events that do not result in the serious disruption of the functioning of a community or society.
Disaster Risk Governance (UN General Assembly, 2016)	The system of institutions, mechanisms, policy and legal frameworks and other arrangements to guide, coordinate and oversee disaster risk reduction and related areas of policy. *Annotation: Good governance needs to be transparent, inclusive, collective and efficient to reduce existing disaster risks and avoid creating new ones.*
Disaster Risk Management (UN General Assembly, 2016)	Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses. *Annotation: Disaster risk management actions can be distinguished between prospective disaster risk management, corrective disaster risk management and compensatory disaster risk management, also called residual risk management.* ***Prospective disaster risk management** activities address and seek to avoid the development of new or increased disaster risks. They focus on addressing disaster risks that may develop in future if disaster risk reduction policies are not put in place. Examples are better land use planning or disaster-resistant water supply systems.* ***Corrective disaster risk management** activities address and seek to remove or reduce disaster risks which are already present and which need to be managed and reduced now. Examples are the retrofitting of critical infrastructure or the relocation of exposed populations or assets.* ***Compensatory disaster risk management** activities strengthen the social and economic resilience of individuals and societies in the face of residual risk that cannot be effectively reduced. They include preparedness, response and recovery activities, but also a mix of different financing instruments, such as national contingency funds, contingent credit, insurance and reinsurance and social safety nets.* ***Community-based disaster risk management** promotes the involvement of potentially affected communities in disaster risk management at the local level. This includes community assessments of hazards, vulnerabilities and capacities, and their involvement in planning, implementation, monitoring and evaluation of local action for disaster risk reduction.* ***Local and indigenous peoples' approach to disaster risk management** is the recognition and use of traditional, indigenous and local knowledge and practices to complement scientific knowledge in disaster risk assessments and for the planning and implementation of local disaster risk management.* ***Disaster risk management plans** set out the goals and specific objectives for reducing disaster risks together with related actions to accomplish these objectives. They should be guided by the Sendai Framework for Disaster Risk Reduction 2015-2030 and considered and coordinated within relevant development plans, resource allocations and program*

	activities. National-level plans need to be specific to each level of administrative responsibility and adapted to the different social and geographical circumstances that are present. The time frame and responsibilities for implementation and the sources of funding should be specified in the plan. Linkages to sustainable development and climate change adaptation plans should be made where possible.
Disaster Risk (UN General Assembly, 2016)	The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity. *Annotation: The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of risk. Disaster risk comprises different types of potential losses which are often difficult to quantify. Nevertheless, with knowledge of the prevailing hazards and the patterns of population and socio-economic development, disaster risks can be assessed and mapped, in broad terms at least.* *It is important to consider the social and economic contexts in which disaster risks occur and that people do not necessarily share the same perceptions of risk and their underlying risk factors.* ***Acceptable risk**, or tolerable risk, is therefore an important sub-term; the extent to which a disaster risk is deemed acceptable or tolerable depends on existing social, economic, political, cultural, technical and environmental conditions. In engineering terms, acceptable risk is also used to assess and define the structural and non-structural measures that are needed in order to reduce possible harm to people, property, services and systems to a chosen tolerated level, according to codes or "accepted practice" which are based on known probabilities of hazards and other factors.* ***Residual risk** is the disaster risk that remains even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained. The presence of residual risk implies a continuing need to develop and support effective capacities for emergency services, preparedness, response and recovery, together with socioeconomic policies such as safety nets and risk transfer mechanisms, as part of a holistic approach.*
Disaster Risk Assessment (UN General Assembly, 2016)	A qualitative or quantitative approach to determine the nature and extent of disaster risk by analysing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend. *Annotation: Disaster risk assessments include: the identification of hazards; a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability, including the physical, social, health, environmental and economic dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities with respect to likely risk scenarios.*
Disaster Risk Reduction (UN General Assembly, 2016)	Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the

	achievement of sustainable development. *Annotation: Disaster risk reduction is the policy objective of disaster risk management, and its goals and objectives are defined in disaster risk reduction strategies and plans.* ***Disaster risk reduction strategies and policies*** *define goals and objectives across different time scales and with concrete targets, indicators and time frames. In line with the Sendai Framework for Disaster Risk Reduction 2015-2030, these should be aimed at preventing the creation of disaster risk, the reduction of existing risk and the strengthening of economic, social, health and environmental resilience.* *A global, agreed policy of disaster risk reduction is set out in the United Nations endorsed Sendai Framework for Disaster Risk Reduction 2015-2030, adopted in March 2015, whose expected outcome over the next 15 years is: "The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries".*
Droughts (Knutson *et al.,* 1998; UNDP, 2008)	A deficiency of precipitation from expected or "normal" that, when extended over a season or longer period of time, is insufficient to meet demands. This may result in economic, social, and environmental impacts. It should be considered a normal, recurrent feature of climate. Drought is a relative, rather than absolute, condition that should be defined for each region. Each drought differs in intensity, duration, and spatial extent. The UNDP (2008) defines drought as the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.
Drought Contingency Plan (Knutson *et al.,* 1998)	A document that identifies specific actions that can be taken before, during and after a drought to mitigate some of the impacts and conflicts that result. Frequently these actions are triggered by a monitoring system.
Drought Impact (Knutson *et al.,* 1998)	A specific effect of drought. People also tend to refer to impacts as *"consequences"* or *"outcomes."* Impacts are symptoms of vulnerability.
Drought Impact Assessment (Knutson *et al.,* 1998)	The process of looking at the magnitude and distribution of drought's effects.
Dry Period (Jordaan, 2011)	Refers to a period of below mean precipitation where vegetation and water resources are impacted negatively. The dry period is not as serious as drought.
Dry Lands (UNDP, 2008).	Areas with an aridity value of less than 0.65; they comprise dry sub-humid, semi-arid, arid and hyper-arid areas (Middleton and Thomas, 1997). Dry lands in terms of water stress; as terrestrial areas where the mean annual rainfall (including snow, fog, hail) is lower than the total amount of water evaporated to the atmosphere.
Early Warning (UNISDR, 2004)	The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response. Early warning systems include a chain of concerns, namely: understanding and mapping the hazard; monitoring and forecasting impending events; processing and disseminating understandable warnings to political authorities and the population,

	and undertaking appropriate and timely actions in response to the warnings.
Early Warning System (UN General Assembly, 2016)	An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events. *Annotations: Effective "end-to-end" and "people-centred" early warning systems may include four interrelated key elements: (i) disaster risk knowledge based on the systematic collection of data and disaster risk assessments; (ii) detection, monitoring, analysis and forecasting of the hazards and possible consequences; (iii) dissemination and communication, by an official source, of authoritative, timely, accurate and actionable warnings and associated information on likelihood and impact; and (iv) preparedness at all levels to respond to the warnings received. These four interrelated components need to be coordinated within and across sectors and multiple levels for the system to work effectively and to include a feedback mechanism for continuous improvement. Failure in one component or a lack of coordination across them could lead to the failure of the whole system.* ***Multi-hazard early warning systems** address several hazards and/or impacts of similar or different type in contexts where hazardous events may occur alone, simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects. A multi-hazard early warning system with the ability to warn of one or more hazards increases the efficiency and consistency of warnings through coordinated and compatible mechanisms and capacities, involving multiple disciplines for updated and accurate hazards identification and monitoring for multiple hazards.*
Economic Loss (UN General Assembly, 2016)	Total economic impact that consists of direct economic loss and indirect economic loss. Direct economic loss: the monetary value of total or partial destruction of physical assets existing in the affected area. Direct economic loss is nearly equivalent to physical damage. Indirect economic loss: a decline in economic value added as a consequence of direct economic loss and/or human and environmental impacts. *Annotations: Examples of physical assets that are the basis for calculating direct economic loss include homes, schools, hospitals, commercial and governmental buildings, transport, energy, telecommunications infrastructures and other infrastructure; business assets and industrial plants; and production such as crops, livestock and production infrastructure. They may also encompass environmental assets and cultural heritage.* ***Direct economic losses** usually occur during the event or within the first few hours after the event and are often assessed soon after the event to estimate recovery cost and claim insurance payments. These are tangible and relatively easy to measure*. ***Indirect economic loss** includes micro-economic impacts (e.g., revenue declines owing to business interruption), meso-economic impacts (e.g., revenue declines owing to impacts on*

	natural assets, interruptions to supply chains or temporary unemployment) and macroeconomic impacts (e.g., price increases, increases in government debt, negative impact on stock market prices and decline in GDP). Indirect losses can occur inside or outside of the hazard area and often have a time lag. As a result they may be intangible or difficult to measure.
Ecosystem (IPCC, 2001; UNISDR, 2004)	A complex set of relationships of living organisms functioning as a unit and interacting with their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus the extent of an ecosystem may range from very small spatial scales to, ultimately, the entire Earth.
Environment (UNDP, 2008).	The combination of external physical conditions that affect and influence the growth, development and survival of organisms. This includes all of the biotic and abiotic factors that act on an organism, population, or ecological community and influence its survival and development. *Biotic* factors include the organisms themselves, their food and their interactions. *Abiotic* factors include such items as sunlight, soil, air, water, climate and pollution. Organisms respond to changes in their environment by evolutionary adaptations in form and behaviour.
Environmental Degradation (UNISDR, 2004)	The reduction of the capacity of the environment to meet social and ecological objectives, and needs. Potential effects are varied and may contribute to an increase in vulnerability and the frequency and intensity of natural hazards. Some examples are: land degradation, deforestation, desertification, effects of wild fires, loss of biodiversity, land, water and air pollution, climate change, sea level rise and ozone depletion.
Environmental Impact Assessment (EIA) (UNDP, 2008)	A public process by which the likely effects of a project on the environment are identified, assessed and then taken into account by the consenting authority in the decision-making process.
Environmental Sustainability Index (ESI) (UNDP, 2008)	An index that measures countries' progress towards environmental sustainability using a set of 21 indicators in the following five core components: (i) environmental systems, (ii) reducing environmental stress, (iii) reducing human vulnerability, (iv) social and institutional capacity to respond to environmental challenges and, (v) global stewardship.
Exposure (UN General Assembly, 2016)	The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas. *Annotation: Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability and capacity of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.*
Farming System (FAO, 2001)	A farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household activities and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many millions of households.
Forecast (WMO, 2010)	Definite statement or statistical estimate of the occurrence of a future event.

Geographic Information System, GIS (UNISDR, 2004)	Analysis that combines relational databases with spatial interpretation and outputs often in form of maps. A more elaborate definition is that of computer programmes for capturing, storing, checking, integrating, analysing and displaying data about the earth that is spatially referenced. GIS is used in this study for hazard, vulnerability and resilience mapping and analysis.
Hazard (UN General Assembly, 2016)	A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation. *Annotations: Hazards may be natural, anthropogenic or socio-natural in origin.* ***Natural hazards*** *are predominantly associated with natural processes and phenomena.* ***Anthropogenic hazards****, or human-induced hazards, are induced entirely or predominantly by human activities and choices. This term does not include the occurrence or risk of armed conflicts and other situations of social instability or tension which are subject to international humanitarian law and national legislation. Several hazards are* ***socio-natural****, in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change.* *Hazards may be single, sequential or combined in their origin and effects. Each hazard is characterized by its location, intensity or magnitude, frequency and probability. Biological hazards are also defined by their infectiousness or toxicity, or other characteristics of the pathogen such as dose-response, incubation period, case fatality rate and estimation of the pathogen for transmission.* ***Multi-hazard*** *means (i) the selection of multiple major hazards that the country faces, and (ii) the specific contexts where hazardous events may occur simultaneously, cascadingly or cumulatively over time, and taking into account the potential interrelated effects. Hazards include (as mentioned in the Sendai Framework for Disaster Risk Reduction 2015-2030, and listed in alphabetical order) biological, environmental, geological, hydrometeorological and technological processes and phenomena.* ***Biological hazards*** *are of organic origin or conveyed by biological vectors, including pathogenic microorganisms, toxins and bioactive substances. Examples are bacteria, viruses or parasites, as well as venomous wildlife and insects, poisonous plants and mosquitoes carrying disease-causing agents.* ***Environmental hazards*** *may include chemical, natural and biological hazards. They can be created by environmental degradation or physical or chemical pollution in the air, water and soil. However, many of the processes and phenomena that fall into this category may be termed drivers of hazard and risk rather than hazards in themselves, such as soil degradation, deforestation, loss of biodiversity, salinization and sea-level rise.* ***Geological or geophysical hazards*** *originate from internal earth processes. Examples are earthquakes, volcanic activity and emissions, and related geophysical processes such as mass movements, landslides, rockslides, surface collapses and debris or mud flows. Hydro-meteorological factors are important contributors to some of these processes. Tsunamis are difficult to categorize: although they are triggered by undersea earthquakes and other*

	geological events, they essentially become an oceanic process that is manifested as a coastal water-related hazard. ***Hydro-meteorological hazards*** *are of atmospheric, hydrological or oceanographic origin. Examples are tropical cyclones (also known as typhoons and hurricanes); floods, including flash floods; drought; heatwaves and cold spells; and coastal storm surges. Hydro-meteorological conditions may also be a factor in other hazards such as landslides, wildland fires, locust plagues, epidemics and in the transport and dispersal of toxic substances and volcanic eruption material.* ***Technological hazards*** *originate from technological or industrial conditions, dangerous procedures, infrastructure failures or specific human activities. Examples include industrial pollution, nuclear radiation, toxic wastes, dam failures, transport accidents, factory explosions, fires and chemical spills. Technological hazards also may arise directly as a result of the impacts of a natural hazard event*.
Hazard Analyses (UNISDR, 2004)	Identification, studies and monitoring of any hazard to determine its potential, origin, characteristics and behaviour.
Hazardous Event (UN General Assembly, 2016)	The manifestation of a hazard in a particular place during a particular period of time. *Annotation: Severe hazardous events can lead to a disaster as a result of the combination of hazard occurrence and other risk factors.*
Hydro-Meteorological hazards (UNISDR, 2004)	Natural processes or phenomena of atmospheric, hydrological or oceanographic nature, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Drought is a hydro-meteorological hazard, but in the context of this study only the term "*hazard"* is used.
La Niña (WMO, 2010)	A cooling of the surface water of the eastern and central Pacific Ocean, occurring somewhat less frequently than El Niño events but causing similar, generally opposite disruptions to global weather patterns. La Niña conditions occur when the Pacific trade winds blow more strongly than usual, pushing the sun-warmed surface water farther west and increasing the upwelling of cold water in the eastern regions. Together with the atmospheric effects of the related Southern Oscillation, the cooler water brings drought to western South America and heavy rains to eastern Australia and Indonesia.
Land Use Planning (UNISDR, 2004; UNDP, 2008).	Physical and socio-economic planning that determines the means and assesses the values or limitations of various options in which land is to be utilised, with the corresponding effects on different segments of the population or interests of a community taken into account in resulting decisions. Land use planning involves studies and mapping, analysis of environmental and hazard data, formulation of alternative land use decisions and design of a long-range plan for different geographical and administrative scales (UNISDR, 2004). Land use planning can help to mitigate disasters and reduce risks by discouraging high-density settlements and construction of key installations in hazard-prone areas, control of population density and expansion, and in the siting of service routes for transport, power, water, sewage and other critical facilities.

Land Degradation (UNDP, 2008).	The reduction or loss in arid, semi-arid and dry sub-humid areas of the biological or economic productivity and complexity of rain fed cropland, irrigated cropland, or range, pasture, forest and woodlands. Land degradation results from a process or combination of processes, including those arising from human activities and habitation patterns that include: (i) soil erosion caused by wind and/or water, (ii) deterioration of the physical, chemical and biological or economic properties of soil and (iii) long term loss of natural vegetation.
Livelihood (UNDP, 2008).	The means for securing the necessities of life so that individuals, households and communities can sustain a living over time, using a combination of social, economic, cultural and environmental resources (UNDP, 2008).
Mitigation (UN General Assembly, 2016)	The lessening or minimizing of the adverse impacts of a hazardous event. *Annotation: The adverse impacts of hazards, in particular natural hazards, often cannot be prevented fully, but their scale or severity can be substantially lessened by various strategies and actions. Mitigation measures include engineering techniques and hazard-resistant construction as well as improved environmental and social policies and public awareness. It should be noted that, in climate change policy, "mitigation" is defined differently, and is the term used for the reduction of greenhouse gas emissions that are the source of climate change.*
Natural Hazards (UNISDR, 2004)	Natural processes or phenomena occurring in the biosphere that may constitute a damaging event. Natural hazards can be classified by origin namely: geological, hydro-meteorological or biological. Hazardous events can vary in magnitude or intensity, frequency, duration, area of extent, speed of onset, spatial dispersion and temporal spacing.
Natural Resources (UNDP, 2008).	Non-renewable resource such as minerals, fossil fuels and fossil water, and renewable resources such as non-fossil water supplies, biomass (forest, grazing resources) marine resources, wildlife and biodiversity.
Preparedness (UN General Assembly, 2016)	The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters. *Annotation: Preparedness action is carried out within the context of disaster risk management and aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response to sustained recovery.* *Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems, and includes such activities as contingency planning, the stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. These must be supported by formal institutional, legal and budgetary capacities. The related term "readiness" describes the ability to quickly and appropriately respond when required.* *A **preparedness plan** establishes arrangements in advance to enable timely, effective and appropriate responses to specific potential hazardous events or emerging disaster situations that*

	might threaten society or the environment.
Prevention (UN General Assembly, 2016)	Activities and measures to avoid existing and new disaster risks. *Annotations: Prevention (i.e., disaster prevention) expresses the concept and intention to completely avoid potential adverse impacts of hazardous events. While certain disaster risks cannot be eliminated, prevention aims at reducing vulnerability and exposure in such contexts where, as a result, the risk of disaster is removed. Examples include dams or embankments that eliminate flood risks, land use regulations that do not permit any settlement in high-risk zones, seismic engineering designs that ensure the survival and function of a critical building in any likely earthquake and immunization against vaccine-preventable diseases. Prevention measures can also be taken during or after a hazardous event or disaster to prevent secondary hazards or their consequences, such as measures to prevent the contamination of water.*
Recovery (UN General Assembly, 2016)	The restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and “build back better”, to avoid or reduce future disaster risk.
Relief/Response (UNISDR, 2004)	The provision of assistance or intervention during or immediately after a disaster to meet the life preservation and basic subsistence needs of those people affected. It can be of an immediate, short term, or protracted duration. In the context of this study relief refers to measures such as subsidies for fodder purchases, interest subsidies or soft loans, extension of debt repayments, or any other measure that support the agricultural sector, communities or farmers in order to financially survive the negative impacts of drought. Relief and response in this context does not include risk reduction measures for future droughts.
Resilience/Resilient (UN General Assembly, 2016)	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management. In the context of this study resilience refers to the capacity of agriculture, farmers or communities to withstand the negative effects of drought without any additional support. The term capacity is also used in the study in the same context.
Rehabilitation (UN General Assembly, 2016)	The restoration of basic services and facilities for the functioning of a community or a society affected by a disaster.
Response (UN General Assembly, 2016)	Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected. *Annotation: Disaster response is predominantly focused on immediate and short term needs and is sometimes called*

	disaster relief. Effective, efficient and timely response relies on disaster risk-informed preparedness measures, including the development of the response capacities of individuals, communities, organizations, countries and the international community. *The institutional elements of response often include the provision of emergency services and public assistance by public and private sectors and community sectors, as well as community and volunteer participation. "Emergency services" are a critical set of specialized agencies that have specific responsibilities in serving and protecting people and property in emergency and disaster situations. They include civil protection authorities and police and fire services, among many others. The division between the response stage and the subsequent recovery stage is not clear-cut. Some response actions, such as the supply of temporary housing and water supplies, may extend well into the recovery stage.*
Risk (UNISDR, 2004)	The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions. Conventionally risk is expressed by the notation; Risk = hazards x Vulnerability. Some disciplines also include the concept of exposure to refer particularly to the physical aspects of vulnerability. Beyond expressing a possibility of physical harm, it is crucial to recognize that risks are inherent or can be created or exist within social systems. It is important to consider the social contexts in which risks occur and that people therefore do not necessarily share the same perceptions of risk and their underlying causes.
Risk Assessment/Analysis (UNISDR, 2004)	A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend. This study also includes resilience or coping capacity as part of risk. Knutson *et al.* (1989) define drought risk analysis as "the process of identifying and understanding the relevant components associated with drought risk as well as the evaluation of alternative strategies to manage that risk". The process of conducting a risk assessment is based on a review of both the technical features of hazards such as their location, intensity, frequency and probability; and also the analysis of the physical, social, economic and environmental dimensions of vulnerability and exposure, while taking particular account of the coping capabilities pertinent to the risk scenarios.
Risk Transfer (UN General Assembly, 2016)	The process of formally or informally shifting the financial consequences of particular risks from one party to another, whereby a household, community, enterprise or State authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party. *Annotation: Insurance is a well-known form of risk transfer, where coverage of a risk is obtained from an insurer in exchange for ongoing premiums paid to the insurer. Risk transfer can occur informally within family and community networks where there are reciprocal expectations of mutual aid by means of gifts or credit,*

	as well as formally, wherein governments, insurers, multilateral banks and other large risk-bearing entities establish mechanisms to help cope with losses in major events. Such mechanisms include insurance and reinsurance contracts, catastrophe bonds, contingent credit facilities and reserve funds, where the costs are covered by premiums, investor contributions, interest rates and past savings, respectively.
Small-Scale Farmers (Jordaan & Jooste, 2003)	Small-scale farmers are by definition those farmers in transition between subsistence and commercial farmers. They are normally too small to apply modern technology and to mechanise and most of their inputs are labour intensive yet they already produce surplus food and fibre for the market.
Subsistence Farmers (Jordaan & Jooste, 2003)	Individuals farming with livestock, horticulture or any system but they do not produce any surplus. Agriculture is a means of livelihood and subsistence farmers utilise products only for personal and their own livelihood means. This group of farmers do not produce any surplus food for the market.
Sustainable Development (UNISDR, 2004)	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development is based on socio-cultural development, political stability and decorum, economic growth and ecosystem protection, which all relate to disaster risk reduction.
Transect Walk/Drive (UNDP, 2008).	A simple method for describing and investigating the location and distribution of resources, features, the landscape and main land uses along a given transect (UNDP, 2008). In the context of this study it was rather a *"transect drive"* where the three districts were inspected.
Underlying Risk Drivers (UN General Assembly, 2016)	Processes or conditions, often development-related, that influence the level of disaster risk by increasing levels of exposure and vulnerability or reducing capacity. *Annotations: Underlying disaster risk drivers, also referred to as underlying disaster risk factors, include poverty and inequality, climate change and variability, unplanned and rapid urbanization and the lack of disaster risk considerations in land management and environmental and natural resource management, as well as compounding factors such as demographic change, non-disaster risk-informed policies, the lack of regulations and incentives for private disaster risk reduction investment, complex supply chains, the limited availability of technology, unsustainable uses of natural resources, declining ecosystems, pandemics and epidemics.*
Vulnerability (UN General Assembly, 2016)	The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards. *Annotation: For positive factors which increase the ability of people to cope with hazards, see also the definitions of "Capacity" and "Coping capacity".*

1 Introduction

Executive summary

Chapter 1 of the report deals with the research background, motivation and the implementation of the project during the four years of research. The research addressed a very serious issue in agricultural risk and disaster management in South Africa. The results of the research provided the basis for a national drought risk plan that considers the uniqueness of the communal farming system and the commercial farming system.

The research approach and research methodology is explained in this chapter. Data availability was a challenge and the research team had to adapt its research approach in its endeavour to find information on drought vulnerability and resilience. The process of action research provided a feedback loop that allowed the research team to discuss preliminary findings with farmers and make the necessary adjustments according their feedback.

One hundred and thirty-nine extension officers, 285 communal farmers and eight mentors participated in 12 workshops in the three districts. Workshops were interactive with the research team that provided training and feedback on research progress during morning sessions and information gathering during afternoon sessions. The research results have already been already shared with commercial farming leaders and AGBiZ leadership at the 2016 AgriSA annual meeting.

Research results were presented as conference presentations at 12 international and five national conferences. Two papers have already been published in peer-reviewed journals, as has one chapter in a book. Three papers are currently under final review and three more papers are in final stages of preparation.

A summary of deliverables is also provided in this chapter. All deliverables were delivered on time and accepted as satisfactory on the WRC reporting system.

1.1 Introduction

Dry periods and droughts remain the major meteorological factor with devastating impacts on the livelihoods of most rural people in South Africa. The agricultural sector specifically incurs millions of Rands in losses every year. For example, the direct mean annual loss (MAL) to the extensive livestock sector in the Northern Cape alone is in the excess of R350 million (Jordaan, 2012).

The pro-active approach towards drought management emphasizes the need for coordination and collaboration among all role players. This includes coordination between monitoring agencies in terms of reliable early warning data, communicated in a comprehensible way to decision-makers, farmers, agricultural businesses and all that have an interest in agriculture. Collaboration at national and provincial level between the Department of Agriculture, Forestry and Fisheries (DAFF) at national level, provincial Departments of Agriculture, National and Provincial Disaster Management Centres (NDMC and PDMC), the Department of Water Affairs (DWA), the South African Weather Service (SAWS) and others is essential in this regard (van Zyl, 2010, Jordaan, 2012).

Most people in agriculture acknowledge climatic extremes and the fact that future dry periods will occur as a given. It is just a matter of when and how severe. The challenge, however, is to prevent dry periods from developing into disaster droughts (Ribot, 1996; Wilhite, 2000; Dercon, 2007; IPCC, 2007; Jordaan, 2012). Important are the vulnerability and the resilience of the agricultural sector as key factors in drought prevention and mitigation. Jordaan (2012) highlighted the critical role of vulnerability and resilience in drought risk management. One cannot assess drought risk by looking at only precipitation, evaporation and transpiration (Wilhelmi, 2002; Wisner at al., 2004; Gbetibouo & Ringler, 2009, Jordaan, 2012). These are variables used for the hazard assessment and not for total drought risk. Hazard assessment is only one part of the risk assessment equation (Wisner *et al*., 2004; Jordaan, 2011).

Vulnerability and resilience are key to any disaster risk assessment and should always be assessed in relation to a specific hazard – drought in this case (Ribot, 1996; Wisner *et al*., 2004; Dwyer *et al*., 2004; National Drought Mitigation Centre, 2011). Already during the 1980s, Easter *et al*. (1985) proposed the integration of socio, environmental and economic factors in watershed management. Currently, much research focuses on climate change and future climate scenarios, yet very little work is done on the vulnerability of the agricultural sector and communities and more specifically in the extensive livestock sector toward climate change (Jordaan, 2011). Gbetibouo & Ringler (2009) report on the vulnerability of the South African farming sector to climate change and they mention the lack of vulnerability assessments at regional level as one of the major gaps in climate risk assessment. Any drought strategy should support the increased resilience against droughts amongst all role players in agriculture (Wisner *et al.,* 2004; Van Zyl, 2006; Jordaan, 2012).

1.2 Research Rationale

The National Disaster Management Framework (NDMF) is clear on the need for disaster risk assessments as one of the key performance areas for any disaster risk reduction strategy – drought in this case (NDMF, 2005). The lack of a coordinated national drought strategy that provides guidelines for drought management is one of the root causes for the lack of drought risk assessments and drought plans for the different sectors and regions (Van Zyl, 2006; de Bruin, 2010; Jordaan, 2012). The livestock sector is of particular importance in this regard, due to its dependence on rainfall.

The motivation for this research was based on the realisation that the agricultural sector in South Africa is exposed to regular dry periods and extreme droughts with devastating effects on certain sectors. In spite of the relatively small contribution of agriculture to GDP, droughts also impact negatively on the national GDP. Despite the negative impacts of drought, South Africa is yet to develop a national drought plan with clear guidelines and indicators for drought classification and drought declaration. In many cases farmers blame drought for problems at farm level production because the difference between aridity and drought is not well understood by all farmers and sectors. South Africa is mostly classified as an arid region and production strategies should be adapted to the climatic (arid) conditions in a specific region. Drought is also not only the result of below average precipitation and warm weather; the vulnerability and resilience of farmers and sectors are also important in drought risk. Understanding the relationship between meteorological conditions, vulnerability and resilience is an important element of drought risk management (Jordaan, 2011).

Jordaan (2011) highlights the difference between commercial farmers and communal farmers in regard to drought impact. Communal farmers, for example, experience normal dry periods as droughts simply because of the lack of adaptive and coping capacity, imperfect markets and additionally the result of ill-defined property right systems, which lead to increased land degradation and overgrazing. The climate affecting them is the same as for the other commercial farmers, yet the vulnerabilities and coping capacity differ dramatically. This poses a challenge to organisations responsible for disaster management with regard to the declaration of drought disasters and resultant drought responses from Government. One of the current indicators for drought declaration is the percentage of normal rainfall and the NDVI, which does not consider the difference in vulnerability to drought between different farming systems. The challenge, therefore, is to determine the most important indicators for drought classification and declaration and to ensure that the process does not benefit farmers who overgraze their land, but also considers the inherent vulnerability of the communal and subsistence farming system in South Africa.

This research provided guidelines on the indicators for drought declaration and implications for the commercial and communal farming systems. Good agricultural practices and drought resilience building strategies related to drought risk management were identified. The project also provided guidelines for drought classification, drought declaration and the development of a drought management plan at national and provincial level.

The Eastern Cape proved to be an appropriate region to compare drought vulnerability, adaptation, coping and resilience of both commercial and communal subsistence farmers because of the historical demarcation of common properties. Large areas in the Eastern Cape are still managed by tribal authorities with mainly common property right systems. These areas are entwined with well-planned commercial farms with well-defined individual and private property right systems. The Eastern Cape also covers different rainfall zones that vary from more than 1000 mm per annum to less than 400 mm per annum with Port St Johns on the East Coast, Queenstown/East London/Port Elizabeth further south, Aliwal North in the north-west and Willowmore in the south-west.

1.3 Contextualisation

The research addressed a very serious issue in agricultural risk and disaster management in South Africa. The results of the research provided the basis for a national drought risk plan similar to the Australian, American and Mexican drought plans. Drought declarations and drought responses in South Africa have been traditionally handled on an *ad hoc* basis, with each province applying different principles. Politicians and pressure groups influenced drought declarations in the past. The need for quantitative guidelines for drought classification and declaration was therefore is a key requirement for drought management in South Africa.

The different departments also acknowledge the difference in vulnerability between commercial and subsistence farmers and this research highlighted the difference in vulnerability and resiliency of these different sectors; also which criteria and indicators for drought declaration and drought response to apply to each sector. The research also highlighted factors that contribute to drought vulnerability and/or drought resilience.

1.4 Objectives

The main objective of the research was to propose adaptation and coping strategies to drought risk based on a drought risk assessment for the rain fed farming sector in parts of the Eastern Cape. This included both commercial and communal subsistence farmers and considered risk as a function of hazard, economic/social/environmental or ecological vulnerability, adaptation and coping capacity.

The project exceeded original objectives and achieved outputs with signicant impact that were not foreseen at the onset of the project. The development and acceptance of a drought classification system for South Africa is an example of outputs beyond the original objectives of the research. The National Drought Task Team accepted the proposed drought classification as well as indicator thresholds for drought classification. The contribution of the Department of Agriculture, Forestry and Fisheries (DAFF) as the lead department on drought management was invaluable.

The sub-objectives of the project are summarized in Table 1.1 together with the corresponding deliverables and reporting chapters.

The main objective and supporting sub-objectives were all achieved and reported on within the specified contract period.

Table 1.1: Sub-objectives, deliverables and final chapters

No	Sub-objective	Deliverable	Chapter in final report
1	Determine drought hazard assessment by calculating standard precipitation Index (SPI) and standard precipitation evaporation index (SPEI) for each quaternary catchment in the designated area. That provides the basis for calculating drought probability, intensity and severity for each catchment.	Deliverable 2: Hazard assessment report	Chapter 3
2	Determine economic, social and environmental vulnerability to drought in the designated area	Deliverable 4: Coping capacity and adaptation assessment 1st interim report Deliverable 5: Interim report on vulnerability and resilience assessment	Chapter 2, 6 & 7
3	Determine current adaptation and coping capacities to drought risk	Deliverable 4: Coping capacity and adaptation assessment 1st interim report Deliverable 5: Interim report on vulnerability and resilience assessment	Chapter 6,7
4	Develop a drought risk profile for the designated area	Deliverable 8: Report on drought risk assessment	Chapter 5
5	Develop drought loss functions for the livestock sector and selected rain fed crops in the research area	Deliverable 9: Report on calculation of drought loss function for the livestock sector and selected rain fed crops	Chapter 8
6	Propose adaptation and coping mechanisms for the commercial livestock sector as well as to communal livestock farmers to future drought risks	Deliverable 10: Recommendations as a report for resilience against drought, inclusive of adaptation and coping capacity	Chapter 11
7	Propose a set of indicators for disaster drought declaration	Deliverable 12: Report that recommends on indicators for drought risk declaration	Chapter 9

1.5 Research Methodology

The techniques to obtain and analyse data and information in this study were analytical, theoretical and descriptive. Both deductive logic and inductive reasoning were applied to analyse the data and information and to make conclusions. The study relied on a comprehensive literature study (Chapter 3) for the gathering of secondary data. The drought risk assessment methodology as proposed by the National Disaster Management Framework (NDMF) in 2005 and Jordaan (2011) was used as a basis for drought risk assessment (Chapter 5). The literature study was important to provide a framework for research and risk assessment and to guide interview structuring and question formulation.

Combinations of techniques, both qualitative and quantitative were applied to obtain primary data and information. Structured questionnaires, group discussions and individual interviews with experts and farmers were used. Specific techniques applied in this study included, *inter alia*, (i) direct observation through transect drives and farm visits, (ii) familiarisation of and participation in activities, (iii) interviews with key informants, group interviews and workshops, (iv) mapping and preparig diagrams, (v) biographies, local histories and literature studies, (vi) ranking and scoring of data obtained through appropriate questionnaires and group discussions, (vii) analysis of results, and (viii) report writing.

The Rapid Rural Appraisal (RRA) was one of the main techniques applied to obtain the necessary primary data and information through inputs from farmers, extension officers and other experts. The

RRA consisted of a series of techniques that generated results of less apparent precision, but greater evidential value than classic quantitative survey techniques. The method was not exclusively rural or rapid, but provided an economic and sufficient way of obtaining evidential data and information, especially in the rural environment with many illiterate farmers and lack of quantitative data and information (Duraiappah *et al.,* 2005; Leedy & Ormond, 2010; Jordaan, 2011). The RRA applied during the research was essentially extractive as a process.

RRA (and analogues) emerged in the 1970s as a more efficient and cost-effective way of learning by researchers and outsiders, than was possible by large-scale social surveys or brief rural visits. RRA emphasizes the importance and relevance of situational local knowledge, and instead of achieving spurious statistical accuracy, it rather focuses on the importance of gaining the correct general information. A style of listening research was entrenched in the method with a creative combination of iterative methods and verification, including triangulation of information from different sources; using two different methods to view the same information (Duraiappah *et al.,* 2005). The RRA drew on many of the insights of field social anthropology of the 1930s to 1950s. As described in the literature, a multi-disciplinary team conducted the RRA in this research.

The action-research methodology on the other hand was used to refine, calibrate and apply initial results of the research. O'Brien (1998) defines action-research as research that aims to contribute both to the practical concerns of people in an immediate problematic situation and to simultaneously further the goals of social science. Thus, there is a dual commitment in action research to study a system and concurrently to collaborate with members of the system in changing it in what is together regarded as a desirable direction. Accomplishing this twin goal required the active collaboration of research team and farmers and extension officers. An advantage was the importance of co-learning as a primary aspect of the research process. This meant that practical solutions were sought during the three years of the research period through individual and group discussions followed with recommendations to farmers and extension officers while the research was in progress.

1.5.1 Sampling and data/information gathering

In order to familiarize the research team with the study area, transect trips were undertaken in the study area at the onset of the project in order to familiarize all research staff with the geography, ecology, social environment and agricultural systems. During these transect tours several conditional vulnerability indicators were identified such as overgrazing, soil erosion, land degradation, cultural practices, and availability of resources and infrastructure.

Sources and types of data and information were identified and grouped as (i) the commercial farming sector, (ii) communal farming sector, (iii) commodity organizations, (iv) the private sector, (v) government departments, and (vi) sources for meteorological data.

1.5.1.1 Commercial farming sector

The research leader launched and introduced the research project to the commercial farming sector during the 2013 annual management meeting of Agri Eastern Cape in Port Elizabeth. The leaders of the district farmers unions and commodity organizations in the Eastern Cape attended the meeting and all pledged their support to the project. Agri Eastern Cape then assisted with the distribution of individual questionnaires to commercial farmers through the network of well-organised farmers associations. Research Monkey®, a web based research tool was also used for questionnaire distribution, but feedback from commercial farmers through both channels was disappointing. From more than 300 questionnaires distributed, only eight respondents returned completed questionnaires. The project leader then utilised individual interviews and small group discussions as the main method for data and information gathering amongst the commercial farming sector. Most farmers associations were informed about the project as a result of the 2013 meeting with the leadership of Agri Eastern Cape, and that allowed easy access to management structures of farmers associations who assisted with contact numbers. Farmer leaders also provided advice on suitable respondents with experience of previous droughts. They also assisted in the identification of respondents who apply good agricultural practices and drought resilience strategies.

The practical knowledge and experience of the project leader [1] allowed for open and honest discussions on drought vulnerability, resilience and drought management strategies. The project leader conducted almost all interviews personally and managed to obtain more information in a relaxed environment than was possible with structured questionnaires. The informal discussions in many cases allowed farmers (and their spouses) to share issues such as the influence of drought stress on their decision making abilities and their capacity to remain resilient in the face of extreme droughts; information that they would never have shared through questionnaires or even through interviews with inexperienced researchers. The advantages of this method concurs with what is achievable through the RRA; *"Instead of achieving spurious statistical accuracy, this method rather focused on the importance of gaining the correct general information"* (Duraiappah *et al.,* 2005; Leedy & Ormond, 2010; Jordaan, 2011).

Fifty-four farmers with previous drought experience were interviewed and informal discussions were held with numerous other farmers during livestock auctions, visits to agricultural cooperatives or elsewhere. These informal and rapid discussions varied from very short 5 minute discussions to 1 hour long discussions depending on time availability of farmers; no prior appointment were made with farmers and farmers were approached alongside the rural roads while travelling to or from the farm, at livestock auctions, at the cooperative while doing business, at restaurants or wherever the opportunity arose. This method allows for triangulation of information obtained during planned

[1] Project leader was an extension officer for 5 years and a practising farmer for 23 years, also with experience of the 1982 and 1992 droughts.

interviews and was extremely valuable. Researchers, however, should be cautious and sensitive in applying this method. Not everybody is keen to discuss farming issues and strategies with an unknown person and it is important to create an atmosphere of trust within the first few seconds of introduction. The link of the research team to the University and the WRC was important for trust in that many farmers expressed their distrust to government driven research projects and initiatives.

1.5.1.2 Communal Farming sector

Large areas in the Eastern Cape are communal land occupied by a large number of small-scale farmers; mostly subsistence, but also a few smaller farmers that farm commercially (Jordaan & Sissons, 2009; Jordaan *et al.,* 2010). The small-scale farmers are not well organised, with the National African Farmers Union (NAFU) and the African Farmers Association of South Africa (AFASA) not well represented and organized in the Province (Jordaan *et al*., 2010). However, the National Wool Growers Association (NWGA) and the National Emergent Red Meat Producers Organization (NERPO) are both well established with study groups amongst the emergent and communal farmers and these structures were used as a channel for research.

Mixed methods of qualitative and quantitative approaches were used to analyse drought vulnerability. The level of literacy and lack of historical farm records limited the use of individual questionnaires amongst communal farmers. Quantitative and qualitative data and information were obtained from communal farmers through structured questionnaires administered by the research team during workshops and individual meetings.

Workshops were conducted in August and September 2014 and these provided the platform to collect data from communal farmers and extension officers. A purposive sampling method was used to select the type of respondents. Group discussions were also used to collect data from extension officers.

The indicator method, based on the BBC framework, was used to assess farmers' vulnerability to drought. Five environmental indicators, eleven social indicators and seven economic indicators were identified and subjected to the assessment process. Data were collected through self-administered questionnaires under supervision of the research team. Questions were based on the information gathered in the literature review and previous experiences of the research team.

Farmers were invited through the extension officer network to two training workshops in each of the three districts. Prior to each workshop, extension officers were briefed on the purpose of the workshop and on guidelines for sampling attendees in order to have good representation. Two workshops for communal farmers were organised in each of the districts and two workshops per district for land reform beneficiaries. Workshops for communal farmers were held at Willowmore and Port Alfred in Cacadu district; Aliwal North and Maclear in Joe Gqabi district and Tsolo and Lusikisiki in OR Tambo district. A summary of the workshop attendance for communal farmers is shown in Table 1.2.

Table 1.2: Attendance to communal farmers workshops

District Municipality	Venue	No. of Extension Officers	No. of Farmers	Total No.
Cacadu	Willowmore	13	46	**59**
	Port Alfred	7	26	**33**
Joe Gqabi	Maclear	27	14	**41**
	Aliwal North	10	15	**25**
OR Tambo	Tsolo	48	58	**106**
	Lusikisiki	17	31	**48**
	TOTAL	**122**	**190**	**312**

Workshops for land reform beneficiaries were also organised at Alexandria, Jansenville, Port St Johns and Aliwal North. Workshops with land reform beneficiaries provided an opportunity for triangulation and a better understanding of the challenges faced by this group of farmers, which is in transition to commercial farming. Although not within the scope of this research, it provided additional questions for future research. A summary of workshop attendance for land reform beneficiaries is shown in Table 1.3.

Table 1.3: Attendance to land reform beneficiary workshop

District Municipality	Venue	No. of Extension Officers	No. of Mentors	No. of Farmers	Total No.
Cacadu	Alexandria	5	3	22	**27**
	Jansenville	5	1	19	**24**
OR Tambo	Port St Johns	3	1	25	**28**
Joe Gqabi	Aliwal North	4	3	29	**33**
	TOTAL	**17**	**8**	**95**	**112**

Four different questionnaires were used to collect data, namely two separate questionnaires for communal farmers, a separate questionnaire for land reform beneficiaries as well as an interview guide for extension officers who assisted with the information gathering. Most questions were close-ended, but respondents were required to respond in writing to open-ended questions (See questionnaires as Attachment 1-A)

The questionnaires were in English, but extension officers assisted with translation to those farmers who were unable to understand English. A number of communal farmers could not write and read and extension officers also assisted them. Questions focused on their past experience of drought, level of risk, whether they have access to resources and coping capacity. Data were collected over a period of five weeks.

The workshops were design in such a way that attendees received information and knowledge during the morning session while providing information during the afternoon session. This methodology adhered to the principles of action research of learning by doing. The research team was struck by the reality that neither communal farmers and land reform beneficiaries nor extension officers were knowledgeable in drought mitigation and coping strategies. The training was therefore designed to inform attendees about concepts such as drought mitigation, prevention, coping, adaptation and resilience; also that drought is not only an act of God, but that farmers have options to mitigate the impact of dry periods and build resilience against drought. This method was extremely helpful in that farmers could provide better feedback after an understanding of the relationship between low precipitation, vulnerability and resilience. An example of a workshop program is shown in Table 1.4.

Table 1.4: Workshop program for communal farmers

Time	Topic	Responsible
09h00 – 09h40	What is drought risk	AJJ
09h40 – 10h30	Elements of drought risk assessment	AJJ
10h30 – 11h00	Coffee	
11h00 – 11h30	Environmental vulnerability	BPM
11h30 – 12h00	Economic vulnerability	OF
12h00 – 12h30	Social vulnerability	FM
12h30 – 13h00	Drought risk reduction: Adaptation, coping, resilience	AJJ
13h00 – 14h00	Lunch	
14h00 – 15h15	Feedback from farmers	All
15h15 – 15h30	Coffee	
15h30 – 16h30	Feedback from farmers	All

- *AJJ Prof Andries Jordaan*
- *BPM Me Boitumelo Phatudi-Mphahlele*
- *OF Mr Oluwatoba Fadeyi*
- *FM Me. Fummie Muyambu*

This study also employed direct observation in collecting data. The method provided the opportunity to collect additional information that was difficult to retrieve via questionnaires or interviews. According to Taylor-Power & Steele (1996), seeing and listening are the key aspects of direct observation. The extensive experience of practical farming and working for many years amongst communal farmers by the principal researcher also contributed in understanding drought vulnerability much better.

1.5.1.3 Agricultural businesses

Agricultural businesses are closely connected to the community they serve and the economies of most small towns depend largely on agriculture. Indicators to measure economic impact on the economy of local small towns were not readily available. Agricultural cooperatives have been privatised during the past 20 years and/or have introduced new computerised record keeping systems. As a result, none of the agricultural cooperatives or newly formed companies could provide historical information on sales and product prices that included the previous extreme droughts of 1982 and 1992. Other business such as vehicle and farm equipment dealers also shifted to new computer systems that cannot access the archived records of the older software systems. Business managers were supportive and sympathetic to the research teams' request for historical data, but they were eventually not willing to allocate time and human resources for data sourcing on a system not compatible to their current software programs. Some of the larger agricultural cooperatives in the designated research area transformed from cooperatives to private companies and some of the historical sales information might have been lost during the transformation and computerization of records (Jordaan, 2012). Individual interviews with business leaders, farmers and community leaders, however, was to provide some qualitative feedback on the impacts of previous droughts.

1.5.1.4 Commodity organizations

Historical production data and information were available at commodity organizations. The support of commodity organizations was positive and CAPE WOOLS provided detailed historical data for wool production per district. Other information and data were also obtained from the National Wool Growers Association (NWGA) and the Red Meat Producers Association (RPO).

1.5.1.5 Government

The Eastern Cape Department of Agriculture and Rural Development (ECDoARD) was supportive in that the regional directors[2] of all three districts received a directive from the Chief Director (ECDoARD) to support the project. All workshops and meetings with communal farmers and extension officers were subsequently organised by the extension services. Extension officers also provided the research team with valuable information.

1.5.1.6 Meteorological data

Primary quantitative meteorological data were obtained from archives at the South African Weather Services (SAWS), Agricultural Research Council (ARC), Council for Scientific and Industrial Research (CSIR), Water Research Commission (WRC), National and Provincial Departments of Agriculture and from individual farmers.

1.5.1.7 Expert inputs

Experts in the field of meteorology, agro-meteorology, agriculture, agriculture economics, grassland sciences, sociology, environmental sciences and plant sciences were consulted at the ARC Dohne research institute, ECDoARD, the University of Fort Hare and the University of the Free State.

1.6 Deliverables

All deliverables were submitted and approved according to the Memorandum of Agreement. A summary of the deliverables with corresponding reporting chapter is shown in Table 1.5.

Table 1.5: Project deliverables

No. and deliverable title	Description	Reporting chapter	Date and value
1. Identification and description of study area	The description of study area should allow for the comparison of vulnerabilities and coping mechanisms to drought between the livestock commercial farming system and communal small-scale and subsistence farming under similar climatic conditions. The selected districts were good	Chapter 2	31/07/2013 R185 000

[2] Extension services

	study areas since commercial farms and communal land are intertwined with each other. This report elaborated on the demarcation of the study area and described features such as climate, agricultural systems, environment, and the socio-economic profile of the selected area		
2. Hazard assessment report	SPI and SPEI were calculated for all the quaternary catchments in the selected districts. Results for SPI, SPEI, dry and wet phase probability, drought intensity and severity were provided on a web-based information system www.dimtecrisk.ufs.ac.za/ec as well as a hard copy report and shown spatially on GIS maps.	Chapter 4	30/11/2013 R275 000
3. Capacity building 1st annual report	Report on progress, capacity building and knowledge transfer for year 1	Chapter 1	28/02/2014 R40,000
4. Coping capacity and adaptation assessment 1st interim report	(i) Identification of economic, social and environmental vulnerability indicators based on relevance, availability, special significance. This interim report included the rationale for the selection of vulnerability indicators and proposed detailed methodology to obtain data and calculations. (ii) Identification of potential adaptation and coping mechanisms for drought. The interim report reported on the literature review for adaptation and potential coping strategies. In addition, the report highlighted potential indicators for measuring adaptation and coping capacity.	Chapter 3	31/07/2014 R490,000
5. Interim report on vulnerability and resilience assessment	This report included preliminary results from the fieldwork: Those were results from questionnaires, group discussions, individual interviews and expert contributions regarding vulnerability and resilience to drought	Chapter 6	30/11/2014 R285,000
6. Capacity building 2nd annual report	Report on progress, capacity building and knowledge transfer for year 2	Chapter 1	28/02/2015 R50,000
7. Report on indicator selection for vulnerability and resilience	This report contains the finalization of indicators for vulnerability, adaptation, coping capacity and resilience based on the information from the 1st interim report on vulnerability and the 1st interim report on indicator selection.		30/04/2015 R170,000
8. Report on drought risk assessment	This report illustrated the calculation for drought risk, inclusive of hazard, vulnerability and coping capacity. The results were shown and illustrated spatially through GIS at the website www.dimtecrisk.ufs.ac.za as well in the hard copy report.	Chapter 5	31/08/2015 R260,000
9. Report on calculation of drought loss function for the livestock sector and selected rain fed crops	Report on the calculation of drought loss function for the livestock sector including calculation of mean annual loss due to drought.	Chapter 8	31/10/2015 R250,000
10. Recommendations as a report for resilience against drought, inclusive of adaptation and coping capacity	Based on information derived form this research and the literature study, Recommendations for adaptation and coping with drought were highlighted for both the commercial and small-scale communal farming sector as well as other role players such as government and municipalities.		15/12/2015 R220,000
11. Capacity building 3rd annual report	Report on progress, capacity building and knowledge transfer for year 3	Chapter 1	29/02/2016 R50,000
12. Report that recommends on indicators for drought risk declaration	Drought risk declaration remains problematic and this report recommended specific indicators and indices to be used by disaster managers for disaster drought declaration. The differences in coping capacity between commercial and communal farmers were identified and recommendations made for different index thresholds. These thresholds are important for disaster declaration and this report elaborated on possible thresholds.		31/10/2016 R65,000
13. Report on conference presentations and	Report on presentations at international and national conferences or symposia and submission of articles to peer reviewed journals		28/02/2017

article submissions		R20,000
14. Final report	Final report that includes and summarised all findings covered during previous reports. Drought hazard, economic vulnerability, environmental vulnerability, social vulnerability, adaptation, coping capacity and drought risk to be spatially illustrated on GIS maps	28/02/2017 R590,000
15. Capacity building final annual report	Final progress report on capacity building and knowledge transfer for year 4	28/02/2017 R0.00

The deliverables were structured according the risk assessment process and followed a logical order that assisted in the development of the final report. All deliverables were submitted, accepted and approved through the WRC quality control system.

1.7 Conclusion

The project was managed according the agreed terms and conditions stated in the MOU between the University of the Free State (UFS) and the Water Research Commission (WRC).

Report on knowledge dissemination and capacity building is attached as Annexures 1A and 1B respectively.

Annexure 1A: Knowledge Dissemination

Knowledge dissemination was one of the original objectives of this project. The research approach of action research depends on a process of knowledge sharing knowledge while gathering, analysing and improving on data and information. The main target audiences for knowledge dissemination were both communal and commercial farmers, extension officers, scientists and students. The project utilised three main channels of knowledge dissemination namely (i) training workshops, (ii) official scientific papers, (iii) scientific conferences, (iv) popular publications and (v) industry related conferences and symposia. Knowledge dissemination is an on-going process and publication of articles in both peer-reviewed and popular publications will be published during the next few years.

The research team already has exploited different channels of knowledge dissemination. These include (i) training workshops, (ii) symposia, (iii) academic conferences, (iv) peer-review journal publications, (v) popular publications, and (vi) inclusion of results in learning materials.

Training Workshops

The Rapid Rural Appraisal (RRA) research method allowed the research team to transfer knowledge and to build capacity during the data gathering process. Two sets of workshops were organized. The one set of workshops was focused on communal farmers and was led by the project leader with the assistance of Ms Nomalanga Mdungela, Ms Fummie Muyambu and Mr Oluwatoba Fadeyi. The second set of workshops with a slightly different program and with a focus on land reform beneficiaries was led by Mr Siviwe Shwavaba (PhD candidate), with the project leader only in a lecturing and mentoring role.

Two workshops per district were organized and facilitated for communal farmers as well as two workshops per district for land reform beneficiaries. One hundred and ninety communal farmers and 122 extension officers participated in the communal farmers workshops and 95 farmers, 17 extension officers and 8 mentors participated in the land reform beneficiary workshops.

Scientific Conferences and Symposia

It is impossible to stay abreast of new knowledge if one considers the speed at which new knowledge is generated. Traditionally printed peer reviewed publications were the main source of scientific knowledge dissemination prior to the Internet and www era. Today it is also so much easier to travel and national and international conferences provide the opportunity to disseminate new knowledge at a much faster speed and to link directly with peers. We therefore targeted national and international conferences to disseminate knowledge during the project period and also to obtain feedback from peers while still working on the project.

We presented papers at 7 national conferences or symposia and at 10 international conferences. The list of conference papers is shown below. Presenting authors are highlighted in bold.

1. **JORDAAN, A.J.** 2016. *Drought Risk Reduction: Anticipate, Absorb, Reshape*. 2016 Symposium. South African National Committee on Irrigation and Drainage. Goudini, Western Cape, South Africa. 11-12 October 2016.
2. **JORDAAN, A.J.,** BAHTA, Y. & SAKULSKI, D.M. 2016. *Index insurance and drought loss functions: Wool farming, South Africa.* 7th International Conference on Integrated Disaster Risk Management. Isfahan, Iran. 1-3 October 2016.
3. **JORDAAN, A.J.,** SAKULSKI, D., MASHIMBYE, C. & MUYAMBO, F. 2016. *Analysing Drought Resilience Through the Community Capitals Framework: Case Study; Eastern Cape, South Africa.* 6th International Conference on Building Resilience: Building Resilience to Address the Unexpected. Auckland, New Zealand. 7-9 September 2016.
4. **JORDAAN, A.J.** & SAKULSKI, D.M. 2016. *Drought Index Insurance for the Livestock Sector: We Need to Find a Way*. Agriculture Insurance and Support Conference. Johannesburg, South Africa. 24-25 August 2016.
5. **JORDAAN, A.J.** 2016. *When is a Dry Period a Drought: Drought Not the Same for All Farmers.* African Drought Conference: Enhancing Resilience to Drought Events on the African Continent. Windhoek, Namibia. 15-19 August 2016.
6. **JORDAAN, A.J.,** SAKULSKI, D.M., MUYAMBO, F. & MASHIMBYE. 2016. *Drought Not Only the Result of Climate Variability.* International Conference; Environmental Legislation, Safety Engineering and Disaster Management. ELSEDIMA 11th Edition. Cluj Napoca, Romania. 26-27 May 2016.
7. **JORDAAN, A.J.** 2016. *Food Security as a Matter of Sustainability.* University Alliance for Sustainability. Summer Symposium. Freie University Berlin. Berlin, Germany.
8. **SHWABABA, S.** & JORDAAN, A.J. 2015. *Perceptions, Responses and Views on Drought Impact Amongst Land Reform Beneficiaries in the Eastern Cape, South Africa*. Dealing With Disasters Annual Conference. Northumbria University, Newcastle-Upon-Tyne, UK. September 2015
9. MDUNGELA, N.M, **BAHTA, Y.T.** & JORDAAN, A.J. 2015. *Farmer's Choice of Drought Coping Strategies to Sustain Productivity in the Eastern Cape of South Africa.* 5th World Sustainability Forum, Basel, Switzerland. September 2015.
10. **JORDAAN, A.J.** 2015. *Drought Indicator Selection: Case Studies from Africa*. Dresden NEXUS Conference, DNS 2015. United Nations Institute for Fluxes and Resources (UNFLORES), Dresden, Germany. March 2015.
11. **JORDAAN, A.J.** 2015. *Disaster Risk Reduction in Africa: Case of Development or Poor Governance*. Polokwane, Limpopo, South Africa. March, 2015. **Keynote address.**
12. **JORDAAN, A.J.** 2014. *Drought Disaster Declaration in South Africa: Different Thresholds for Different Agricultural Systems?* Community Capitals Framework Institute, National Drought Monitor Centre, Lincoln, Nebraska, USA. October, 2014.
13. **SHWABABA, S** & JORDAAN, A.J. 2014. *Assessing the Integration of Disaster Risk Management into the Land Reform Farming Sector.* Post 2015: Drivers, Scales and Context of disaster Risk in

the SADC Region. 2nd Biennial Conference, Southern Africa Society for Disaster Reduction. Windhoek, Namibia, October, 2014.

14. **JORDAAN, A.J.** 2014. *Drought Risk Reduction and Development Agriculture: Case Studies from Africa*. International Conference; Environmental Legislation, Safety Engineering and Disaster Management. ELSEDIMA 10th Edition. Cluj Napoca, Romania. September 2014
15. **SHWABABA, S.** & JORDAAN, A.J. 2014. *Planning for a Drought Resilient Land Reform Farming Sector: An Evaluation of Policies, Models and Strategies Toward Drought Impact Mitigation.* 29th Disaster Management Institute for South Africa (DMISA) Conference, Durban, South Africa, September 2014.
16. **JORDAAN, A.J**., SAKULSKI, D.M. & JORDAAN, A.D. 2013*. Drought Insurance for Extensive Livestock Farmers Based on Standard Precipitation Index as a Tool for Drought Risk Reduction*. International Society for Integrated Disaster Risk Management (IDRiM) Annual Conference. Northumbria University, Newcastle Upon Tyne, UK. September 2013.
17. **SAKULSKI, D.M.** & JORDAAN, A.J. 2013. *Vulnerability, Adaptation and Coping to Drought in the Eastern Cape*. African Water Symposium. Bloemfontein, South Africa. May 2013.

The main audiences of the different conferences were either disaster management practitioners or scientists from different disciplines. The research team plan to present more papers from this research to at least 5 additional conferences during 2017 and 2018.

Formal Meetings

The research team also managed to share the preliminary results at meetings with farmers and within provincial and national Departments of Agriculture. The results from this project contributed directly to the development of drought indicators for South Africa. The findings of this research were passed on to the specialist committee for the National Drought Task Team on drought indicators. The development of drought indicators for South Africa is a direct result of this research.

Almost every farmer interviewed during the research mentioned the need for affordable drought insurance. As a result of that need, the research team organised a workshop with experts from the insurance industry in South Africa. The possibility of index insurance was discussed. This initiative was later followed with an agriculture and insurance support conference in Johannesburg. The insurance industry is now looking into affordable drought insurance packages for agriculture, but this remains an on-going process. It became clear that drought insurance is not viable without the involvement and support from government.

The main audiences of the formal meetings were experts and officials within the private sector and government departments.

Scientific Publications

Publishing in peer-reviewed journals remained a cumbersome and long process. Two papers have already been published plus one chapter in a book. In addition, three further papers have been accepted and are currently (February 2017) undergoing final editing and will be published in 2017.

The articles published and accepted are the following.

1. BAHTA, Y.T., JORDAAN, A.J. & MUYAMBO, F. 2016. Communal farmers' perception of drought in South Africa: Policy implication for drought risk reduction. *International Journal of Disaster Risk Reduction,* 20:39-50.DOI:10.1016/j.ijdrr.2016.10.007 (http://dx.doi.org/10.1016/j.ijdrr.2016.10.007)
2. MUYAMBO, F., JORDAAN, A.J. & BAHTA, Y.T**.** 2016. Assessing social vulnerability to drought in South Africa: Policy implication for drought risk reduction. *Jamba: Journal of Disaster Risk Studies.*
3. MDUNGELA, N.M., BAHTA, Y.T. & JORDAAN, A.J. (2016). Farmers Choice of Drought Coping Strategies to Sustain Productivity in the Eastern Cape Province of South Africa. *Frontier Sustainability.*
4. MDUNGELA, N.M, BAHTA, Y.T. AND JORDAAN, A.J. 2016. Indicators for economic vulnerability to drought in the Eastern Cape province of South Africa. *Development in Practice*. (Accepted, February 2017)
5. MUYAMBO, F., JORDAAN, A.J. AND BAHTA, Y.T**.** 2016. The role of indigenous knowledge in drought risk reduction of communal farmers in South Africa- *Jamba: Journal of Disaster Risk Studies.* (Under final review, February 2017)

At least three more papers are to be prepared for publication in 2017 or 2018.

Annexure 1B: Capacity and Competency Development

Capacity building was a key component of this research and it was envisaged as part of the original proposal that the Project would have an academic footprint of 5 Masters students and 1 PhD student. Non-formal capacity building is also regarded as an important part of the research and the original proposal mentioned capacity building amongst target groups such as extension officers, commercial farmers and communal farmers as a key element of the project. This objective was also achieved during the project and it is discussed in more detail in the next sections.

Students

Selection of Students

Capacity building of students is one of the core deliverables of this project and students were selected based on criteria such as (i) field of academic expertise, (ii) previous performance and capacity to complete post graduate studies, (iii) availability, (iv) capacity to work in a team, (v) previously disadvantaged status, (vi) local Eastern Cape language skills, and (vii) motivation to work on the topic and with the rest of the project team. Selection criteria are discussed in more detail below:

Field of academic expertise: The project was multi-disciplinary in nature with a focus on the hazard itself, disaster risk reduction, economic vulnerability, environmental vulnerability, social vulnerability and coping capacity. In addition, results needed to be visualized through GIS and that also required inputs from a person with GIS background. We managed to select a variety of students with different academic backgrounds and academic departments. Students registered with the Department of Agricultural Economics, the Department of Soil, Crop and Climate Science, the Department of Geography and DiMTEC, all at the University of the Free State, participated in the research.

Previous performance: Experience and study records from previous degrees were considered as one of the criteria for selection. Students had to prove through study records that they had achieved at least 65% during the final year of their previous degree.

Availability: Students were required to work on the research during 2014, 2015 and/or 2016. The project started during 2013, with a completion date in February 2017. We therefore had to schedule students' research according to project deliverables and they had to adhere to deliverable due dates.

Teamwork: Students from different backgrounds and fields of expertise had to work together and with farmers through interviews and group discussions. The inter-personal skills of the selected students were therefore also considered as an important criterion for selection.

Previous disadvantaged status: All students who participated on the project qualified as being previously disadvantaged. Three students from other African countries were selected, however, because of their specific field of expertise and interest. These students were (i) Mr Oluwatoba Fadeyi, a student with Nigerian citizenship who completed his MSc Agric Economics at UFS with distinction and who was selected to work with Prof Grove on drought loss functions, (ii) Mr Daniel Mlenga, a Swaziland citizen who worked for 1 year on the project as part of his PhD, and (iii) Ms Fumiso Muyambu, a Zimbabwean citizen who completed her Higher Diploma in Disaster Management as the top student in 2013. All other students were South African citizens.

Local language: All of the selected students were required to be fluent in English. It was also important for fieldwork amongst communal farmers to select people who could understand Xhosa. Seven of the eight students could understand Xhosa. The lack of a student with a good understanding of Afrikaans was, in hindsight, somewhat problematic. A number of communal farmers in the western part of Cacadu and Joe Gqabi spoke Afrikaans and the commercial sector held most of their meetings in Afrikaans. Our students could not follow these discussions and the project leader had to conduct almost all the fieldwork amongst the commercial sector himself.

Motivation to work on the project: It was important to select students who were motivated to work on drought related issues. We took care not to select students who applied for the project team because of the funding opportunity alone. The opportunity for funding in itself is a great motivator, but we were careful to select students with a real interest in the topic and who were serious in completing their studies in time.

Students were therefore selected for Masters and PhD studies based on their field of academic expertise. A summary of the students who worked on the project is shown in Table 1B.1.

Table 1B.1: Students registered on project

Student name	Department	Degree	Field of study
Thabisile Miya	DiMTEC	Masters Disaster Management	Hazard science
Nomalanga Mdungela	Agricultural Economics	Masters Agricultural Management	Economic vulnerability
Fummie Muyambu	DiMTEC	Master Disaster Management	Social vulnerability
Boitumelo Phatudi-Mphahlele	Soil, Crop & Climate Sciences	MSc Agro-meteorology	Environmental vulnerability
Curtis Nhlamulo	Geography	MSc Geography	GIS
Siviwe Shwavaba	DiMTEC	PhD Disaster Management	Risk assessment
Daniel Mlambo	DiMTEC	PhD Disaster Management	Risk assessment
Oluwatoba Fadeyi	Agriculture Economics	PhD Agricultural Economics	Loss functions

Student performance

Project management anticipated that some students might not complete their studies owing to various circumstances. However, the project team is satisfied that the goals in terms of capacity building for post-graduate students were achieved. Some of the students are still in process of finalizing their disertations while some of them have already obtained employment as a result of their experience gained in the project. The following is a summary of students' performance

- Two students graduated with Masters degrees.

- Three Masters students obtained permanent appointments and expect to hand in their dissertations and complete studies during 2017
- Two PhD students should complete studies during 2017
- One PhD student left the program.

A detailed summary of students' performance is shown in Table 1B.2.

Table 1B.2: Student performance

Name	Degree	Comment
Thabisile Miya	Masters Disaster Management	Appointed as Deputy Director Disaster Management in Kwa-Zulu-Natal. One of the key personnel in managing drought in KZN. Completed all research plus analysis. Only final thesis editing outstanding (Feb 2017). Reason for not completing is time constraint due to drought management commitments.
Nomalanga Mdungela	Masters Agricultural Management	Completed Masters in Agricultural Management. Appointed by Standard Bank as Agricultural Economist.
Fummie Muyambu	Master Disaster Management	Completed Masters in Disaster Management. Currently enrolled for PhD. 5 months study visit in Hungary on ERASMUS exchange program.
Boitumelo Phatudi-Mphahlele	MSc Agro-meteorology	Appointed as researcher at SAWS. Continuing with studies at Pretoria University with bursary from SAWS.
Curtis Nhlamulo	MSc Geography	Appointed as GIS specialist at a private engineering company. In final stages of thesis submission. Should hand in mid-2017. Dr C Barker is study leader.
Siviwe Shwavaba	PhD Disaster Management	Busy with finalization of thesis. Should hand in mid-2017.
Daniel Mlambo	PhD Disaster Management	Was not involved full-time in project. Study area in Swaziland with similar topic. Contributed to literature chapters on vulnerability and resilience. Completed own literature study. Partly completed fieldwork. Should hand in end of 2017 or early 2018.
Oluwatoba Fadeyi	PhD Agricultural Economics	Left project

Successful capacity building is much more than only attaining the qualification. The teamwork and inter-disciplinary experience gained during fieldwork was immensely important to students. The fact that most students from the project are currently employed in good permanent positions is an indication of the contribution of the project to prepare students for the work place. The exposure to practical challenges with multi disciplinary solutions provided students with valuable insight. This is proof of the relevance of this research and of the degrees linked thereto.

Extension officers and farmers

The Rapid Rural Appraisal (RRA) research method allows the research team to transfer knowledge and to build capacity during the data gathering process. Two sets of workshops were organized. The one set of workshops was focused on communal farmers and led by the project leader with the assistance of Ms Nomalanga Mdungela, Ms Fummie Muyambu and Mr Oluwatoba Fadeyi. The second set of workshops with a slightly different program and with a focus on land reform beneficiaries these were led by Mr Siviwe Shwavaba (PhD candidate) with the project leader only in a lecturing and mentoring role.

Two workshops per district were organized and facilitated for communal farmers as well as two workshops per district for land reform beneficiaries. One hundred and ninety communal farmers and 122 extension officers participated in the communal farmers workshops and 95 farmers, 17 extension officers and 8 mentors participated in the land reform beneficiary workshops. A summary of the communal farmers' workshops is shown in Table 1B.3.

Table 1B.3: Farmers and extension officers attendance during the workshop

District Municipality	Venue	No. of Extension Officer	No. of Farmers	Total
Cacadu	Willowmore	13	46	**59**
	Port Alfred	7	26	**33**
Joe Gqabi	Maclear	27	14	**41**
	Aliwal North	10	15	**25**
OR Tambo	Tsolo	48	58	**106**
	Lusikisiki	17	31	**48**
	TOTAL	**122**	**190**	**312**

A summary of the workshops for land reform beneficiaries is shown in Table 1B.4.

Table 1B.4: Farmers and extension officers attendance during the workshop

District Municipality	Venue	No. of Extension Officer	No of Mentors	No. of Farmers	Total
Cacadu	Alexandria	5	3	22	**27**
	Jansenville	5	1	19	**24**
OR Tambo	Port St Johns	3	1	25	**28**
Joe Gqabi	Aliwal North	**4**	**3**	**29**	**33**
	TOTAL	**17**	**8**	**95**	**112**

All workshops were designed in such a way that we could train attendees and inform them about elements that constitute drought risk and then also gather data from attendees. The morning sessions consisted of lectures in an informal way where farmers were motivated to participate and ask questions. The practical experience of the project leader about similar farming systems in other African countries assisted in making the lectures practical and lively for attendees. Structured questionnaires were used during the first afternoon sessions in order to obtain feedback from farmers. That was followed by a discussion and feedback in small groups. Extension officers assisted during the group sessions and their support was invaluable. A typical workshop program for communal farmers is shown in Table 1B.5.

Table 1B.5: Workshop program for communal farmers

Time	Topic	Responsible
09h00 – 09h40	What is drought risk	AJJ
09h40 – 10h30	Elements of drought risk assessment	AJJ
10h30 – 11h00	Coffee	
11h00 – 11h30	Environmental vulnerability	BPM
11h30 – 12h00	Economic vulnerability	OF
12h00 – 12h30	Social vulnerability	FM
12h30 – 13h00	Drought risk reduction: Adaptation, coping, resilience	AJJ
13h00 – 14h00	Lunch	
14h00 – 15h15	Feedback from farmers	All
15h15 – 15h30	Coffee	
15h30 – 16h30	Feedback from farmers	All

- *AJJ* *Prof Andries Jordaan*
- *BPM* *Ms Boitumelo Phatudi-Mphahlele*
- *OF* *Mr Oluwatoba Fadeyi*
- *FM* *Ms Fummie Muyambu*

The workshops held for land reform beneficiaries were structured in a similar way as those for the communal farmer beneficiaries, with lectures during the first part of the workshop and feedback from farmers during the latter part of the workshop. The feedback was, however, handled differently in that farmers had to develop mind maps in small groups about their drought challenges and problems. Workshop program for land reform beneficiaries is shown in Table 1B.6.

Table 1B.6: Workshop program for land reform beneficiaries

Time	Topic	Responsible
09h00 – 09h40	What is drought risk	AJJ
09h40 – 10h30	Elements of drought risk assessment	AJJ
10h30 – 11h00	Coffee	
11h00 – 11h30	Environmental vulnerability	BPM
11h30 – 12h00	Economic vulnerability	OF
12h00 – 12h30	Social vulnerability	FM
12h30 – 13h00	Drought risk reduction: Adaptation, coping, resilience	AJJ
13h00 – 14h00	Lunch	
14h00 – 15h15	Feedback from farmers	All
15h15 – 15h30	Coffee	
15h30 – 16h30	Feedback from farmers	All

Initially we invited extension officers, communal farmers as well as commercial farmers to the workshops, but as expected, the communal and commercial systems are totally different in their needs and experiences. Education levels were also different between the two groups, which poses a challenge for lecturing and discussions. We also had to translate some of the lectures into Xhosa or Afrikaans during the communal farmer workshops. We therefore continued with the workshops without commercial farmers. The content of our lectures was new to communal farmers as well as to extension officers.

Communal farmers provided the following feedback after attending the workshops:

- *This is the first time that we have been taught anything on drought*
- *I am looking differently at drought now*
- *I have a much better understanding of drought*
- *Nobody before today explained drought to us*
- *I realize I can do something about drought*

Extension officers were also largely ignorant about drought issues. We identified a huge knowledge gap amongst extension officers. Many of the extension officers are qualified only with agricultural diplomas, with little practical understanding of farming. The general perception from the research team was low motivation levels of extension officers, mostly because of frustration for the high volumes of administrative work, a lack of vehicles and/or travel allowances to visit farmers and a lack of real results. The senior extension staff though was more motivated, better trained and educated, with higher degrees in extension. The research team received excellent support from all staff in the different regions of the Department of Agriculture and Rural Development. Extension staff supported the research team with invitations to workshops, workshop venues and in many cases they also organized transport for farmers. Extension officers were also helpful in the provision of information and data upon request.

The contact with extension officers also provided the opportunity for the research team to transfer knowledge and share research results. Some of extension staff commented as follows after completion of the workshops:

- *I understand drought much better now*
- *I had never heard about the importance of social, economic and environmental vulnerability*
- *With this knowledge we can give farmers much better advice on how to cope with drought*
- *We need more training like this*
- *….Yah, farmers can do something about drought; We do not always have to wait for government*
- *We are occupied too much with projects and we do not have time and vehicles to give this type of training to farmers*

2 Description of Research Area

Jordaan, A.J.

Executive Summary

Three districts in the Eastern Cape (EC) were selected as the study area, based on the following:

- *Diversity in climate with precipitation that varies from more than 1000 mm per annum in the eastern coastal region to as little as 250mm in the west;*
- *Soil and agricultural potential with high potential agricultural land in the OR Tambo district and low potential Karoo in Cacadu;*
- *Extensive and intensive livestock systems;*
- *Dry land systems and irrigation systems;*
- *Vast areas of communal land and highly successful commercial farming systems, with OR Tambo in its entirely being communal land controlled by Chiefs and with no private land ownership system.*
- *Different farming systems.*

The districts Joe Gqabi, OR Tambo and Cacadu were eventually selected as the three study areas. The spatial units for calculation of drought risk were the quaternary catchments.

2.1 Description of Eastern Cape Province

The Eastern Cape (EC) is one of the nine Provinces in South Africa (SA) and borders KwaZulu-Natal (KZN), Free State (FS) and Lesotho to the north, and the Northern Cape (NC) and Western Cape (WC) to the west. The Indian Ocean forms the southern and eastern border of the EC (Figure 2.1).

The province boasts a natural beauty that includes temperate forests, rolling landscapes of hinterland, semi-desert areas of the Karoo to the west and beautiful and unspoiled coastlines to the south and east. The northeast touches the southern tips of the Drakensberg mountain series while mountains and foothills are common in the southern parts of the province. The coastal region in the east is temperate with high rainfall areas in the northern coastal region (Province of the Eastern Cape, 2010).

Fig 2.1. Satellite image of the Eastern Cape
Source: Google Earth, 2013

The capital of the Eastern Cape is Bisho, located inland between the port cities of East London and Port Elizabeth, which is the largest city in the province. The main industrial centres are East London, Uitenhage and Port Elizabeth, the latter known for its automotive manufacturing industry. The province is located at an equal distance from the other industrial zones in South Africa in Cape Town, Durban and in Gauteng and is linked with modern rail, road and flight connections. The three ports in the province, East London, Port Elizabeth and the new Ngqura port at Coega link the province to the international market for import and export (Province of the Eastern Cape., 2010). Most wool from South Africa, for example, is exported from the Port Elizabeth port.

The Eastern Cape is made up of one metropolitan municipality, six district municipalities, and 38 local municipalities (See Figure 2.2).

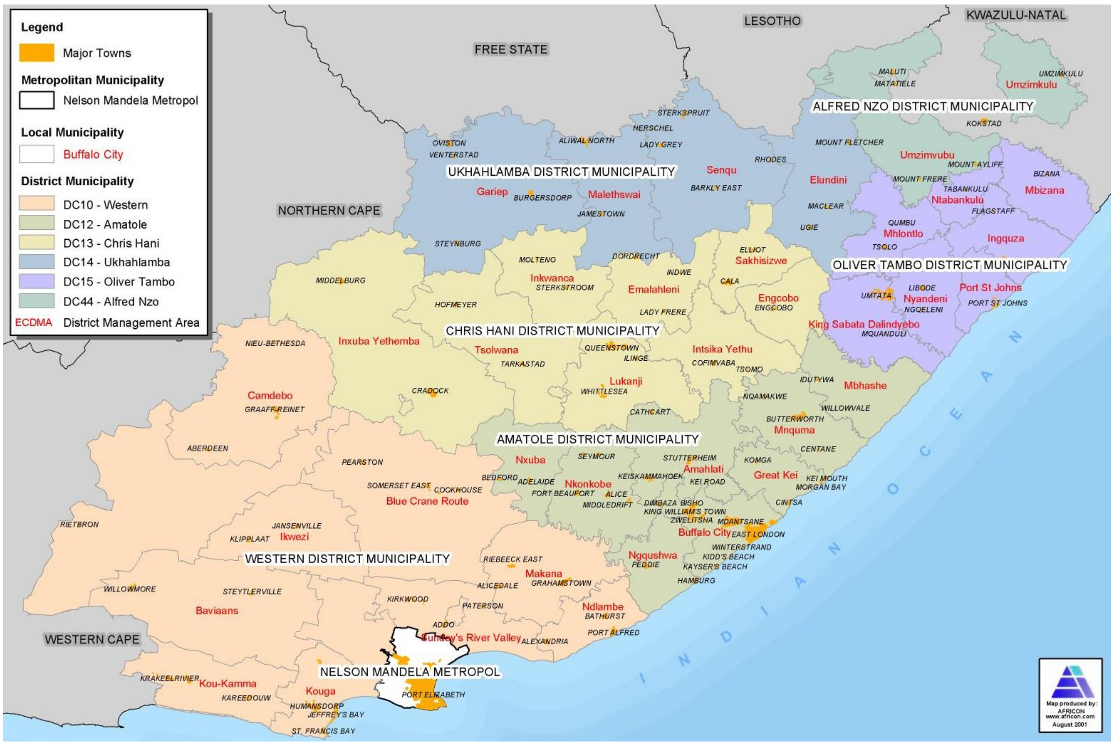
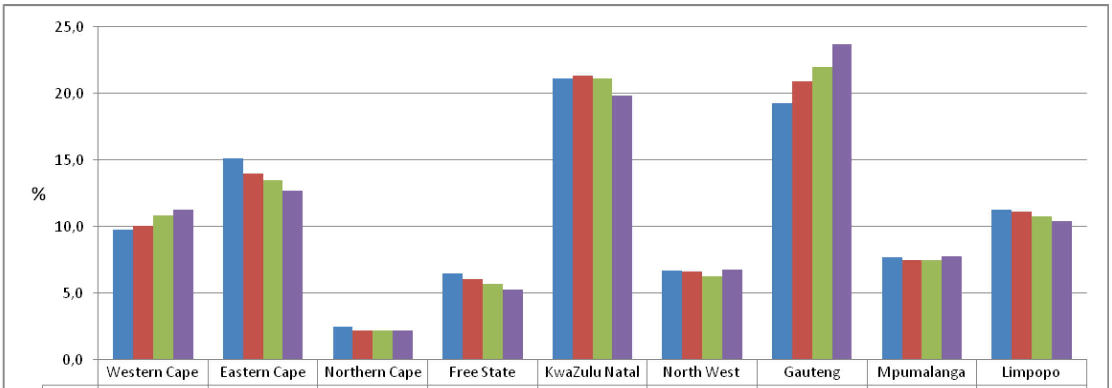


Fig 2.2. Eastern Cape showing District and Local Municipalities

2.1.1 Eastern Cape Demographics

Population numbers in South Africa increased from 40,5 million in 1996 to 44,8 million in 2001 to 48,5 million in 2007 and 51,7 million in 2011. In contrast to the national population growth, population numbers in the Eastern Cape (EC) declined from 15,1 million in 1996 to 12,7 million in 2011 (Figure 2.3; StatsSA, 2012).



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu Natal	North West	Gauteng	Mpumalanga	Limpopo
1996	9,7	15,1	2,5	6,5	21,1	6,7	19,3	7,7	11,3
2001	10,1	14,0	2,2	6,0	21,4	6,7	20,9	7,5	11,1
2007	10,9	13,5	2,2	5,7	21,2	6,3	22,0	7,5	10,8
2011	11,2	12,7	2,2	5,3	19,8	6,8	23,7	7,8	10,4

Fig 2.3. Population numbers per province 1996 – 2011
Source: StatsSA, 2012

The only two provinces with increased population numbers are Gauteng and the Western Cape. The main reason for the migration of people from other provinces to these two provinces is the search for employment and better livelihoods.

Population density in rural areas has a direct influence on drought risk since high rural population density is normally characterized by overgrazing and land degradation. Jordaan (2011) identified rural population density and the lack of land ownership as amongst the main reasons for increased vulnerability to drought. The population density per km^2 in the EC is illustrated in Figure 2.4. It is clear from this map that the highest population density is located in the two cities, Port Elizabeth and East London with more than 250 people per square kilometre. Population density in the rural areas of OR Tambo plays a significant role in the exposure to exogenous shocks such as drought.

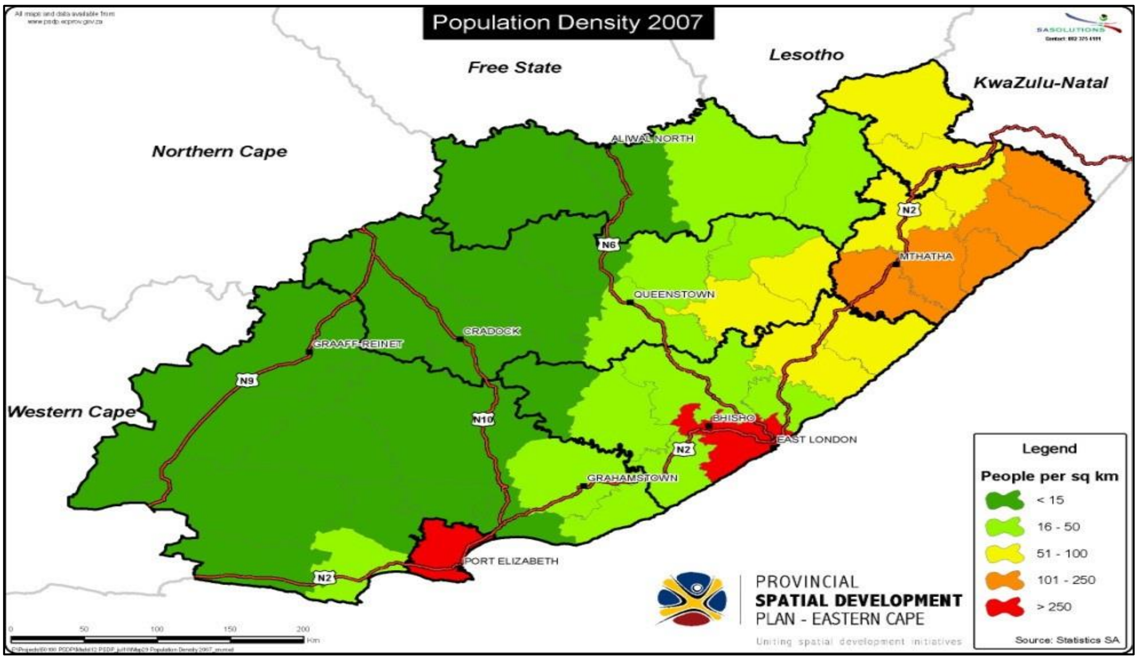
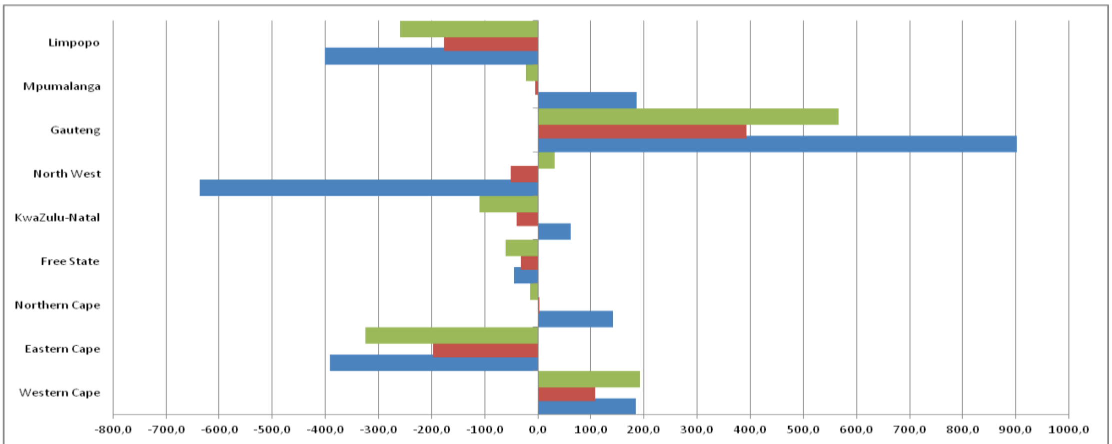


Fig 2.4. Population density expressed as people per square kilometre
Source: Province of the Eastern Cape, 2010

Figure 2.5 shows the inter-provincial migration of people moving from one province to others. The largest out-migration for the 2011 Census is the Eastern Cape province with 325 100 people having migrated out of the province since the 2007 community survey. Over the 10-year period since the 2001 census the Eastern Cape and Limpopo both experienced the highest out-migration of all provinces in South Africa. Both provinces have large rural areas of communal land from the former homelands; Venda in Limpopo and Ciskei and Transkei in the Eastern Cape. It seems therefore that people move from rural areas to provinces with better opportunities. Out-migration from these areas could be an indicator for vulnerability.



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo
2011	192,4	-325,1	-15,2	-59,8	-109,9	31,7	566,8	-21,7	-259,1
2007	108,5	-196,7	2,4	-32,6	-39,8	-51,7	392,4	-5,3	-177,2
2001	185,0	-392,0	141,0	-44,2	61,9	-637,2	901,6	185,3	-401,3

Fig 2.5. Net migration per province (1000s)
Source: StatsSA, 2012

Figure 2.6 illustrates the population pyramid of the Eastern Cape for the three previous censuses and the 2007 community survey. The shapes of the pyramids depict trends in fertility, mortality and migration. The shape of the pyramid in the Eastern Cape shows a pattern of a young population and possibly high migration or mortality for people older than 20 years of age. The pyramid also shows a trend with declining numbers since 1996 amongst children and youth younger than 20 years of age. Interesting is an increase in population numbers amongst people older than 20.

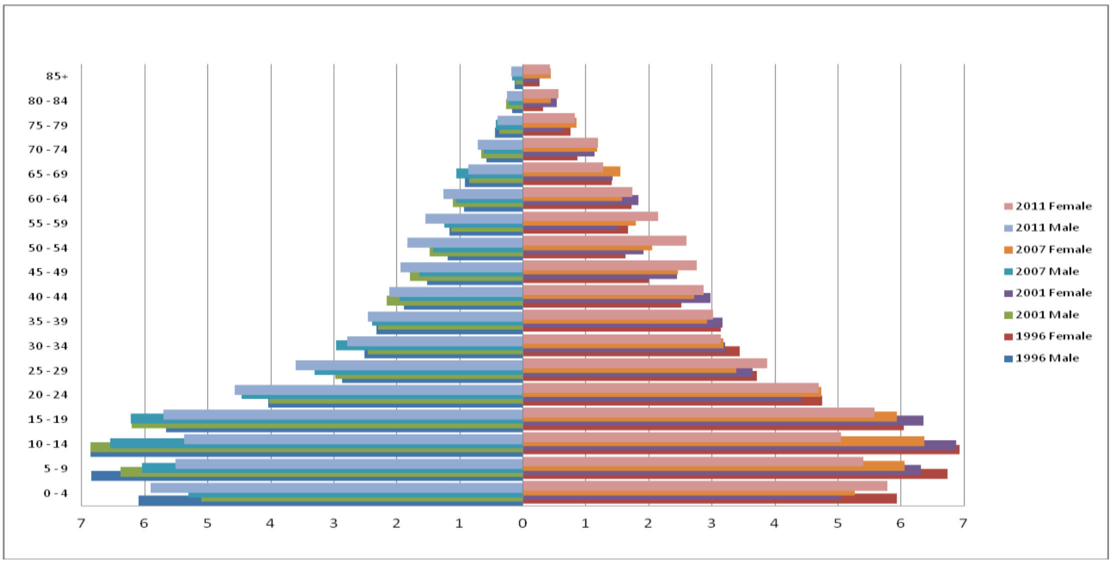


Fig 2.6. Population pyramid for the Eastern Cape 1996 – 2011
Source: StatsSA, 2012

Education is an important indicator for vulnerability and resilience to external shocks. Figure 2.7 shows the percentage of people aged 20 years and older with no schooling. Consistent with the rest of South Africa is the decline in adult illiteracy, also evident in the Eastern Cape. Adult illiteracy in the EC declined from 20,9% of the population in 1996 to 10,5% in 2011.

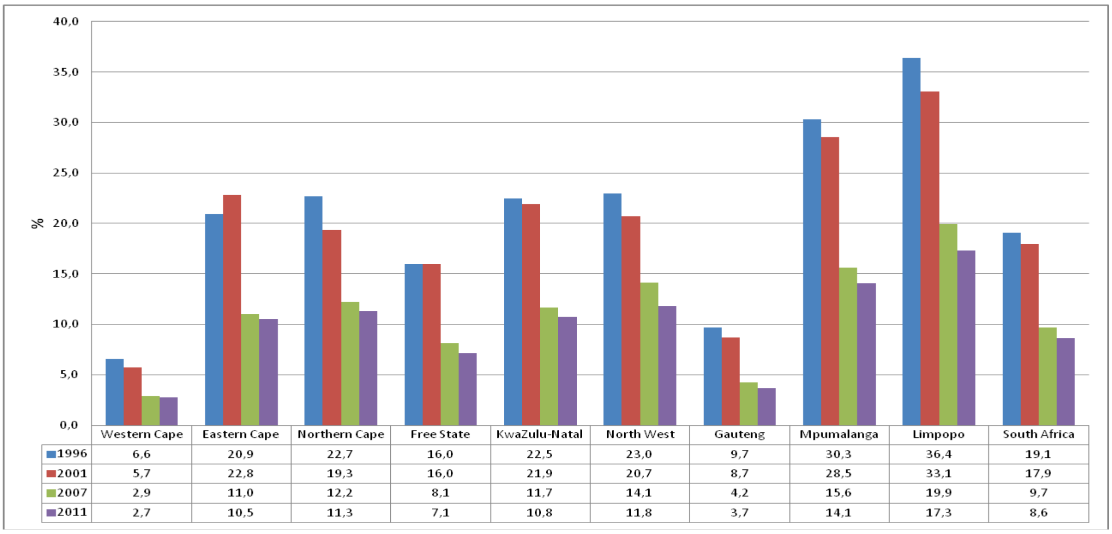


Fig 2.7. Percentage with no schooling for people older than 20 years of age 1996-2011
Source: StatsSA, 2012

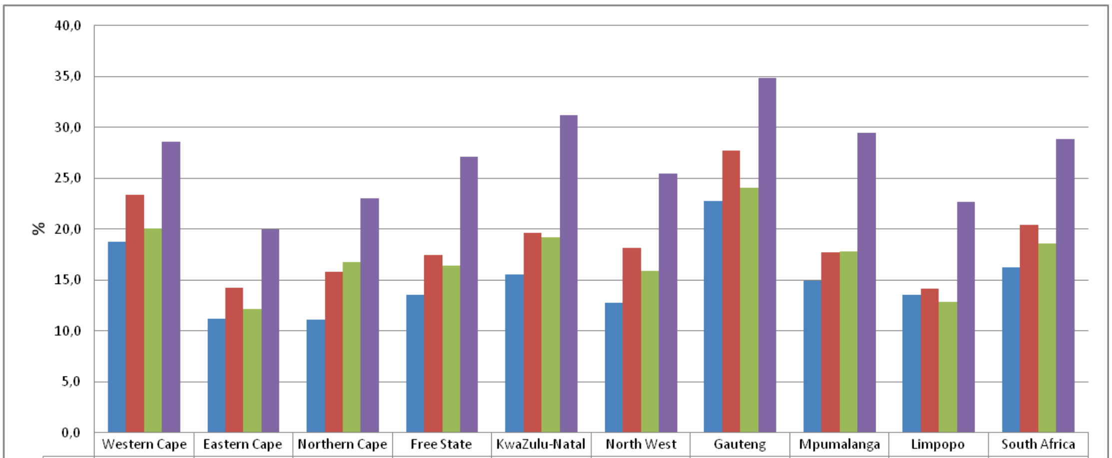
An alarming statistic is the fact that people of age 20 and older with no schooling in the EC actually increased between 2007 and 2011 from 366 589 to 375 754. An increase with positive results in terms of resiliency building are matriculants and people with higher education qualifications, whose numbers increased from 402 853 in 2007 to 715 117 in 2011 and 220 223 in 2007 to 303 279 in 2011 respectively (See Table 2.1).

Table 2.1: Level of education for people 20 years and older in the EC, 1996-2011

	1996	2001	2007	2011
No schooling	607 746	729 112	366 589	**375 754**
Some primary	612 790	623 409	738 407	**653 118**
Completed primary	257 921	235 194	243 853	**223 075**
Some secondary	949 592	947 206	1 346 084	**1 300 491**
Grade 12 / Std 10	325 870	455 415	402 853	**715 117**
Higher	148 501	202 507	220 223	**303 279**
Total	**2 902 420**	**3 192 843**	**3 318 009**	**3 570 833**

Source: StatsSA, 2011.

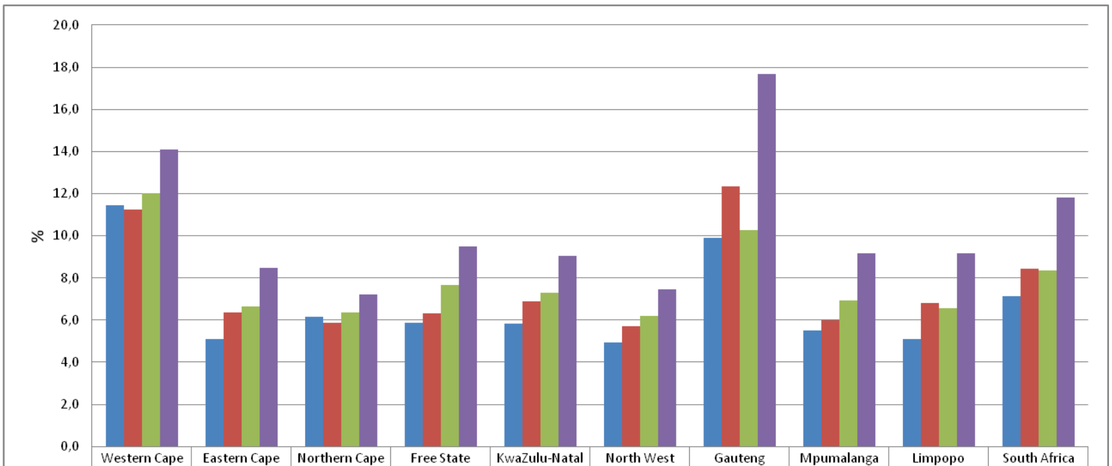
Figure 2.8 illustrates that about 28,9 % of people aged 20 years and older completed grade 12 in South Africa. The increase in proportion of people older than 20 with Grade 12 since 2007 is dramatic in all provinces, but the Eastern Cape remains the province with the lowest percentage of matriculants in South Africa at only 20,6%.



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	South Africa
1996	18,8	11,2	11,1	13,5	15,6	12,8	22,8	14,9	13,6	16,3
2001	23,4	14,3	15,8	17,5	19,6	18,1	27,7	17,7	14,1	20,4
2007	20,1	12,1	16,7	16,4	19,2	15,9	24,1	17,8	12,8	18,6
2011	28,6	20,0	23,0	27,1	31,2	25,4	34,8	29,5	22,7	28,9

Fig 2.8: Percentage of matriculants per province 1996-2011
Source: StatsSA, 2012

Higher education is also an important indicator for resilience and the proportion of people with higher education qualifications increased from 5,3% in 1996 to 8,5% in 2011, as shown in Figure 2.9. This does not represent an increase in the actual number of people with higher education qualifications since population numbers in the province declined since 1996. The Eastern Cape is again the province in South Africa with the lowest proportion of people with higher education qualifications at only 8,5%.

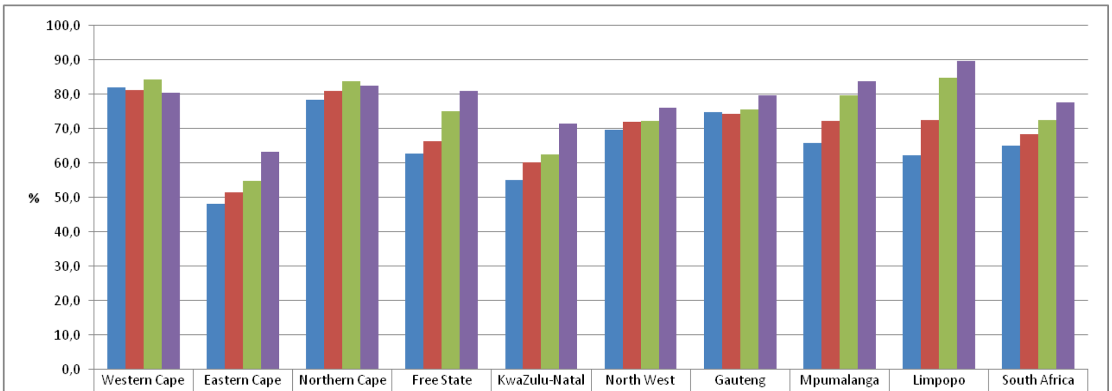


	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	South Africa
1996	11,5	5,1	6,2	5,9	5,8	5,0	9,9	5,5	5,1	7,1
2001	11,2	6,3	5,9	6,3	6,9	5,7	12,3	6,0	6,8	8,5
2007	12,0	6,6	6,3	7,7	7,3	6,2	10,3	6,9	6,6	8,4
2011	14,1	8,5	7,2	9,5	9,1	7,5	17,7	9,2	9,2	11,8

Fig 2.9: Percentage of people aged 20 years and older with higher education qualifications
Source: StatsSA, 2012

2.1.2 Household goods and services

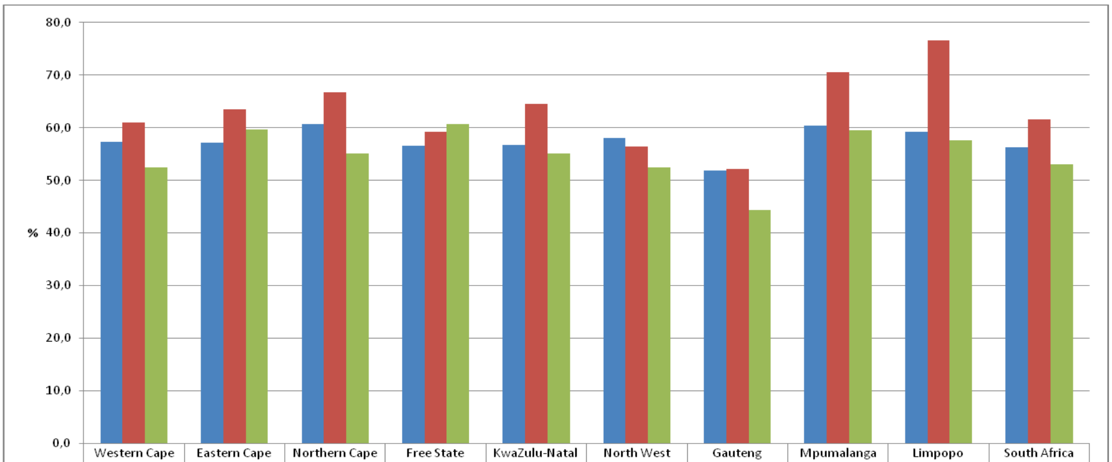
The type of dwelling and ownership in rural areas are vulnerability and coping capacity indicators that is useful for calculating drought risk (Jordaan, 2011). Figure 2.10 illustrates the percentage of households per province who live in formal dwellings. The number of households in the Eastern Cape with formal dwellings increased from 48% in 1996 to 63,2% in 2011; an increase of some 15%, but the Eastern Cape remains the province with the lowest proportionate number of formal dwellings in South Africa.



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	South Africa
1996	82,1	48,0	78,3	62,9	55,2	69,6	74,9	65,9	62,2	65,1
2001	81,3	51,5	81,0	66,5	60,2	72,0	74,4	72,2	72,5	68,5
2007	84,2	54,8	83,7	75,2	62,5	72,2	75,5	79,6	84,9	72,6
2011	80,4	63,2	82,4	81,1	71,6	76,2	79,8	83,8	89,8	77,6

Fig 2.10: Percentage of livelihoods with formal dwellings per province 1996-2011
Source: StatsSA, 2012

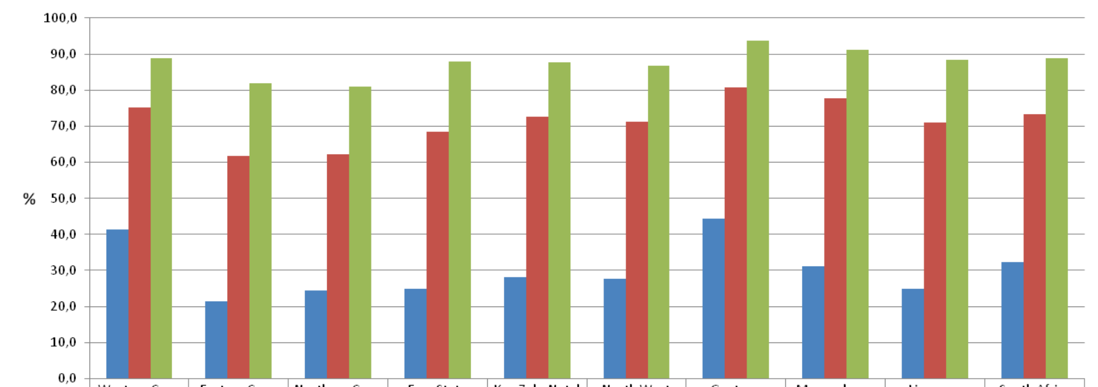
The proportionate number of household that own their dwellings increased from 57,1% in 2001 to 63,5% in 2007 and 59,6% in 2011 (See Figure 2.11). This is a high percentage and the Eastern Cape compares well with the rest of South Africa.



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	South Africa
2001	57,3	57,1	60,8	56,6	56,7	58,1	51,9	60,4	59,2	56,3
2007	61,1	63,5	66,7	59,2	64,5	56,4	52,2	70,5	76,6	61,6
2011	52,4	59,6	55,1	60,7	55,1	52,4	44,3	59,5	57,7	53,1

Fig 2.11: Percentage of households that own dwellings by province, 2001-2011
Source: StatsSA, 2012

Ownership is one of the main indicators for resilience since people can use property as collateral during periods of external shocks, or they can sell assets in order to cope with external shocks (Jordaan, 2012).

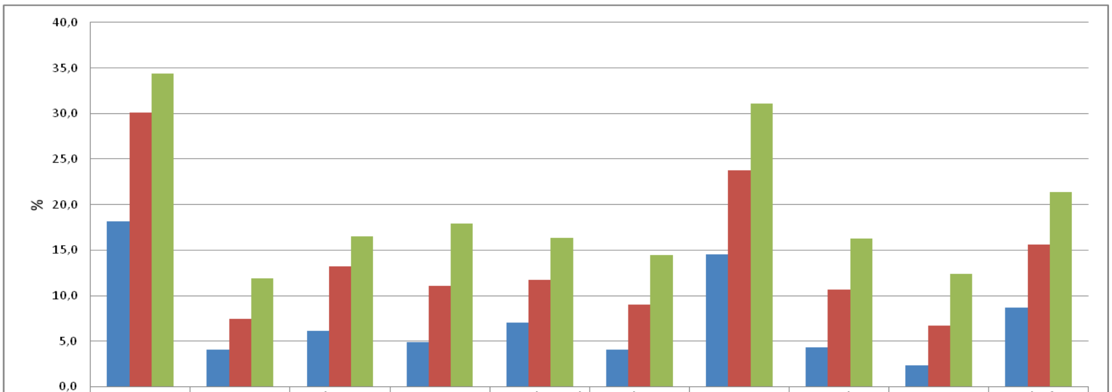


	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	South Africa
2001	41,4	21,5	24,5	24,8	28,2	27,7	44,4	31,1	24,8	32,3
2007	75,1	61,7	62,2	68,5	72,6	71,3	80,7	77,8	70,9	73,3
2011	88,9	81,9	81,1	87,9	87,6	86,8	93,8	91,1	88,5	88,9

Fig 2.12: Percentage of households with cell phones per province, 2001-2011
Source: StatsSA, 2012

Household goods and particularly items such as cell phones, televisions, radio, computers and Internet access are important indicators of resilience since these items are used for early warning and dissemination of information (Jordaan, 2011). Illustrated in Figure 2.12 is the proportionate number of people per province with cell phones. The increase in cell phone ownership is dramatic in the Eastern Cape and shows the same tendency as in the rest of South Africa; from only 21,5% of the population in 2001 to 81,9% in 2011. The South African Weather Service (SAWS) and the DAFF make use of cell phone networks to distribute weather early warnings and a cell phone coverage of more than 80% is an indication of the potential to build resilience through early warnings and information dissemination (Jordaan, 2011).

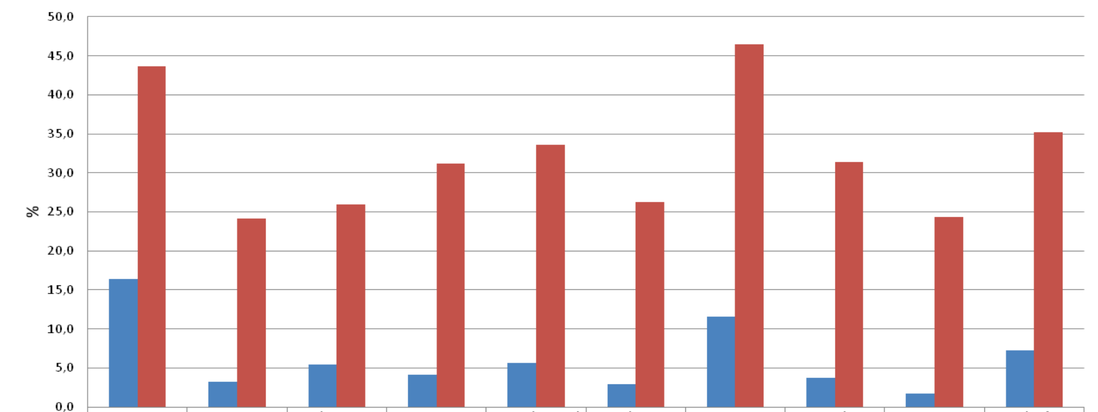
Computers are also an indicator for resilience since one can expect farmers with access to computers as being better equipped for proper planning and record keeping. The percentage of households in South Africa with computers increased from 8,6% in 2001 to 21,4 % in 2011 (See Figure 2.13). The percentage of people with computers in the EC is the lowest in SA with only 11,9% of households owning computers in 2011.



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	South Africa
2001	18,2	4,1	6,1	4,9	7,0	4,1	14,5	4,3	2,4	8,6
2007	30,1	7,5	13,2	11,1	11,7	9,1	23,8	10,7	6,7	15,6
2011	34,4	11,9	16,5	17,9	16,4	14,4	31,1	16,3	12,4	21,4

Fig 2.13: Percentage of households using computers per province, 2001-2011
Source: StatsSA, 2012

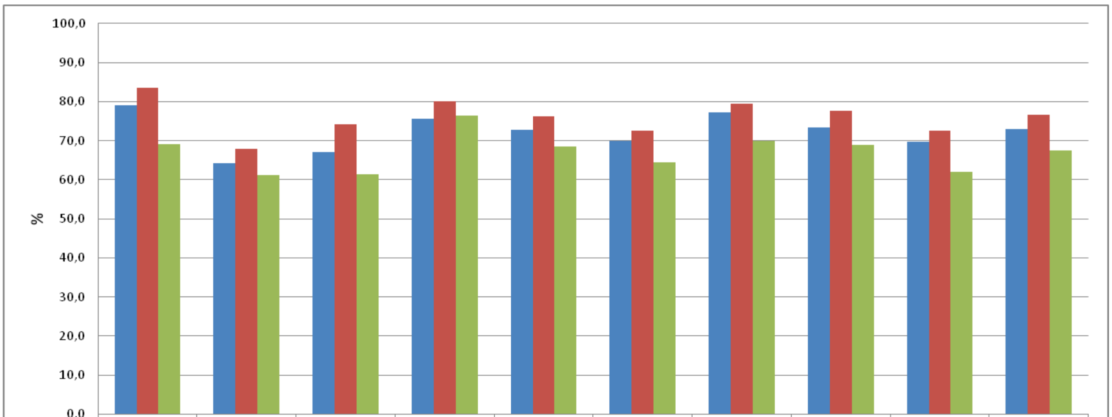
Access to the internet has become important and in future will play an ever increasingly important role for early warning dissemination. Illustrated in Figure 2.14 is the dramatic increase in the percentage of households with internet access. Internet access for South African households increased from 7,2% in 2007 to 35,2% in 2011. The EC shows an equally dramatic increase from 3,2% in 2007 to 24,1% in 2011. In spite of the dramatic increase, internet access in the EC is still the lowest in SA.



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	South Africa
2007	16,4	3,2	5,4	4,1	5,6	2,9	11,6	3,7	1,8	7,2
2011	43,7	24,1	25,9	31,2	33,6	26,3	46,4	31,4	24,3	35,2

Fig 2.14: Percentage of households per province with internet access, 2007-2011
Source: StatsSA, 2011

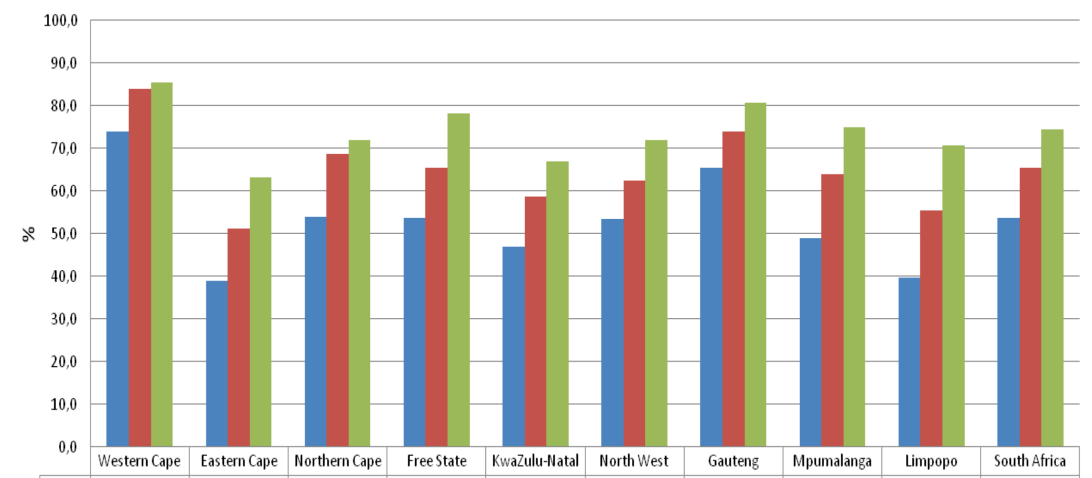
Radio is the most common channel of communication, especially in rural areas (Jordaan, 2011). The proportion of households with radios declined in SA from 73% in 2001 to 67,5% in 2011 (See Figure 2.15). The same decline is evident in the EC with 64,3% in 2001 to 61,1% in 2011. The decline could be attributed to the fact that households have shifted to digital media such as cell phones and television. One can expect a higher percentage of radio exposure in rural areas than television and the radio might be a useful medium for communicating early warning and information on drought risk reduction.



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	South Africa
2001	79,1	64,3	67,2	75,5	72,9	69,9	77,2	73,3	69,7	73,0
2007	83,4	67,9	74,2	80,2	76,2	72,6	79,6	77,6	72,6	76,5
2011	69,2	61,1	61,5	76,4	68,4	64,5	69,8	68,9	62,1	67,5

Fig 2.15: Percentage of households with radios per province, 2001-2011
Source: StatsSA, 2011

Figure 2.16 illustrates the percentage of households with television sets per province. The average for SA was 53,8% in 2001, 65,5% for 2007 and 74,5% for 2011 while the EC again has the lowest proportional numbers of televisions with 39% in 2001, 51,3% in 2007 and 63,2% in 2011. One can expect the lowest proportional numbers of televisions to be in the rural areas where signal strength might not be good. Jordaan (2011) found that a large percentage of farmers in the Northern Cape rely on the television for weather forecasts and drought early warning and television could thus be used as an indicator for drought resilience.



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo	South Africa
2001	74,1	39,0	54,0	53,8	46,9	53,5	65,4	49,1	39,8	53,8
2007	84,1	51,3	68,7	65,5	58,7	62,5	74,0	64,0	55,6	65,5
2011	85,5	63,2	72,0	78,2	67,1	71,9	80,8	75,0	70,9	74,5

Fig 2.16: Percentage of households with television sets per province, 2001-2011
Source: StatsSA, 2011

2.1.3 Labour

Unemployment and labour opportunities are both valuable indicators for resilience against external shocks. Commercial, smallholder and communal farmers seek alternative income sources in times of external shock such as droughts and the formal employment market provides a good alternative as a coping mechanism during external shocks The lack of alternative employment opportunities is indicative of high vulnerability (Jordaan, 2011). What is disturbing about the labour market in the EC is that around 2 million people are economically not active, as shown in Table 2.2.

Unemployed people add up to 615 849 people and represent 37,4% of the potentially productive population. The fact that fewer people have been in employment since 2007 (1,1 million in 2007 to 1 million in 2011) is reason for concern; so is the increase in economically inactive people (1,78 million in 2007 to ~ 2 million in 2011). These are indications of increased vulnerability and this vulnerability could be exacerbated by external shocks such as droughts.

Table 2.2: Labour market and unemployment in the Eastern Cape, 1996-2011

	1996	2001	2007	2011
Employed	778 634	748 881	1 104 300	**1 028 964**
Unemployed	724 054	890 373	724 723	**615 849**
Not economically active	1 757 729	1 948 969	1 780 709	**2 001 779**
Unemployment Rate	**48,2**	**54,3**	**39,6**	**37,4**
Total	**3 260 418**	**3 588 223**	**3 609 732**	**3 646 591**

Source: StatsSA, 2011

Unemployment rates for all provinces and in South Africa as a whole are shown in Figure 2.17. The official unemployment rate in SA is slightly down from 1996 at 33,9% to 29,8% in 2011. The EC however, together with Limpopo, remain the two provinces with the highest unemployment rates in SA; that in spite of the fact that both these provinces were declared as Presidential Development Nodes (Coetzee, 2013). Unemployment in the EC remains high at 48,2% in 1996, 54,3% in 2001, 39,6% in 2007 and 37,4% in 2011.

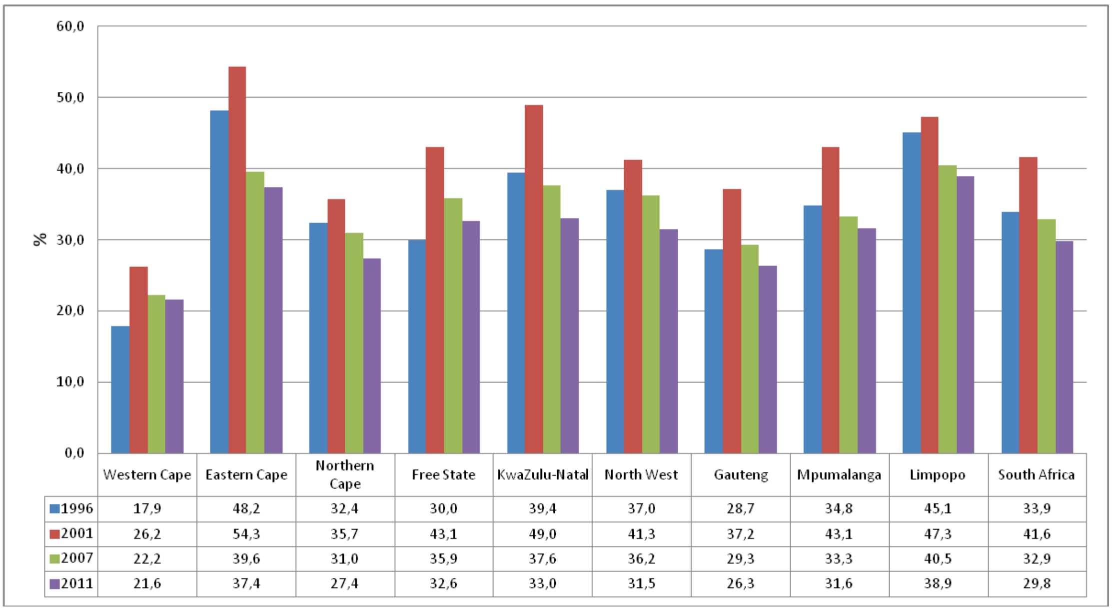


Fig 2.17: Unemployment rate per province 1996-2011
Source: StatsSA, 2011

2.1.4 Household Income

Household income is an important indicator for vulnerability to any external shock and the EC together with Limpopo have the lowest average household incomes for 2011 of only R64 550 and R56 841 respectively. This is way below the average for South Africa with R103 195 per annum (See Table 2.3). The increase in household income, however, is not as dramatic when one considers the consumer price index (CPI). When considering the CPI, households in 2011 received only 13% more than in 2001. In spite of much higher cash earnings, the average household in the EC cannot afford much more than in 2001. This is an area of concern considering the increased number of matriculants and people with higher education qualifications in the province.

Table 2.3: Average household income per province, 2001-2011

Province	2001	2011
Gauteng	R78 541	R156 222
Western Cape	R78 157	R143 461
Northern Cape	R39 757	R86 158
KwaZulu-Natal	R38 905	R83 050
Mpumalanga	R31 186	R77 597
Free State	R30 726	R75 314
North West	R30 189	R69 914
Eastern Cape	R29 334	R64 550
Limpopo	R22 985	R56 841
South Africa	**R48 385**	**R103 195**

Source: StatsSA, 2011

2.1.5 Geography and Environmental Features of the Eastern Cape

The Eastern Cape is approximately 170 000 square kilometres in size and covers 13,9% of South Africa's land area.

2.1.5.1 Vegetation

The EC is the only province in SA containing eight of the nine biomes of SA, as illustrated in Figure 2.18. The only biome not present in the EC is the desert biome, which is only to be found in the Richtersveld in the Northern Cape.

The province gradually transisions to an interior of Nama-Karoo and grassland in the west with succulent Karoo and Fynbos in the south. The south-eastern part of the province is characterized by the Albany thicket biome with the Savannah biome and Indian Ocean Coastal belt along the coast. The landscape is mountainous in the south with perennial and non-perennial rivers and streams flowing from the interior semi-arid Karoo to the coastal zone. To the north are rolling landscapes, mountains and dense forests in some of the coastal regions, with the majestic Drakensberg Mountains in the northern interior. The ecological diversity is also characterized by a tremendous diversity of climates, allowing for a large range of agricultural activities. The different biomes are used as an indicator for environmental vulnerability to drought since biomes react differently to dry periods and the recovery period after drought also differs.

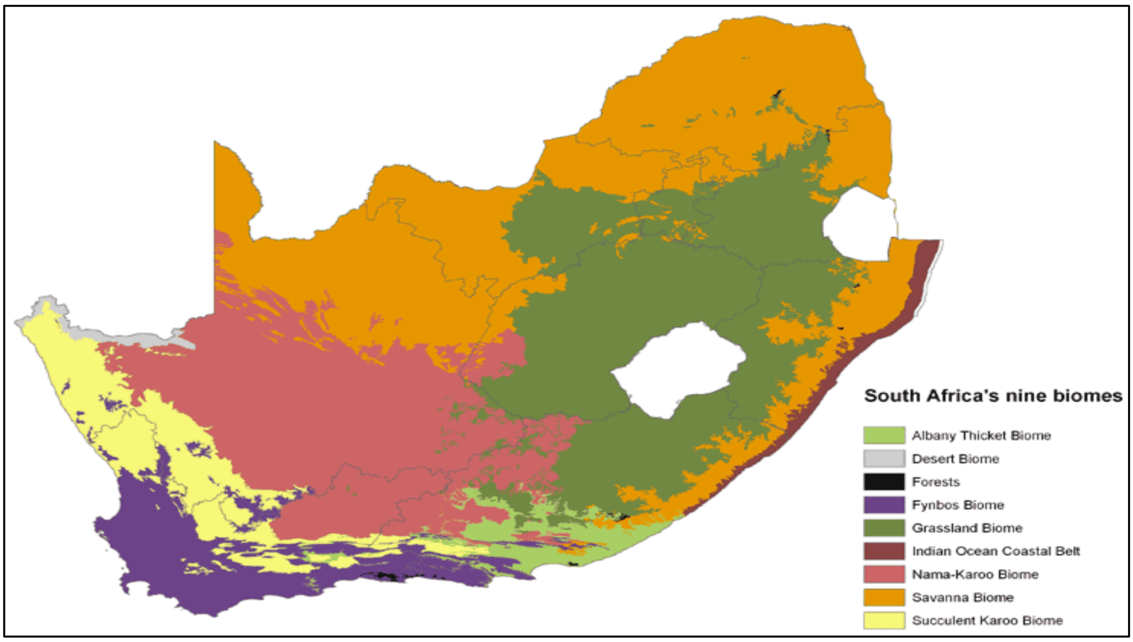


Fig 2.18: Biomes of South Africa
Source: SANBI, 2013

The dominant biomes in the EC province together with the quaternary catchments are illustrated in Figure 2.19.

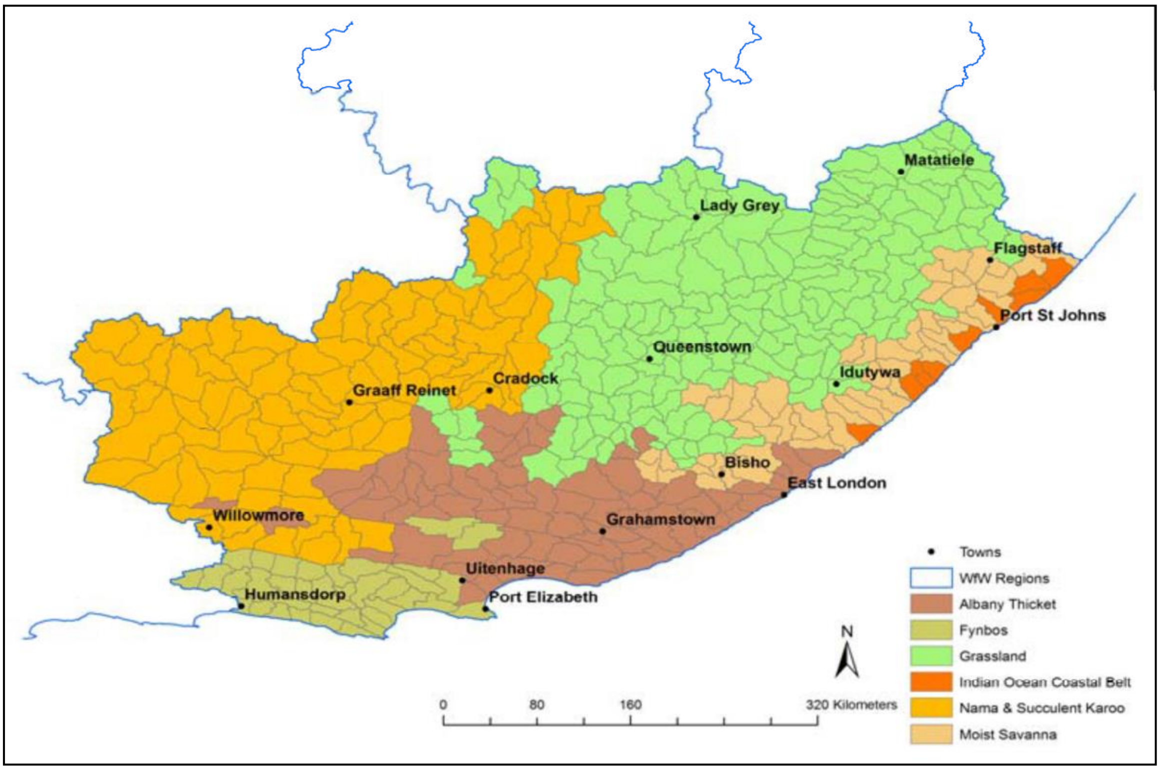


Fig 2.19: Dominant biomes and quaternary catchments
Source: Forsyth, O'Farrel & Le Maitre, 2011.

2.1.5.2 Land cover

The province is blessed with much fertile land and agriculture is the most important activity outside the metropolitan areas. Land use and vegetation cover are amongst the most important indicators for environmental vulnerability to drought. According to Berliner & Desmet (2007) the following land use activities pose varying degrees of threat to biodiversity in the EC:

- Rural, urban and coastal development
- Mining activities (dune and hard rock mining)
- Commercial agriculture (crop production, commercial livestock farming)
- Afforestation
- Communal livestock and crop production
- Subsistence resources harvesting (medicinal plants, fire wood, building materials, hunting)

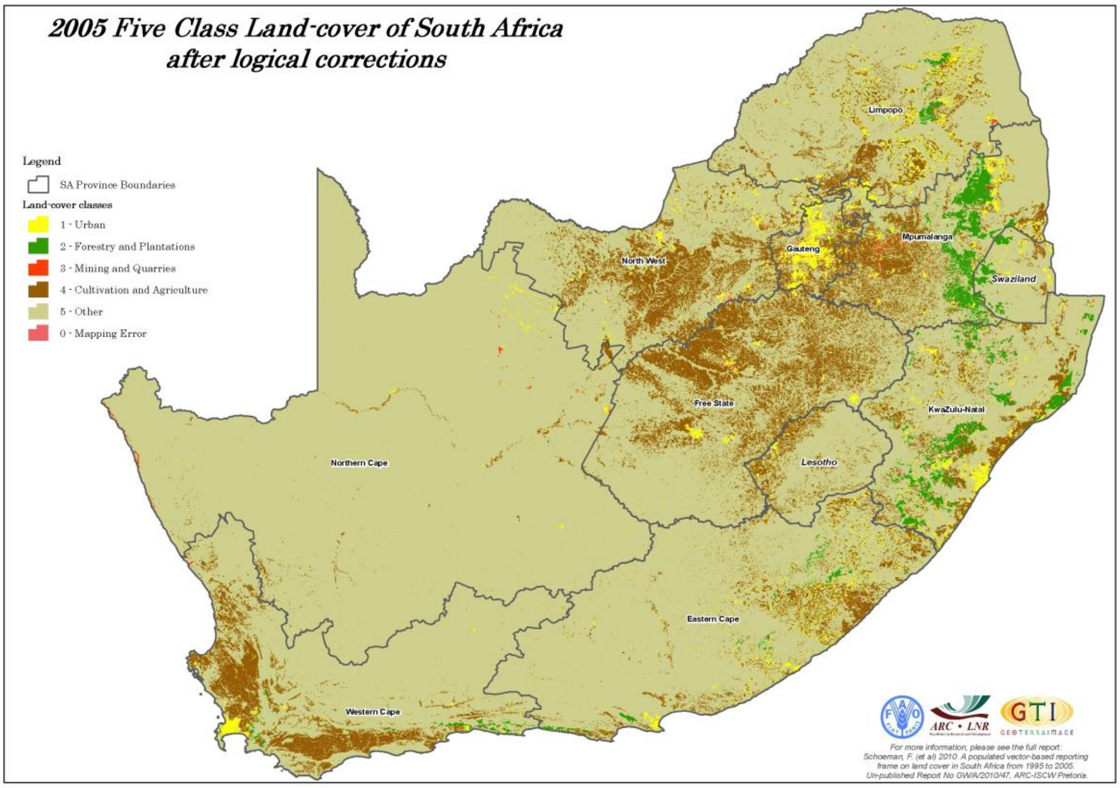


Fig 2.20: Land cover map of South Africa
Source: ARC, 2007.

Berliner & Desmet (2007) also mentioned the potential negative and exacerbating impact of climate change on the biodiversity in the province. Cultivation is not as intense in the EC when comparing the land use of the EC with provinces such as the Free State, Western Cape, North West, Mpumalanga and KwaZulu-Natal (See Figure 2.20).

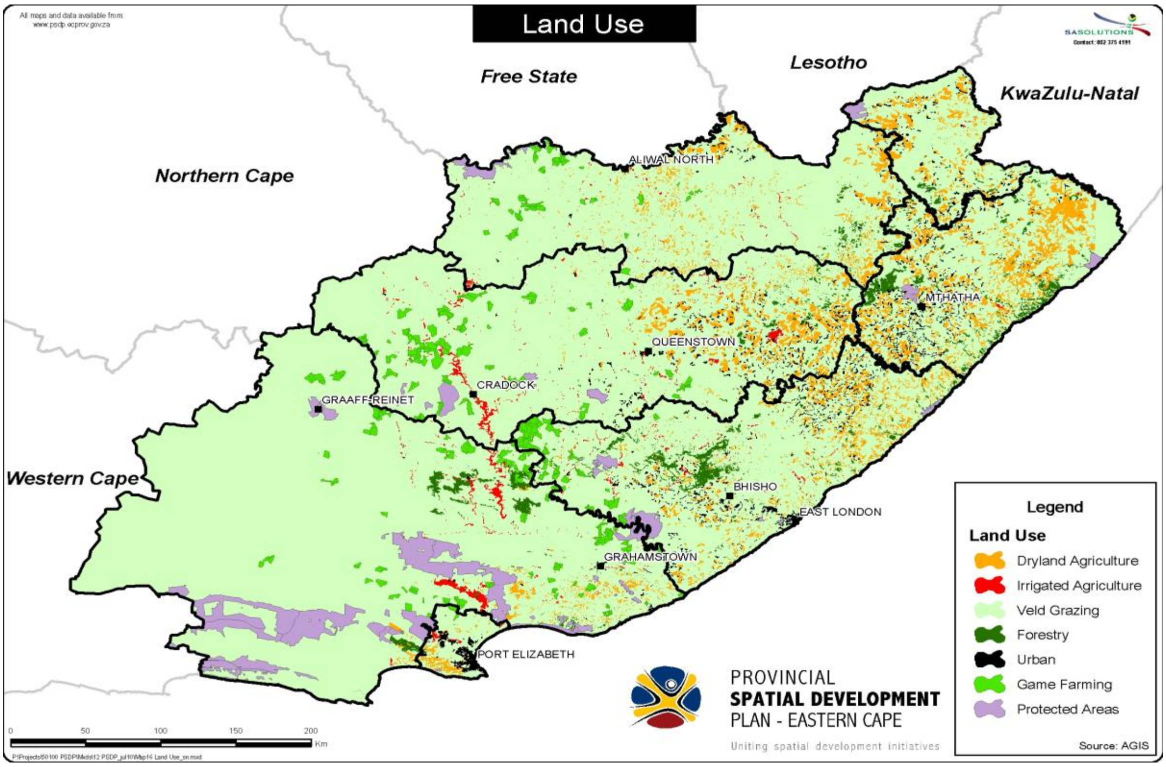


Fig 2.21: Land use in the Eastern Cape
Source: Province of the Eastern Cape, 2010(b).

Most of the cultivation in the EC takes place in the OR Tambo District Municipality, the north-eastern part of Amathole District Municipality, the eastern part of Chris Hani municipality and also the eastern part of Joe Gcabi District Municipality (See Figure 2.21). Intensive fruit production is also evident in the Langkloof valley located in the Cacadu District Municipality at the most southern tip of the province. Irrigation agriculture is concentrated along the Fish River in the central part of the province.

According to the EC province's Spatial Development Plan (2010) and the Department of Agriculture and Rural Development (2012) 84%, or 14,2 million ha of the province is utiliezed as natural grazing. Also summarized in Table 2.4 is 537 000 ha utilised for dry land cropping for commercial purposes – mostly in Cacadu and Joe Gqabi District Municipalities - and 642 000 ha of dry land cropping on communal land – mostly in the former Transkei, namely in the OR Tambo and Amathole District Municipalities. Irrigation land adds up to 166 000 ha – mostly for dairy prodcution along the coastal zone in Cacadu District Municipality and fruit production in the Langkloof valley.

Table 2.4: Land use in the Eastern Cape[3]

LAND USE	AREA (ha)	%	COMMENT
Dry land Cropping Commercial *	537 000	3	Cacadu, Joe Gqabi
Dry land Cropping Communal *	642 000	4	Transkei, ORT, Amathole
Irrigated Crops*	166 000	1	Cacadu, Chris Hani
Natural Veld (Grazing&Browsing) *	14 212 000	84	
Incl Protected Areas (Conserve)	(428 000)	(4)	
Incl Wildlife & Game farming	???	(2)	
Forests	339 000	2	ORT, Amathole
Plantations	(180 000)	1	ORT, Amathole
Urban (incl. urban commonage) & rural settlement	756 000	4,5	
Total	**16 892 000**	**100**	

Source: DAFF, 2012(b).

Biodiversity is negatively influenced by land use systems. The map shown in Figure 2.22 illustrates the biodiversity sensitivity and land use.

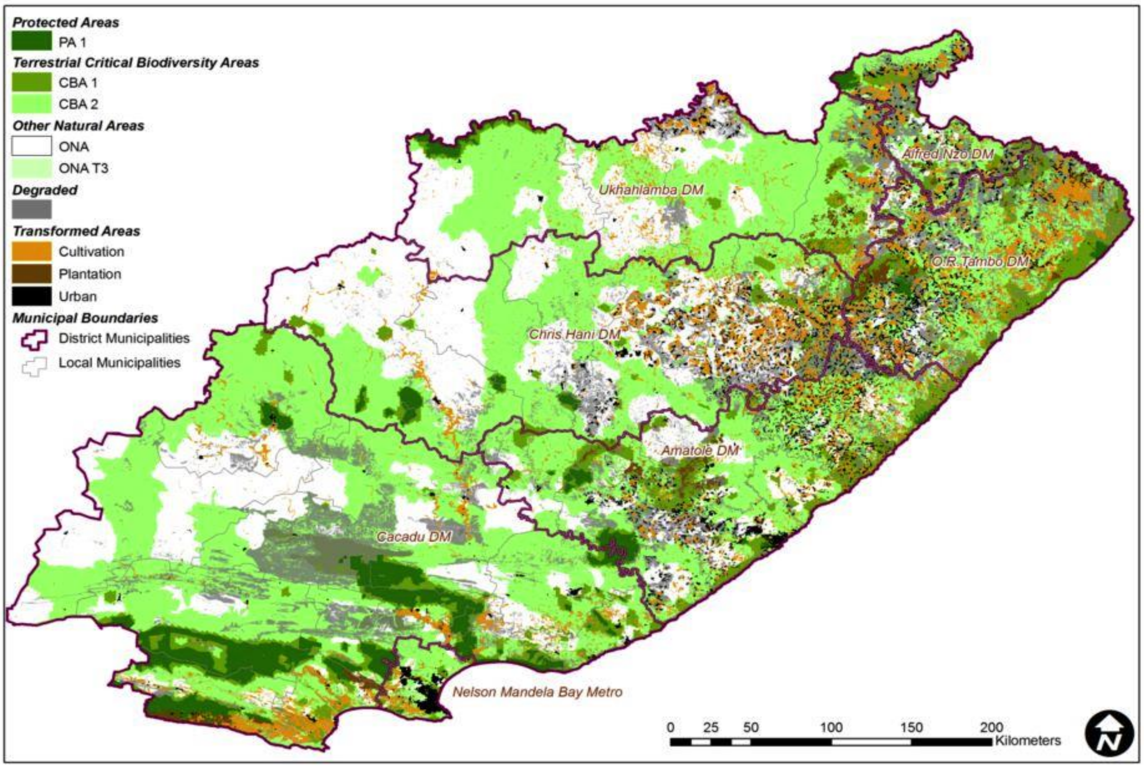


Fig 2.22: Land use and biodiversity sensitive areas
Source: Berliner & Desmet, 2007.

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[3] Data for wildlife and game farming not available.

According to the biodiversity sensitivity index shown by Berliner and Desmet (2007) most of the EC is sensitive to biodiversity degradation. Already degraded areas are evident in the central hinterland of Cacadu District Municipality (DM), in the southern and eastern parts of Chris Hani DM, in central and northern parts of Joe Gcabi DM, northern and southern parts of Amathole DM and most of OR Tambo and Alfred Nzo District Municipalities.

Indicated on Figure 2.23 are the largest protected areas (Green/dark in Figure 2.23) consisting of the Addo National Park as well as the Baviaanskloof Nature Reserve and the Garden Route Nature Reserve in the southern part of the Cacadu District Municipality. Sensitive areas where priority protection is recommended is also shown in orange on Figure 2.23.

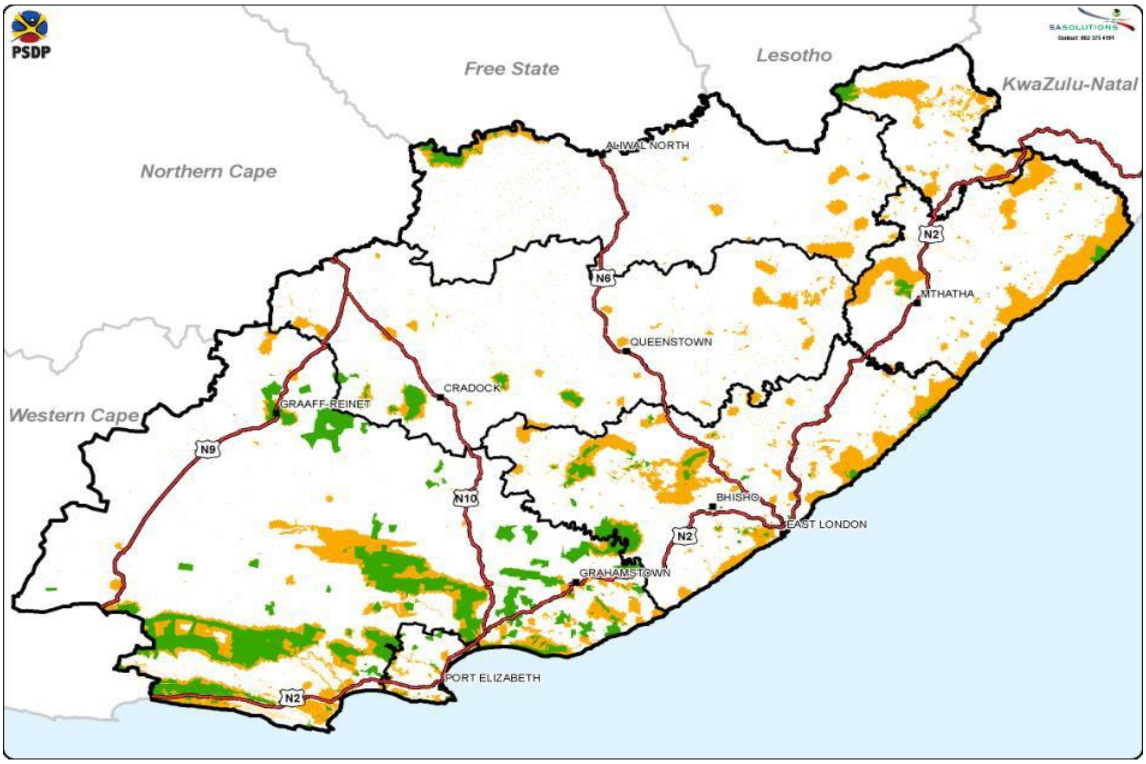


Fig 2.23: Protected areas
Source: Province of the Eastern Cape, 2010(b)

Forestry areas are important components of the ecological system and play an important role in the biodiversity and economic systems of the EC. Figure 2.24 illustrates the potential forestry areas (areas coloured light green). In some regions the forestry sector also competes with the high potential agricultural areas (areas coloured in purple), namely in the northern and western part of OR Tambo, the eastern parts of Joe Gcabi and Chris Hani and the central parts of Amathole District Municipalities.

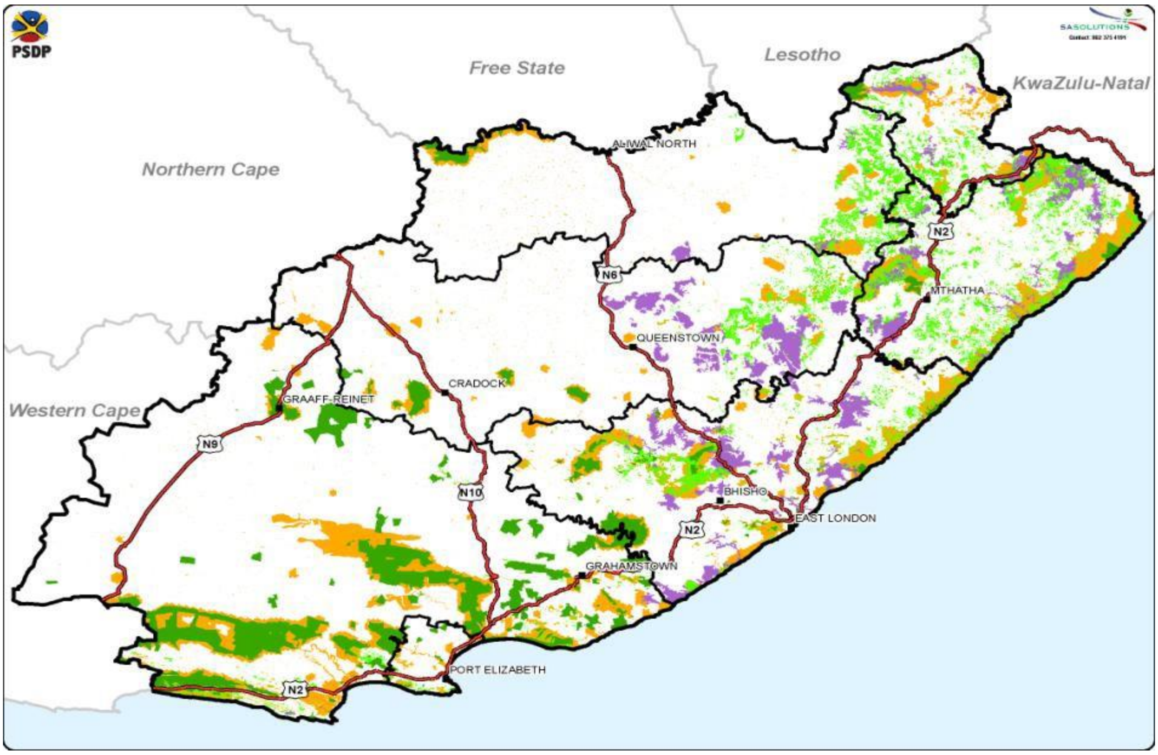


Fig 2.24: Forestry and high potential agricultural areas
Source: Province of the Eastern Cape, 2010(b)

High potential agricultural land and forestry have specific characteristics within the context of drought risk assessment and drought management. The vulnerabilities and coping mechanisms differ from areas with lower agricultural potential and the thresholds for meteorological indicators might differ. Indicators that measure short term dry periods such as the 3-month Standard Precipitation Index (SPI), for example, could be more valuable as an indicator for drought in crop producing areas whereas the 24-month SPI might be more valuable for forestry areas.

It is imperative to manage the high potential agricultural areas carefully in the interests of long term food security. Irrigated areas along the Fish River are sensitive towards salination and the challenges for drought management on irrigated land differs dramatically from the challenges of rain fed agriculture.

In addition to the areas indicated in Figure 2.24, the Provincial Spatial Plan (2010) also highlighted several additional areas in the province that required special attention in terms of special management. The spatial planners in the province have overlaid the various natural resources, environmental and protected areas over each other and based on these results have identified the important environmental and resource areas sensitive to future development. These areas are also important in the context of drought management in the interests of sustainability and ecological integrity. These areas are indicated in Figure 2.25.

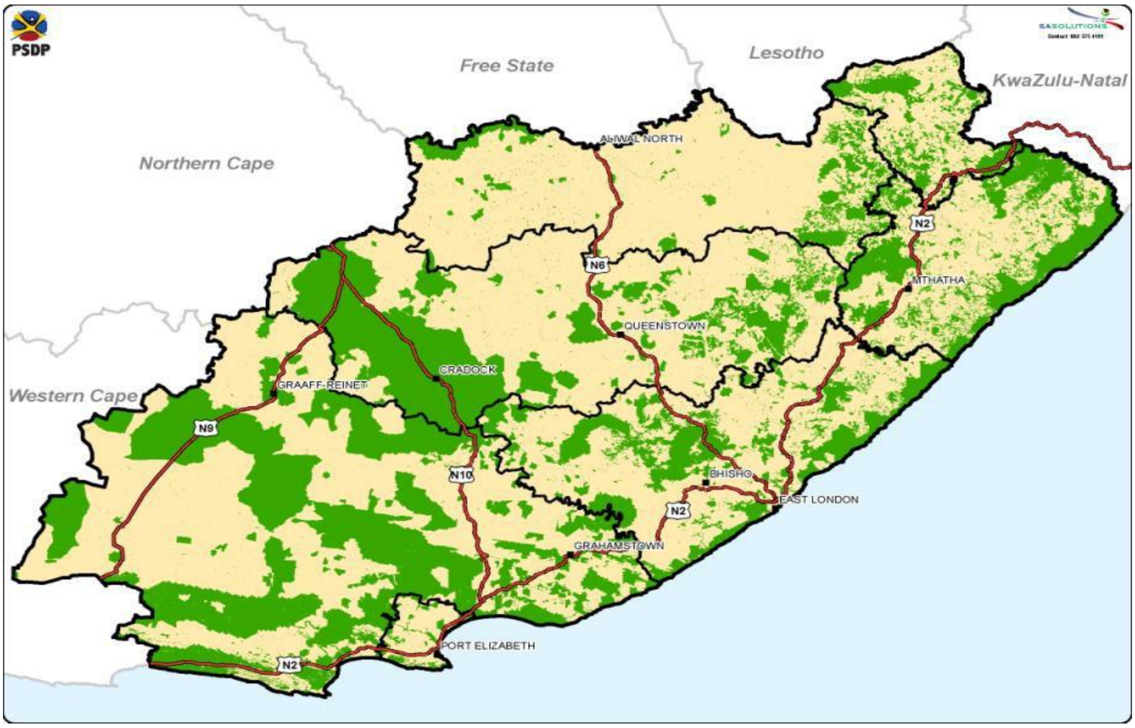


Fig 2.25: Environmental and natural resource high potential sensitive areas
Source: Province of the Eastern Cape, 2010(b)

The combination of soil, climate and vegetation results in high levels of bio-productivity. The bio-productivity map illustrated in Figure 2.26 clearly shows the high potential bio-productivity in the OR Tambo district municipality. Bio-productivity gradually decreases towards the west with less than 0,5 tons per ha per annum in the western part of Cacadu district municipality. Bio-productivity in OR Tambo district municipality in north-eastern part of the district is the highest and varies between 6 to 10 tons per ha per annum. This is also one of the most degraded areas with the highest population density and the high level of rural poverty in a high potential region is a contradiction characterized by most rural African communities. The lack of settlement planning and the land use system are important indicators for vulnerability, coping capacity and drought risk and a study in this region could provide valuable insights.

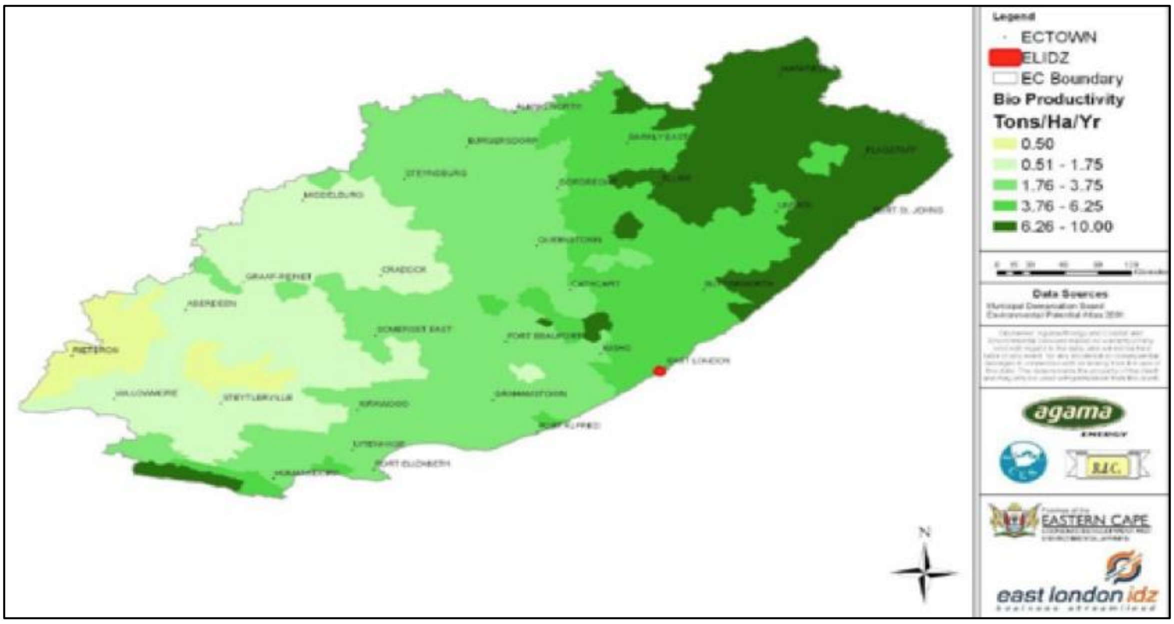


Fig 2.26: Biological productivity
Source: Province of the Eastern Cape, 2010(b)

2.1.5.3 Water

Water is a key resource for development and availability of water is a key element in resilience against dry periods and droughts. The water supply and resource management situation in the EC varies radically. The EC is the only province in SA with potential surplus water resources, with the Umzimvubu River in the OR Tambo and Alfred Nzo District Municipalities seen as the largest underdeveloped water resource in SA. The Kei catchment in Amathole District Municipality also offers additional potential for development, but the catchments of the Kraai and Sundays rivers are seriously water stressed. The Buffalo River is heavily polluted and fully utilised with siltation in most dams posing a risk to future development (Province of the Eastern Cape, 2010b). The water development potential for the province is illustrated in Figure 2.27.

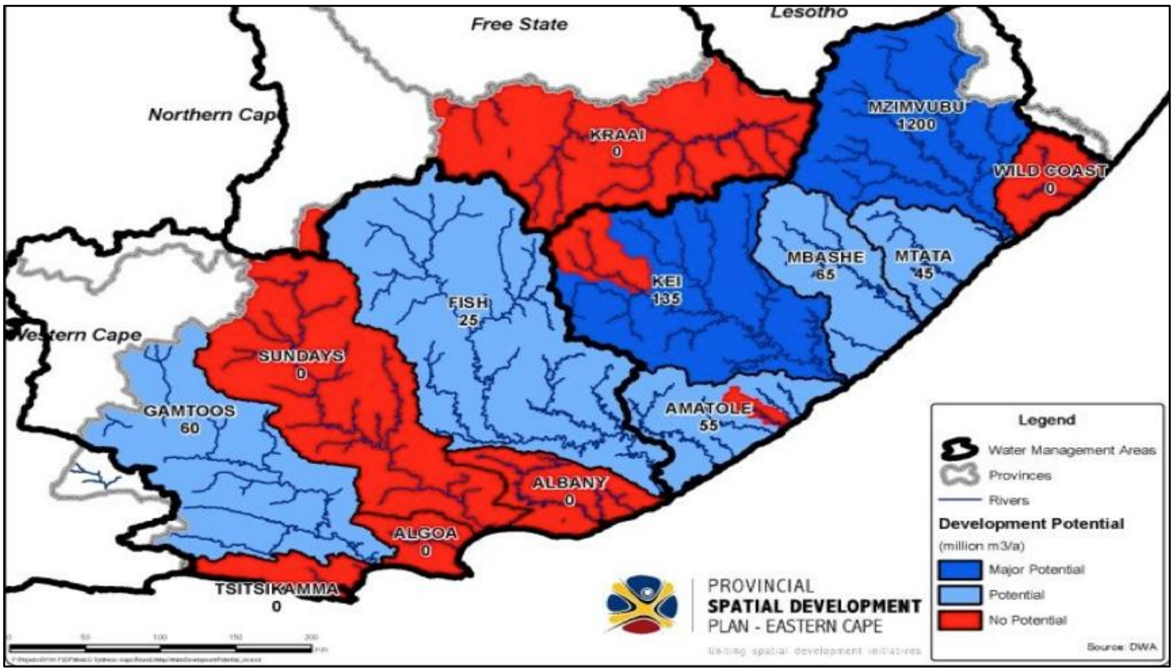


Fig 2.27: Water development potential
Source: Province of the Eastern Cape, 2010(b)

Groundwater plays an important role in the western part of the province and is the main water source for animal drinking water. Implications of over-utilization could be devastating to agriculture in those areas.

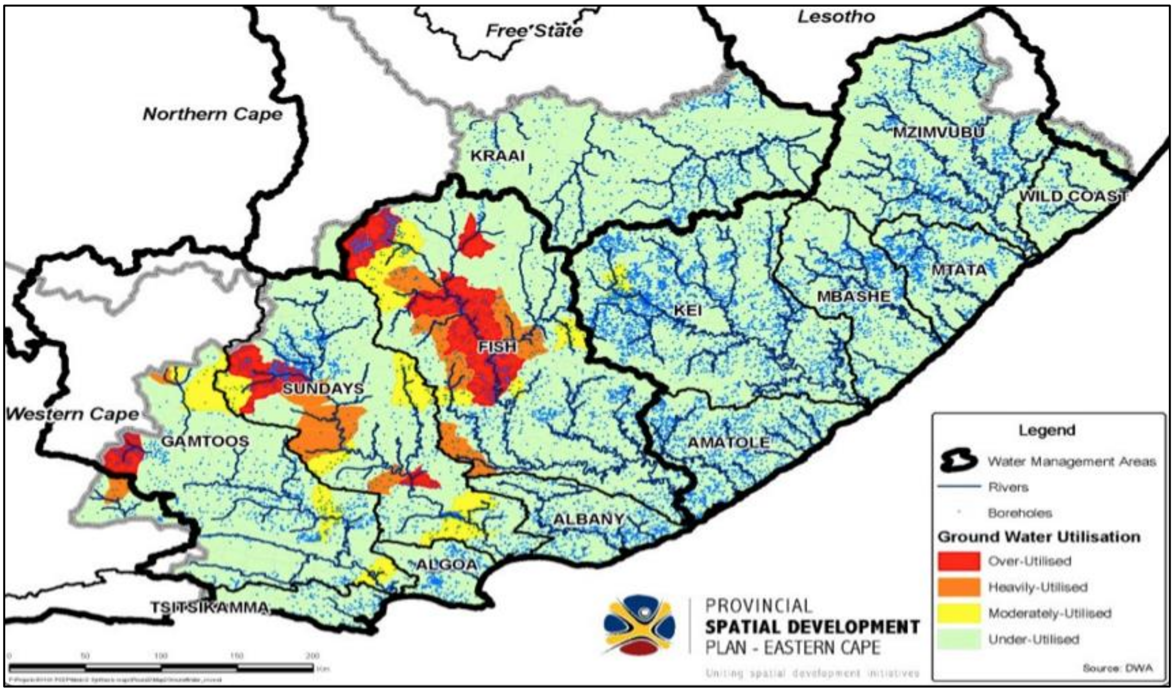


Fig 2.28: Groundwater sensitivity map
Source: Province of the Eastern Cape, 2010(b)

Groundwater as a local source is often more affordable than otherwise imported water through bulk water supply schemes. Groundwater in the EC is generally of a high quality and is reliable if managed properly. The challenges for groundwater management are to protect water from over-abstraction, contamination and unfair allocation. The groundwater sensitivity map (Figure 2.28) clearly shows the areas of over-utilization alongside the Fish and the Sundays rivers. These areas are located in the Chris Hani and Cacadu District Municipalities.

2.1.6 Land Use Pressures

Berliner & Desmet (2007) applied the analytical hierarchy procedure of Saarty's (1994) and determined land use pressure ratings for the EC. They used a multi-criteria assessment process of weighting different criteria that drive land use pressures. The result of their assessment was expressed for individual cluster units and is useful as planning units for catchments. In the case of the drought risk assessment the boundary unit for assessment is the quaternary catchments and the results of Berliner & Desmet (2007) can be adjusted to the quaternary catchment unit that will make it valuable for calculating environmental vulnerability to drought.

Berliner and Desmet (2007) calculated the following pressure indices:

- Subsistence resource use index
- Development pressure
- Agricultural potential expressed as arability index
- Afforestation index
- Ecological integrity index
- Degradation index and
- Aggregated land use pressure index.

The above indices are important in context of understanding vulnerability towards drought and are discussed in the following section.

2.1.6.1 Subsistence resource use pressure index

Large areas of the EC consist of communal land, mainly from the former Transkei and Ciskei homelands. In addition, all towns own rural land around the urban fringe and small-scale subsistence farmers or city dwellers farming with cattle, goats and sheep utilise this land for subsistence agriculture. Hardin & Badin (1977) describe the degradation of communal land due to uncontrolled use as the "*tragedy of the commons*". The tragedy of the commons is characterized by the exploitation of natural resources for fuel wood, bush meat, building materials and medicinal plants. Furthermore, the natural resource base is over-utilised and overgrazed and that leads to bush and/or desert encroachment, soil erosion and low soil fertility. Many livelihoods in the EC are heavily dependent on local resources for survival and they have few survival options. More than 90% of OR Tambo and

Alfred Nzo District Municipalities fall into the category of communal land. Dold & Cocks (2002) reported that 93% of species used as traditional medicines are harvested in an unsustainable way. They also reported that the Forest biome is the most threatened, owing to over-harvesting, and this is followed by Thicket biome. This information is important in the context of drought risk since the vulnerability of these biomes is exacerbated by the over-utilization of the biomes.

DWAF (2003) reported that the over-harvest of many forests and the overgrazing of grasslands are due to the erosion of traditional authorities' powers to regulate natural resource use. According to Berliner & Desmet (2007) the degree of subsistence pressure on natural resources is dependent on two key factors, namely (i) the density of people reliant on the resource, and (ii) the accessibility of the resource. Based on number of people dependent for survival on natural resources and accessibility Berliner & Desmet (2007) developed a subsistence resource-use pressure index, which is also useful as a vulnerability index for drought (See Figure 2.29)

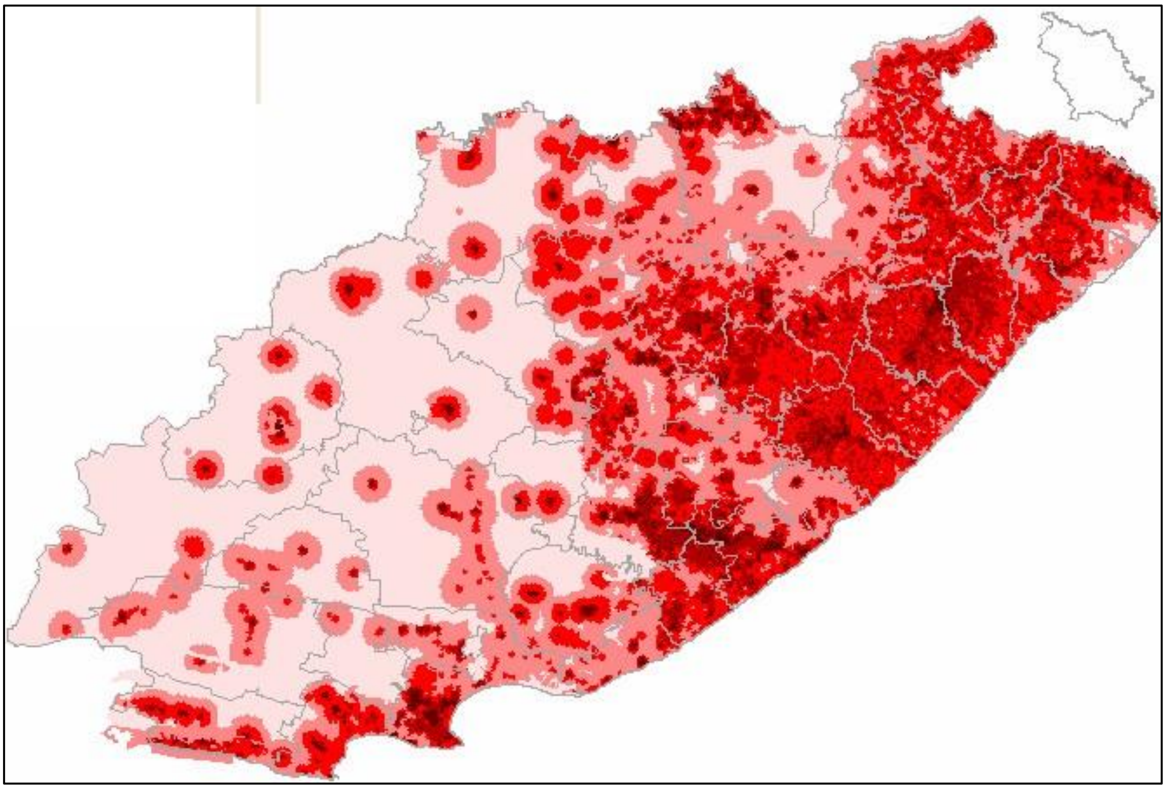


Fig 2.29: Subsistence resource-use pressure index
Source: Berliner & Desmet, 2007

2.1.6.2 Arability Index

Berliner & Desmet (2007) also developed an arability index based on climate, soil potential, slope and suitability for cultivation. They came to the conclusion that high potential areas are particularly at risk due to over-exploitation and resource degradation. Relatively large areas in the northern parts of the EC have been converted to dry land cropping systems and the demand for low input cost crop production is on the increase. The demand for land, increased population pressure and poverty in rural areas is likely to increase the pressure on land suitable for rain fed crop production.

Factors putting additional pressure on available high potential arable land are:

- the massive food production plan,
- the intention of the EC Provincial Biofeuls Task Team to use 500 000 ha of tribal land, which is ideal for crop farming, and convert that to an intensive monoculture using Genetically Modified (GM) crops for the production of biofeuls, and
- development of large scale agricultural projects such as the beetroot cultivation project for biofeuls.

Irrigation cropping also changes both the potential and natural ecology of an affected area. Schoeman *et al.* (2000) developed a vulnerability index for both dry land and irrigation cropping for the Department of Agriculture's land capability classification.

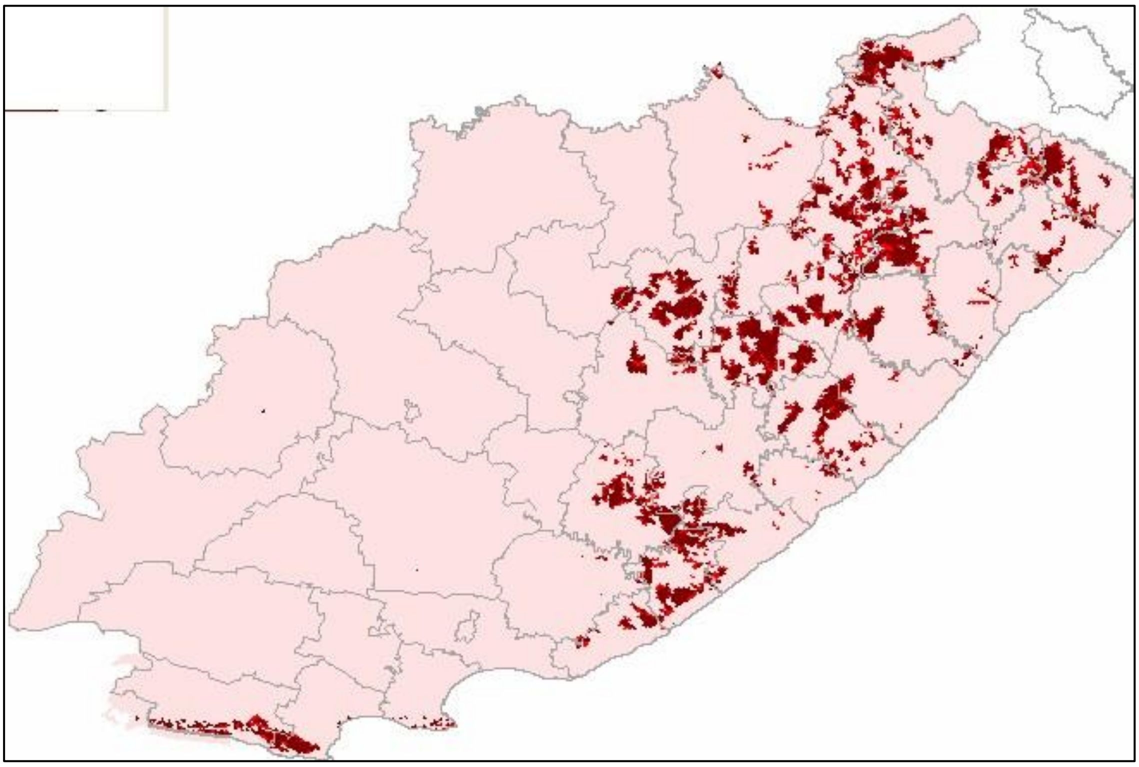


Fig 2.30: Arabillity index
Source: Berlinger & Desmet, 2007

The areas with a high arability index are shown in red in Figure 2.30. Based on these results a high arability index is located in the OR Tambo District Municipality, the eastern parts of Chris Hani and Joe Gcabi District Municipalities, north-eastern part of Alfred Nzo District Municipality, the central part of Amathole District Municipality and in the Langkloof at the most southern tip of the Cacadu District Municipality. In the context of vulnerability to droughts, the arabillity index is useful as both an economic vulnerability index as well as an environmental vulnerability index.

2.1.6.3 Afforestation Index

According to DWAF (2005) the EC is the only province in SA with available additional land for afforestation. The forestry area in the EC covers approximately 169 000 ha and estimates by the Wild Coast SDI is that potential exists for an additional 120 000 ha in the province. This will influence the vulnerability to dry periods and most probably will increase neighbouring communities' vulnerability to dry periods. Figure 2.31 illustrates in red the areas of high forestry potential in the EC.

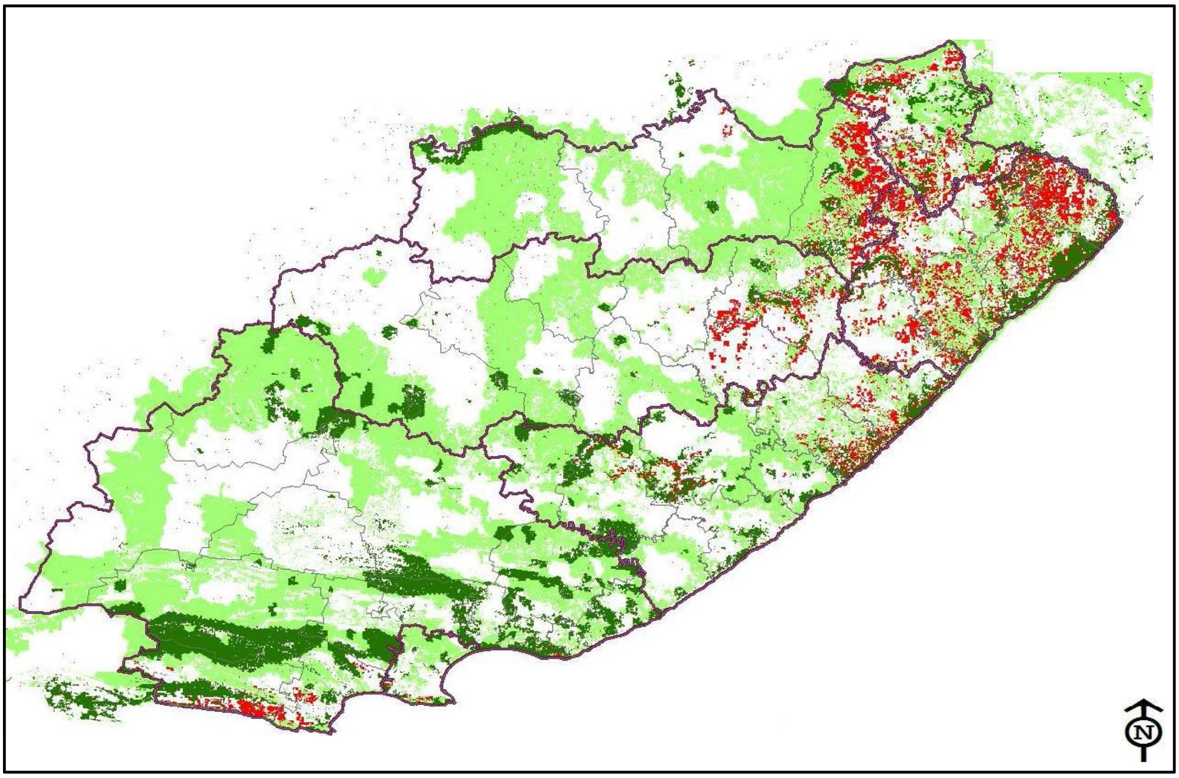


Fig 2.31: Potential forestry areas
Source: Berliner & Desmet, 2007

Most of potential forestry areas are located in the OR Tambo District Municipality and in the Eastern parts of Joe Gcabi District Municipality in the Ugie - Mount Fletcher region.

Plantation forestry is regarded as a vehicle for socio-economic development in the province (DWAF, 2005). While this form of land use is economically feasible, it does have an impact on the food security status of people and on the socio-economic and cultural as well as environmental systems. Not only does forestry replace the natural vegetation, it also has an impact on the surrounding areas and particularly in downstream catchments. The hydrological characteristics of rivers are influenced since trees utilise more water than the replaced vegetation and less water than usual becomes available downstream. Forestry increases the vulnerability to dry periods of communities downstream since small springs and streams that provide water for rural communities might dry up as a result of forests' increased demand for water.

2.1.6.4 Ecological Integrity Index

According to Berliner & Desmet (2007) ecological integrity relates to the ecological health of ecosystems, for example transformed ecosystems will potentially compromise ecological functionality. The ecological integrity index is useful as an indicator for conservation planning as it relates to:

- the ability of a planning unit (quaternary catchment in context of the drought risk assessment in this study) to provide ecosystem goods and services such as freshwater, flood attenuations, medicinal plants etc.,
- the resilience to ecosystems to external shocks such as droughts, and
- the connectivity of the planning unit to allow movement of plants and animals.

The ecological Integrity Index map as developed by Berliner & Desmet (2007) is illustrated in Figure 2.32.

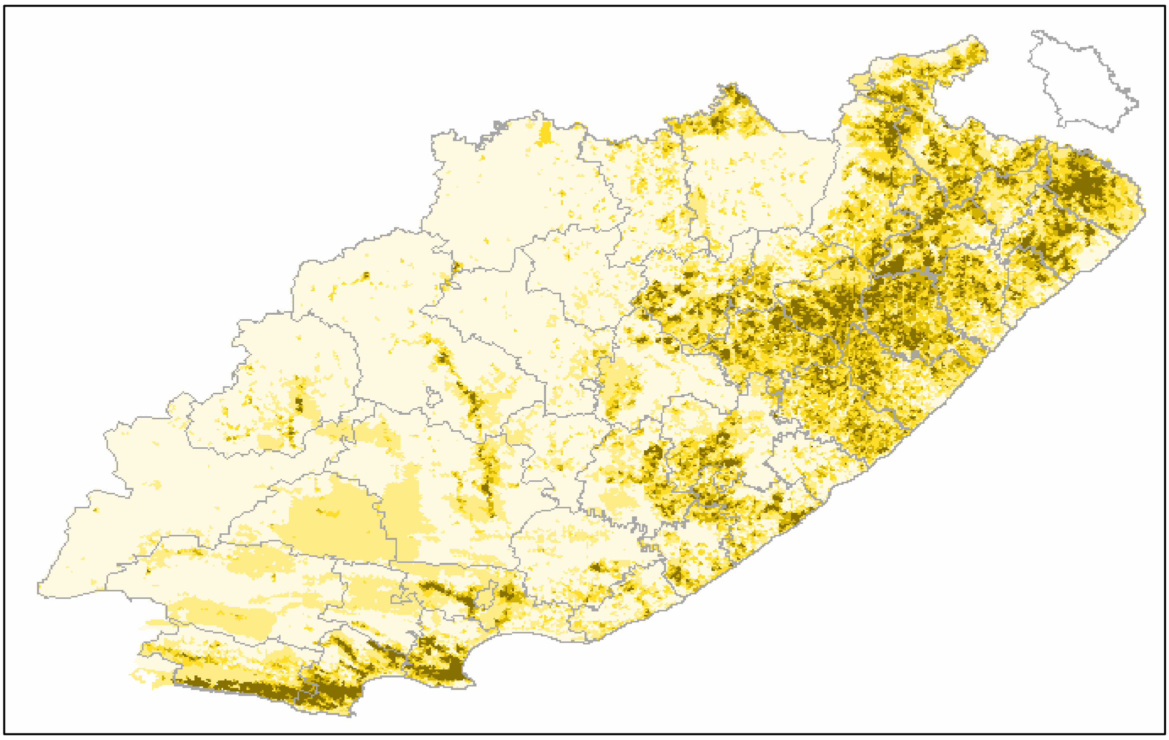


Fig 2.32: Ecological Integrity Index
Source: Berliner & Desmet, 2007

Transformation and degradation are two important characteristics for the determination of an ecological integrity index. The ecological integrity indicator is an important composite indicator for environmental vulnerability to drought since the following indicators are used for calculating the ecological integrity index:

- Degree of alien infestation
- Transformation at the planning unit
- Transformation of the quaternary catchment
- Degradation of the planning unit, and
- Degradation index of the quaternary catchment.

Vulnerability to drought is expected to be high in areas with low ecological integrity index.

2.1.6.5 Land degradation

Land degradation and soil erosion is not localized within only one district. The soil erosion map in Figure 2.33 clearly illustrates soil erosion as a problem in all the districts and not only in the communal land areas of the former Transkei and Ciskei as expected from communal land. It seems that soil erosion is not necessarily linked to communal land, but the link between soil erosion and vulnerability to drought could be an interesting field of research in context of this study.

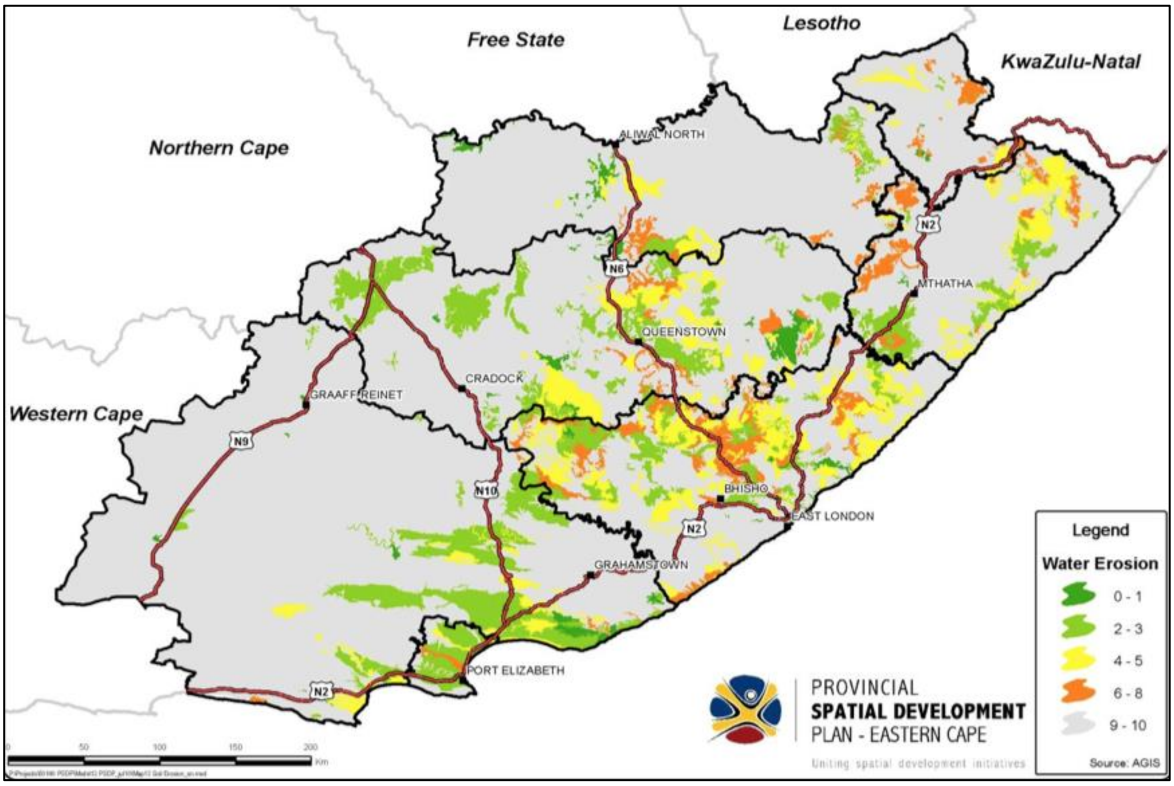
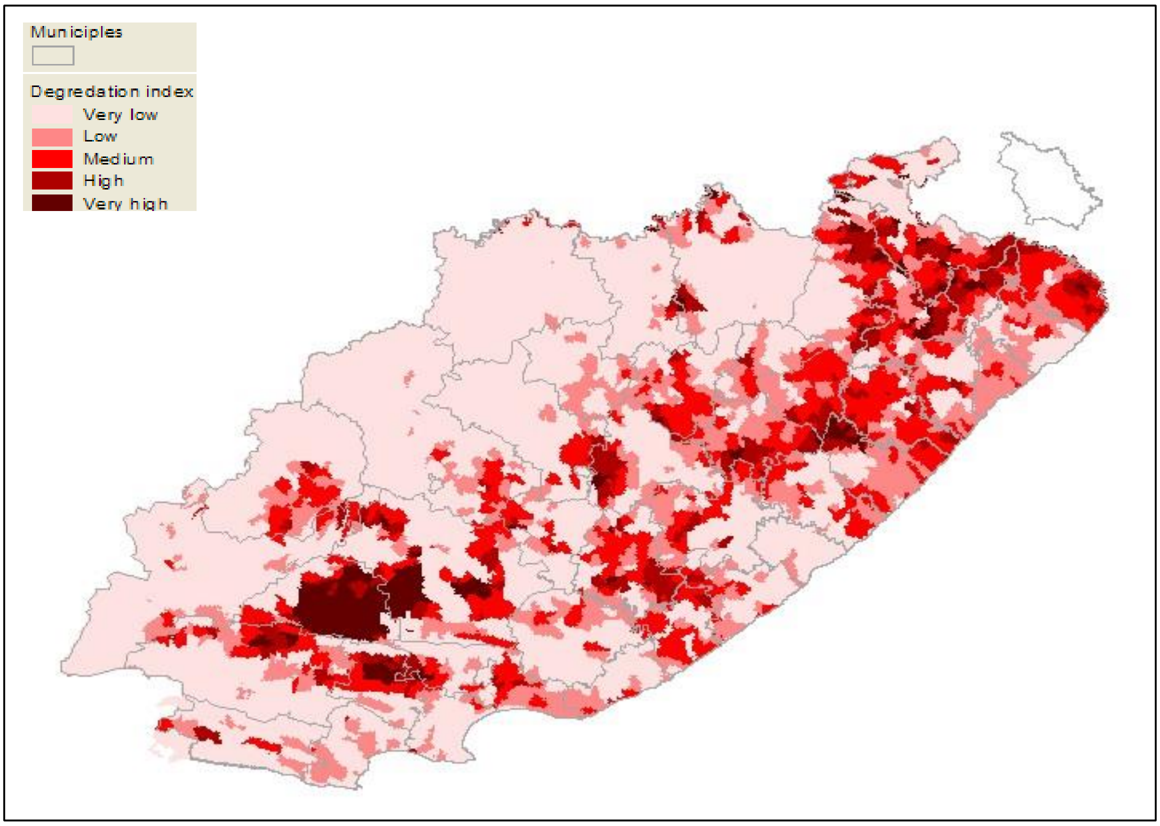


Fig. 2.33: Soil erosion
Source: Province of the Eastern Cape (b), 2010

Land degradation in total is important as an environmental vulnerability indicator for drought risk. Berliner & Desmet (2007) also include it as an index contributing toward the ecological integrity index.

Figure 2.34 illustrates the land degradation index per sub quaternary catchment in the EC. This is an important index that will contribute toward the calculation of environmental vulnerability and ultimately to drought risk.

Fig 2.34: Degradation per sub quaternary catchment
Source: Berliner & Desmet, 2007



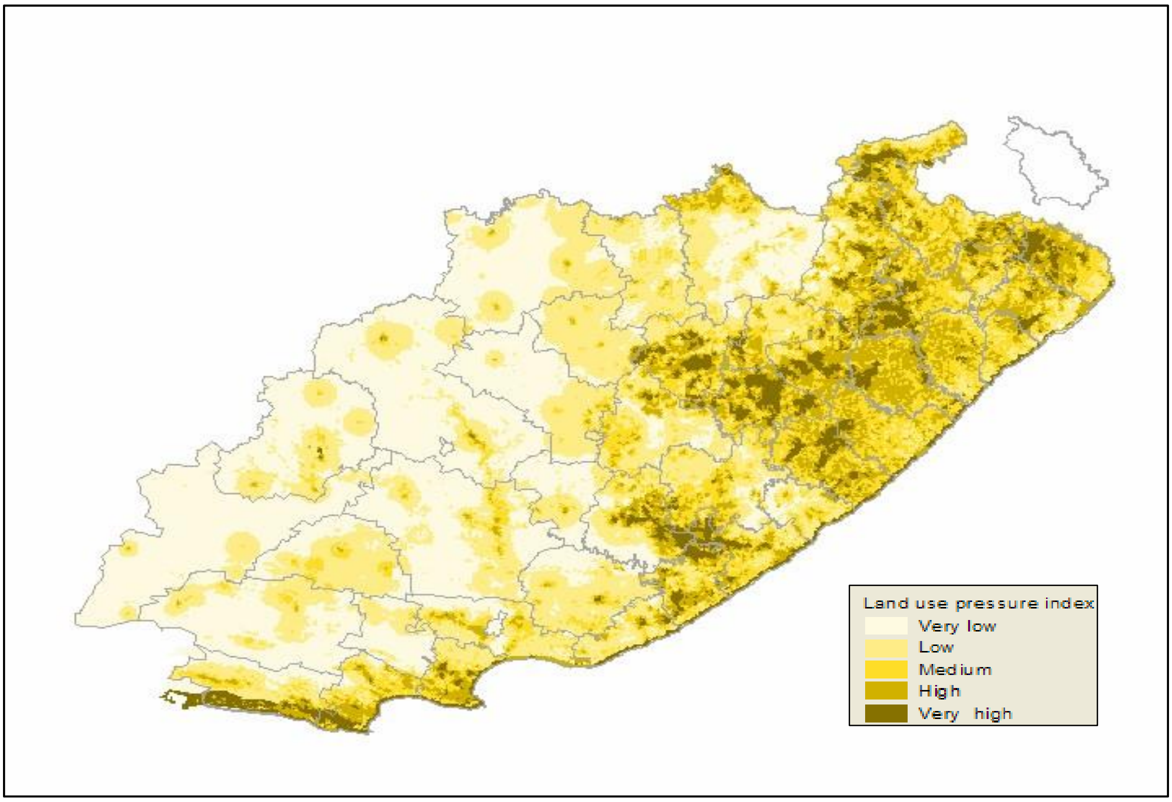
Land degradation is a problem in all district municipalities in the EC. Degraded land and vegetation cannot withstand the impact of dry periods and farmers farming on degraded land normally experience a normal dry period as a drought (Jordaan, 2011).

2.1.6.6 Aggregated Land Use Pressure Index (ALUPI)

Berliner and Desmet (2007) also calculated the aggregated land use pressure index using inputs and weightings of a number of contributing factors and indices. The indicators used for calculating the ALUPI include (i) population density, (ii) population density of neighbours, (iii) electrification, (iv) distance to settlement, (v) distance to coast (5km), (vi) distance to coast (1km), (vii) agricultural potential, (viii) afforestation potential, (ix) transformation PU, (x) transformation quaternary catchment, (xi) degraded PU, (xii) degraded sub-quaternary catchment, and (xiii) alien infestation Details of methodology and weightings are discussed in the section on vulnerability assessment.

The map for the aggregated land use pressure index is shown in Figure 2.35.

Fig 2.35: Aggregated land use pressure index
Source: Berliner & Desmet, 2007



The aggregated land use pressure index is also valuable in the context of drought vulnerability since most of the important indices are included in the results for the ALUPI. Based on these results it is clear that highest vulnerability is in the former homelands of Transkei and Ciskei, in the OR Tambo and Amathole District Municipalities, with the Langkloof valley at the most southern tip of the Cacadu District Municipality also with a high ALUPI.

2.1.6.7 Pressure index on freshwater aquatic environment

Snyder *et al.* (2005) and Foley *et al.* (2005) highlighted the relationship between land cover and land use on the chemical, physical and biological characteristics of streams and rivers. River integrity is negatively influenced by land uses such as settlement, cultivation, afforestation and degradation. Changes in catchment and river characteristics more often than not exacerbate the impact of dry periods and increase the vulnerability of the eco-system toward dry periods. Berliner & Desmet (2007) found contradicting results in the EC with a poor relationship between quaternary catchment integrity and levels of transformation and degradation within catchments, and they ascribe this to the inter-basin water transfers in the EC where seasonal rivers now have permanent flow.

Nel *et al.* (2006) estimated that river integrity is significantly affected once transformation within catchments exceeds 25%. Berliner & Desmet (2007) used Nels' (2006) results and calculated that approximately 60% of sub-catchments within the EC fall below this threshold, meaning that 40% are in an undesirable state, with 25% in a highly undesirable state.

2.2 Climate of the Eastern Cape

The Eastern Cape is characterized by a diversity of climates with a mild warm temperate to sub-tropical climate along the coastal zones. The climate and temperature gradually changes from a more sub-tropical climate in Pondoland north of Port St Johns to a humid zone south of Port St Johns up to East London. The region between East London and Port Elizabeth is characterized by a warm coastal belt, which gradually changes to a temperate winter rainfall "*southern cape"* climate south of Port Elizabeth. Conditions can become extreme deeper inland with extremely hot and dry conditions, which is in stark contrast to the milder climate of the coastal zones. The Drakensberg Mountain area is characterized by berg winds and snow in the winter, with winter night-time temperatures often below zero degrees Celsius, which make these areas amongst the coldest in South Africa. The Karoo hinterland has hot and dry summers with frost during the winter months.

The EC generally has mild winters with temperature averages between 7 and 20 degrees Celsius and warm summers with average temperatures ranging from 16 to 29 degrees Celsius. The EC also has 300 out of 365 sunny days per year, which make it one of the provinces with the most sunshine days in South Africa.

The EC is blessed with an abundance of water resources and is currently the only province in SA with surplus water. Regular rainfall occurs in the Drakensberg Mountains and the former Transkei, feeding a number of major rivers in the northern parts of the province. The lowland coastal belt, extending 30 km to 60 km inland can have rain all the year round, although the southern EC regions west of Port Elizabeth are the only winter rainfall area within the province. The rest of the province experiences summer rainfall with more than 1000 mm per annum in the north-eastern coastal zone and less than 400 mm in the far western region of the province. The 500 mm isohyet splits the province in half from Aliwal North in the north to Port Alfred in the south. The largest part of the province receives less than 400 mm rain per annum (See Figure 2.36 for annual precipitation in mm).

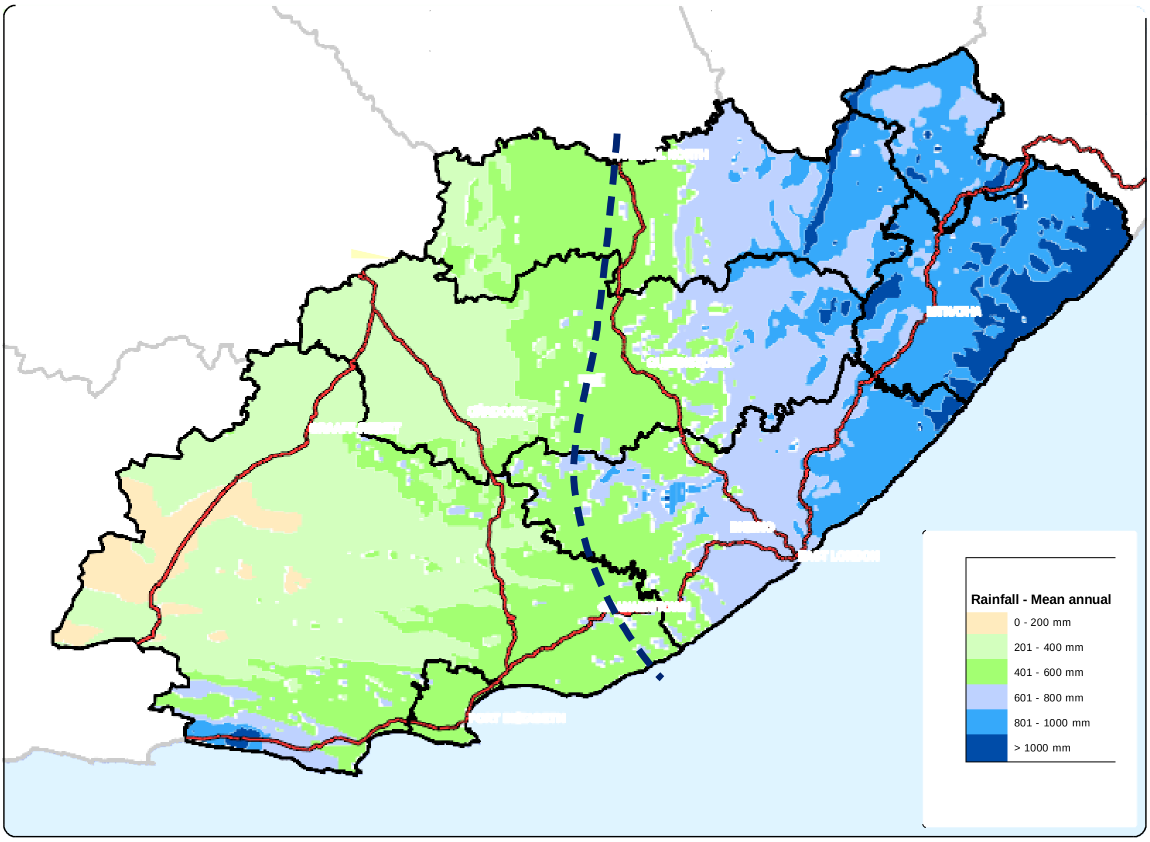


Fig 2.36: Mean annual precipitation (mm)
Source: SAWS, 2012.

2.3 Agriculture in the Eastern Cape

Agriculture in the EC is classified as either commercial and developing commercial or as subsistence and small-scale. The number of commercial farmers has declined by nearly 10% between 2002 and 2007 from 4 376 to 4 006. The EC has the second largest number of subsistence and communal farmers after KwaZulu-Natal, with 310 400 farmers; that is 24% of the 1,29 million subsistence farmers in SA. Two thirds of the population in the EC lives in rural areas and agriculture is an important factor in the development of peoples' livelihoods in the province. Six hundred and forty three thousand households, or 37,3% of total households in the EC, are involved in agricultural activities. Of these 48,5% are involved in livestock production, 54,3% in poultry production and 60,5% in grains and food crops – mostly for subsistence – and 34,2% in fruit and vegetables (AgriSETA, 2010).

The primary sectors are the worst performing economic sectors in the EC, contributing less than 3% to the EC economy. Agriculture, forestry and fisheries are the dominant industries in the primary economic sector of the EC, representing about 94% of this sector. The districts contributing most to agricultural output are Cacadu, Amathole and Chris Hani (Province of the Eastern Cape, 2011c). The Alfred Nzo and OR Tambo districts, on the other hand, are the two least developed districts and consist of mainly communal land sustaining the majority of subsistence and communal farmers in the province.

Agriculture's contribution to employment in the EC reduced from 50% in the late1990s and early 2000 to less than 7% in 2011. The agricultural, forestry and fishery industries employed 333 000 people during 2000 and that number declined to fewer than 80 000 in 2011. The reduction in employment in this sector is also reflected in the agricultural output. Important, however, is the fact that many farmers are shifting towards game farming, which is less labour intensive and most of the income from game farming is reflected in the tourism, accommodation and catering sectors.

The total area of the EC is 17,1 million ha of which 86,8%, or 14,8 million ha consists of farm land. Around 6,9%, or 1,2 million ha, is arable with 13,6 million ha available for grazing. About 3,7%, or 623 400 ha, consists of conservation areas with 140 000 ha under forestry and 1,49 million ha, or 8,7% of the land in the province, is used for other purposes. Table 2.5 summarizes the land distribution per province in SA and provides insight on the position of the EC relative to other provinces.

Table 2.5: Land distribution per province

	Total area	Farm land	% of total	Potentially arable land	% of total	Arable land utilised	Grazing land	% of total	Nature conserve.	% of total	Forestry	% of total	Other	% of total
Total RSA	ha	ha	%	ha	%	2	ha	%	ha	%	ha	%	ha	%
Western Cape	12 938 600	11 560 609	89,3	2 454 788	19,0	–	9 105 821	70,4	730 731	5,6	198 938	1,5	448 322	3,5
Northern Cape	36 338 900	29 543 832	81,3	454 465	1,3	–	29 089 367	80,1	4 295 068	11,8	–	–	2 500 000	6,9
Free State	12 943 700	11 760 100	90,9	4 221 423	32,6	*	7 538 677	58,2	272 500	2,1	400	–	910 700	7,0
Eastern Cape	***17 061 600***	***14 817 723***	***86,8***	***1 172 901***	***6,9***	*****	***13 644 822***	***80,0***	***623 400***	***3,7***	***133 520***	***0,8***	***1 486 957***	***8,7***
KwaZulu-Natal	9 148 100	6 529 315	71,4	1 199 675	13,1	*	5 329 640	58,3	1 377 900	15,1	465 688	5,1	775 197	8,5
Mpumalanga	8 181 600	4 978 827	60,9	1 734 896	21,2	*	3 243 931	39,6	2 331 900	28,5	549 818	6,7	321 055	3,9
Limpopo	11 960 600	10 548 290	88,2	1 700 442	14,2	*	8 847 848	74,0	1 161 600	9,7	65 410	0,5	185 300	1,5
Gauteng	1 876 000	828 623	44,2	438 623	23,4	–	390 000	20,8	228 400	12,2	20 190	1,1	798 787	42,6
North West	11 871 000	10 098 473	85,1	3 360 459	28,3	*	6 738 014	56,8	764 500	6,4	–	0,0	1 008 027	8,5
Total	**122 320 100**	**100 665 792**	**82,3**	**16 737 672**	**13,7**	*****	**83 928 120**	**68,6**	**11 785 999**	**9,6**	**1 433 964**	**1,2**	**8 434 345**	**6,9**
Developing Agric														
Western Cape	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Northern Cape	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Free State	232 200	188 100	81	34 900	15,0	*	153 200	66,0	33 000	14,2	400	0,2	10 700	4,6
Eastern Cape	***5 175 400***	***4 001 856***	***77,3***	***529 400***	***10,2***	*****	***3 472 456***	***67,1***	***100 400***	***1,9***	***86 187***	***1,7***	***986 957***	***19,1***
KwaZulu-Natal	3 607 400	3 089 912	85,7	360 700	10,0	*	2 729 212	75,7	75 800	2,1	140 491	3,9	301 197	8,3
Mpumalanga	677 500	492 507	72,7	137 898	20,4	*	354 609	52,3	56 800	8,4	23 130	3,4	105 063	15,5
Limpopo	3 612 400	3 394 518	94,0	530 700	14,7	*	2 863 818	79,3	127 200	3,5	6 060	0,2	84 622	2,3
Gauteng	–	–	–	–	–	–	–	–	–	–	–	–	–	–
North West	3 807 900	3 312 873	87,0	951 975	25,0	*	2 360 898	62,0	387 000	10,2	–	0,0	108 027	2,8
Total	**17 112 800**	**14 479 766**	**84,6**	**2 545 573**	**14,9**	*****	**11 934 193**	**69,7**	**780 200**	**4,6**	**256 268**	**1,5**	**1 596 566**	**9,3**
Commercial Agric														
Western Cape	12 938 600	11 560 609	89,3	2 454 788	19,0	2 126 342	9 105 821	70,4	730 731	5,6	198 938	1,5	448 322	3,5
Northern Cape	36 338 900	29 543 832	81,3	454 465	1,3	218 247	29 089 367	80,1	4 295 068	11,8	–	0,0	2 500 000	6,9
Free State	12 711 500	11 572 000	91,0	4 186 523	32,9	3 995 948	7 385 477	58,1	239 500	1,9	–	0,0	900 000	7,1
Eastern Cape	***11 886 200***	***10 815 867***	***91,0***	***643 501***	***5,4***	***601 651***	***10 172 366***	***85,6***	***523 000***	***4,4***	***47 333***	***0,4***	***500 000***	***4,2***
KwaZulu-Natal	5 540 700	3 439 403	62,1	838 975	15,1	834 637	2 600 428	46,9	1 302 100	23,5	325 197	5,9	474 000	8,6
Mpumalanga	7 504 100	4 486 320	59,8	1 596 998	21,3	1 742 601	2 889 322	38,5	2 275 100	30,3	526 688	7,0	215 992	2,9
Limpopo	8 348 200	7 153 772	85,7	1 169 742	14,0	660 090	5 984 030	71,7	1 034 400	12,4	59 350	0,7	100 678	1,2
Gauteng	1 876 000	828 623	44,2	438 623	23,4	405 773	390 000	20,8	228 400	12,2	20 190	1,1	798 787	42,6
North West	8 063 100	6 785 600	84,2	2 408 484	29,9	2 314 833	4 377 116	54,3	377 500	4,7	–	0,0	900 000	11,2
Total	**105 207 300**	**86 186 026**	**81,9**	**14 192 099**	**13,5**	**12 900 122**	**71 993 927**	**68,4**	**11 005 799**	**10,5**	**1 177 696**	**1,1**	**6 837 779**	**6,5**

Source: DAFF, 2012

Land classified for developing agriculture in the EC is located mainly of the former Transkei and Ciskei. The communal land of the former Ciskei and Transkei is approximately 5,2 million ha, or 30,3%, of total land in the province. Of these, 4 million ha is farm land, i.e. 27% of total farm land, of which 3,47 million ha is classified as grazing (See Table 2.6) That means that each of the 310 400 small-scale farmers have approximately 11 ha land available. The grazing capacity of most communal areas in the EC varies between 3 and 6 ha per large stock unit (LSU), implying that on average communal farmers only have land for 3 to 4 cattle or 18 to 24 goats or sheep. These numbers are not sufficient to sustain a family and one can expect gross overgrazing and therefore increased vulnerability to drought in these areas.

Table 2.6: Commercial and developing agricultural land

	Commercial Agric (ha)	Developing Agric (ha)	% Commercial Agriculture	% Developing Agriculture
Total land	11 886 200	5 175 400	69,7%	30,3%
Farm land	10 815 867	4 001 856	73,0%	27,0%
Potential arable land	643 501	529 400	54,9%	45,1%
Arable land utilised	601 651			
Grazing	10 172 366	3 472 456	74,6%	25,4%
Nature conservation	523 000	100 400	83,9%	16,1%
Forestry	47 333	86187	35,5%	64,5%
Other	500 000	986957	33,6%	66,4%

Source: DAFF, 2012

The most common land use activities amongst subsistence farmers are livestock rearing, some cultivation in high potential areas and exploitation of natural resources for fire wood, building materials and medicinal plants. The vast majority of livelihoods living on the developing land derive their income from on-farm as well as off-farm sources. Off-farm sources include wages, remittances from migrants and commuters, and state welfare grants, which in most areas is the main source of income (Andrew *et al*., 2003). The potential off-farm income is an important indicator for resilience against drought and contributes much toward the coping capacity of rural farmers against drought (Jordaan, 2011). Andrew *et al.* (2003) found that small stock and its fibres are commonly traded on the market for cash income while cattle are mainly used for daily subsistence (from milk) and for cultural purposes. Cattle remain a cultural asset and rural peoples' wealth is calculated according to the number of cattle they own (Andrew *et al.,* 2003).

The dualistic nature of farming systems in most cases creates the impression that small-scale subsistence and communal farming is wasteful, destructive and economically unproductive. While there is much room for improvement, one cannot ignore the importance of the potential production derived from the 310 400 subsistence farmers in the EC. Jordaan (2012), for example, found that some of these so-called subsistence farmers are in fact commercial farmers in spite of the fact that they form part of the communal farming system. Jordaan (2012) analysed the results of the Elundini livestock improvement program in the Mount Fletcher region and from a sample of 1 200 farmers found the mean number of ewes owned per farmer was 60 (median = 40), with 10% of the farmers farming with more than 300 ewes, which put these farmers in the commercial domain. Jordaan (2012) also calculated that the 1200 farmers in the study sample in the Mount Fletcher area contributed more than R50 million annually to the region's economy. Detailed production statistics for farmers classified as developing farmers or communal farmers in the rest of the province are not readily available, but one can assume that they contribute considerably to livelihood food security in the EC.

Commercial agriculture consists mainly of livestock, with some pockets of crop production and horticulture in high potential areas. Livestock farming in the EC consists mainly of sheep and more particularly wool sheep farming, angora goats, beef and dairy cattle and game. The summary of some crops and livestock produced in the EC is shown in Table 2.7. According to these data derived from the Abstract of Agricultural Statistics (DAFF, 2012), crop production contributes little, at less than 1% to total production in SA. Livestock production, on the other hand, is an important sector in relation to the rest of SA with 23% of cattle numbers, 30% of sheep numbers, 37% of goat numbers and 6% of pig numbers in SA. The EC also supplies about 25% of milk in SA (ECDC, 2009).

Table 2.7: Production of crops and livestock

	Total SA	EC production	% of total
Maize	10 360 000	68 000	<1%
Wheat	1 850 000	20 000	~1%
Sunflower seed	860 000	220	<1%
Soya beans	710 000	1500	<1%
Dry beans	41 980	1000	~2%
Cattle	13 830 622	3 146 250	~23%
Sheep	24 607 715	7 316 381	~30%
Goats	6 328 768	2 355 392	~37%
Pigs	1 600 066	96 466	~6%

Source: DAFF, 2012

The EC is the world leader in the production of mohair with more than 600 000 angora goats. SA produce about 50% of the world's mohair and most of this is produced in the EC. The EC is SA's second-largest producer of citrus fruit, with oranges contributing 80% of citrus production. The province is also well known for production of Clementine and Satsuma tangerines and naval oranges. Deciduous fruits such as apples, pears and apricots are also produced, especially in the fertile Langkloof valley in the Cacadu District Municipality. SA is the second largest producer of chicory in the world and most chicory in SA is produced around Alexandria between Port Elizabeth and Port Alfred. The EC is also well known for pineapple production and most of the pineapples in SA are produced in the EC (ECDC, 2013).

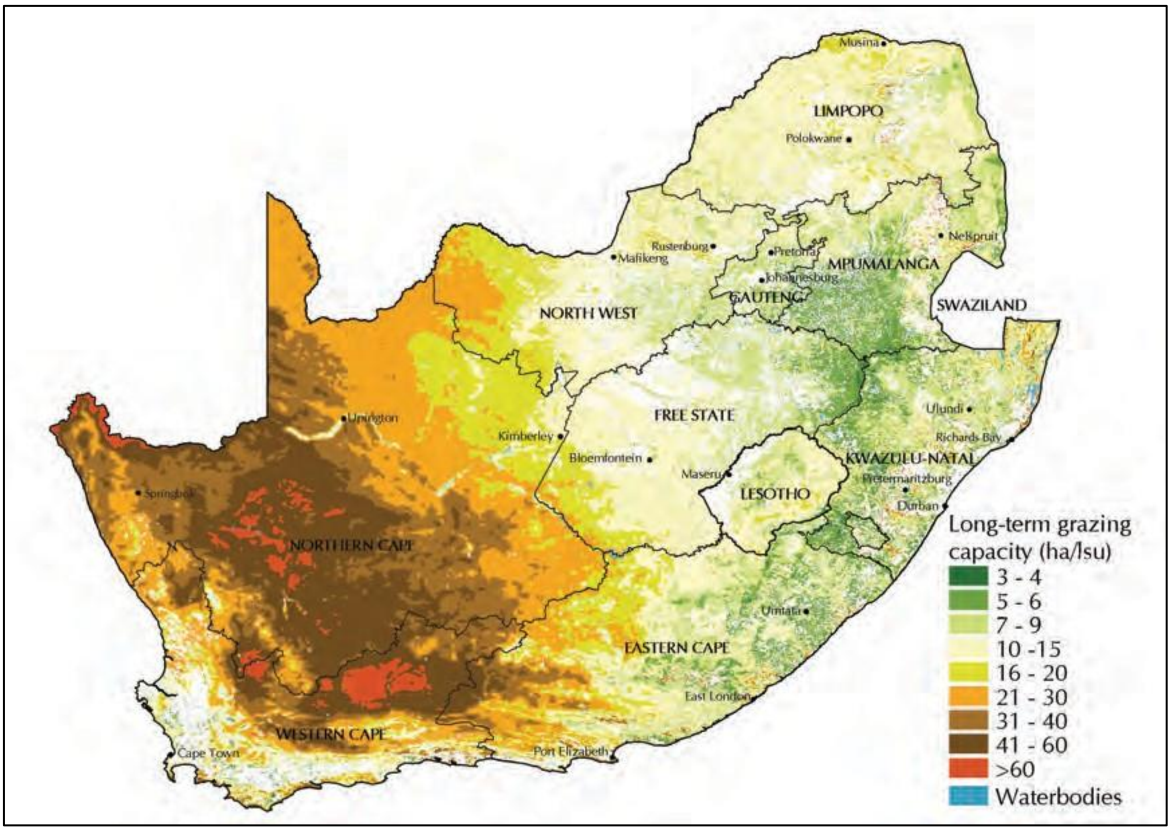


Fig 2.37: Long term grazing capacity of SA (ha/LSU)
Source: DAFF, 1993

The livestock sector is the largest agricultural sector in the EC and the grazing capacity of the province is the main contributor toward production per ha. The grazing capacity for SA is illustrated in Figure 2.37. It is clear from this map that the highest grazing capacity of between 3 to 6 ha per LSU is located in the OR Tambo and Alfred Nzo District Municipalities. The western part of Cacadu district has the lowest grazing capacity of about 40 – 60 ha per LSU.

Grazing capacity is key in the context of drought risk assessment and the implementation of a drought plan.

2.4 Agricultural Related Development Projects

Several development programs in the EC are focused on the development of the region and rural economies in order to ensure sustainable livelihood incomes for the rural poor and to stimulate the primary economic sector in the province. These programs focus on livestock production, grain and food production and subsistence production of food. The following section is a summary of the most important development and agrarian reform projects. It is important to understand these projects in the context of drought risk assessment since the success of these projects ultimately depends on the successful implementation of drought mitigation strategies.

2.4.1 Livestock Production Improvement Program

The Livestock Production Improvement Program is an economic development initiative based on livestock production through application of best practices by farmers. It aims at providing enabling conditions (infrastructure, technology) for the emergence of commercial livestock farmers from the communal farming and the developing agricultural sector. This program provides a *"pathway"* for small-scale farmers to enter the commercial domain.

The objectives of the program are:

- Promotion of sustainable and profitable livestock production within the resource potential of a specific region;
- Promotion of marketable livestock and its products (e.g. meat, wool, etc.); and
- Provision of superior animal genetic breeding material and encouraging the use of adapted animals by the Eastern Cape farmers.

2.4.2 Massive Food Production Program (MFPP)

The Massive Food Production Program is a rural economic development initiative that targets grain food production through subsidizing input supplies, mechanization, marketing and agro-processing by means of a conditional grant scheme.

The objectives of the MFPP are:

- Food security - commercial field crop production to address local and provincial food needs;
- Poverty alleviation and rural economic development through the establishment of competent and economically sustainable crop farmers; and
- Conservation Cropping Practices - progressively establishing the general use of conservation field cropping practices that optimize the sustainable and profitable use of arable areas, including the practice of minimum tillage.

2.4.3 Siyazondla Homestead Food Production

The Siyazondla Program is a homestead food production program targeting the poor, vulnerable and food insecure households who have access to a small piece of land (garden) complementing the food parcels they receive.

2.4.4 Siyakhula Step-Up Food Production Program

The Siyakhula Step-up Commercial Food Production Program is a rural economic development initiative that targets and develops small-scale operations in grain food production through subsidizing input supplies, mechanization, marketing and agro-processing by means of a conditional grant scheme.

2.4.5 Mechanization Conditional Grant Scheme (MCGS)

The concept of the MCGS is to stimulate and promote the acquisition and efficient use of appropriate mechanical equipment for the production of agricultural products in the underdeveloped production areas of the Eastern Cape to overcome challenges that limit the effective use of the natural resources for agricultural production:

The objectives of the MCGS are to:

- Develop food security through mechanization capacity for agricultural production in order to address local and regional food and livestock forage needs;
- Provide a step-up mechanization facility for economically sustainable agricultural development in underdeveloped areas and/or within historically disadvantaged groups; and
- Promote conservation cropping practices by progressively establishing the general use of conservation agricultural practices that optimize the sustainable and profitable use of agricultural resources, including the practice of minimum tillage.

2.4.6 Eastern Cape Communal Soil Conservation Scheme

The legislative framework for this scheme is the Agricultural Development Act 1999 (Act No. 8 of 1999) Provincial Notice No. 57 of 2001. The concept of the Eastern Cape soil conservation scheme is to promote sustainable utilization of agricultural resources by providing incentives in the form of grants to construct soil conservation works in communal areas.

The objectives of the soil conservation scheme are to:

- To promote the construction of certain soil conservation works;
- To maintain the production potential of land;
- To combat or prevent excessive soil loss through erosion; and
- To regulate the payment of subsidies out of monies appropriated for the purposes of the scheme.

2.4.7 Land Care Program

Land Care is a community-based approach where members of the community are assisted by the Department of Agriculture and Rural Development to identify, plan and implement practices to ensure sustainable production systems, to address environmental issues and to protect natural resources.

The objectives of Land Care are to:

- Promote partnerships between the communities, the private sector and government in the management of resources;
- Establish institutional arrangements to develop and implement policies, programs and practices that will encourage the sustainable use of natural resources;
- Encourage skills development for sustainable livelihoods;
- Encourage opportunities for the development of business enterprises with a sustainable resource management focus; and
- Enhance the long term productivity of natural resources.

2.4.8 Soil Conservation Scheme (CARA, Act 43 of 1983)

The concept of CARA is to promote sustainable utilization of agricultural resources by providing incentives in the form of subsidies to landowners to construct soil conservation works. The difference between CARA and the EC Communal Soil Conservation Scheme is that CARA is focused on landowners

The objectives of CARA are to:

- Promote the construction of certain soil conservation works with the view to maintaining the production potential of land;
- Combat or prevent excessive soil loss through erosion; and
- Regulate the payment of subsidies out of monies appropriated for the purposes of the scheme.

2.4.9 Comprehensive Agricultural Support Program

The concept of the program is through a conditional grant to provide support services, promote and facilitate agricultural development, targeting beneficiaries of land reform and previously disadvantaged communities and farmers.

The objectives of the program are to:

- Establish a farmer support financing mechanism to enhance productivity;

- Improve competitiveness and profitability;
- Facilitate equitable access to agricultural infrastructure, services and participation by previously disadvantaged farmers;
- Increase sustainable agricultural development;
- Create job opportunities and reduce poverty;
- Increase economic activity from agriculture; and
- Increase household food security.

2.4.10 Farmer Organization Development

The concept of this program is to organize farming communities into co-operatives, commodity groups, farmers associations to be able to lobby Government and Private Sector support for their own development. Most of the development projects are concentrated in the eastern Joe Gqabi District Municipality, the southern part of Alfred Nzo District Municipality, the western part of OR Tambo District Municipality, the eastern part of Chris Hani District Municipality and the northern part of Amathole District Municipality (See Figure 2.38)

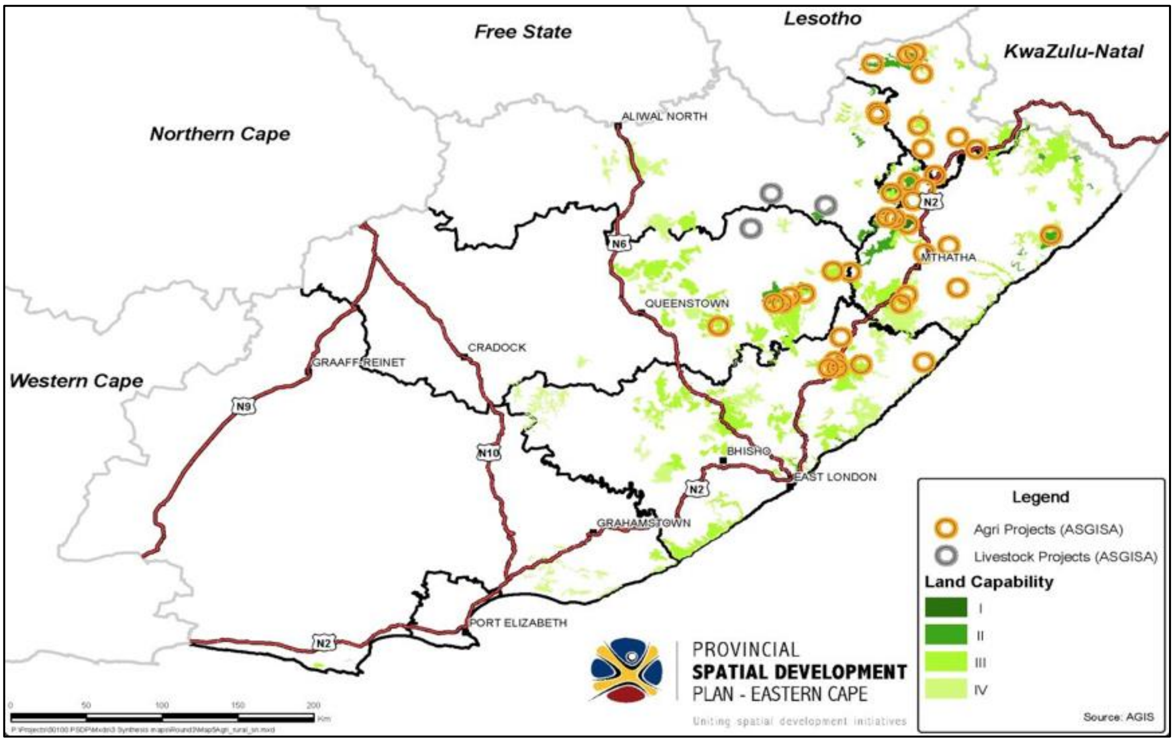


Fig 2.38: Development projects
Source: Source: Province of the Eastern Cape, 2010(b)

The objectives of the program are to:

- Identify the committed farmers and their lines of interest; and to
- Assist farmers in organizing themselves to become fully-fledged business entities e.g. Co-ops, commodity groups and farmers' associations.

2.5 District Municipalities

The main objective of this research was to target three district municipalities in the EC and complete a drought disaster risk assessment and answer relevant research questions. The primary criteria which were considered for the selection of the selected districts are given below. The potential to extend the scope of the project to all the district municipalities in the EC was negotiated with the Department of Agriculture and Rural Development, but it is not conclusive yet, depending future budget constraints. For the purpose of this report, only four districts are described from which three will be selected as focus districts for this research. The four districts selected for the initial phase and reasons for the selection are:

- Amathole District Municipality
  - Amathole has a good distribution of commercial and communal farming areas alongside each other;
  - Meteorological data are available, although not represented as well as in the district of Cacadu;
  - The potential exists to compare a coastal zone climate with inland climate; and
  - The University of Fort hare is located in the district and they have done much research already in this area; potentially it would therefore relatively easy to obtain some data and just built on that.
- OR Tambo District Municipality (ORTDM):
  - ORTDM is one of the Presidential nodes targeted for development;
  - It is the district with the most communal farmers in South Africa;
  - It is also the only district in SA with surplus water available for further development;
  - Opportunity exists to undertake a drought risk assessment in a rainfall region with annual precipitation that varies from 1200 mm to 700 mm;
  - Historically not much research has been done on the survival strategies of communal farmers and there is a definite gap in knowledge in this field;
  - The Department of Agriculture and Rural Development in the EC indicated that they prefer this district to be included in the research;
  - Politically this is an important district for Government since the SA growth and Development Plan envisages much development projects for this region;
  - Rural households are very poor and highly vulnerable with more than 310 000 small-scale farmers depending on agriculture in this district; while
  - On the negative side is the fact that not many meteorological data and data from communal farmers are available.
- Cacadu District Municipality
  - Cacadu is the district in the EC with the highest output in agriculture;
  - The largest contingent of commercial farming in the EC is located in Cacadu;
  - Climate varies from winter rainfall in the south to coastal summer rainfall and the arid Karoo in the west;

- The SAWS in Port Elizabeth indicated that Cacadu is the district with the best distribution of meteorological data available within the EC;
    - Cacadu is the district in the province experiencing the most droughts; and
    - The Department of Agriculture and Rural Development in the EC indicated that they prefer this district to be included in the research.
- Joe Gqabi District Municipality (JQDM)
    - Rainfall ranges from 800 mm in east to less than 400 mm in west and this provides a good opportunity to assess drought risk under different climatic conditions;
    - It consists of Karoo, grassland and mountainous areas with potential to assess drought risk in varying climatic and geographic zones, including mountainous areas;
    - The highest concentration of rain fed grain production in the EC occurs in the eastern part of the district;
    - Primary data amongst communal livestock farmers are available due to the Elundini Livestock Improvement Program; and
    - The selection of Joe Gqabi with OR Tambo will provide the opportunity to analyse meteorological trends from the coast to the high Drakensberg Mountains.

Demography is an important social vulnerability indicator for exogenous shocks and drought in the context of this study. The demographic profile of the four district municipalities is summarized in Table 2.8.

Table 2.8: Demography of four district municipalities

	Amathole	Cacadu	Joe Gqabi	OR Tambo
Population	892 637	450 584	349 768	1 364 943
Nr households	237 776	125 632	97 775	298 229
Household size	3,6	3,4	3,4	4,3
Female headed hh (%)	53%	38,5%	49,3%	57,9%
Dependency ratio (%)	73,6%	52%	71,4%	80,5%
Males/100 females	88,6	95,6	89,8	85,7
10 yr population growth (%)	-8,2%	14,9%	2,3%	5,2%
Official unemployment (%)	42,9%	24,9%	35,4%	44,1%
Youth unemployment (%)	53,4%	31,4%	43,3%	54,2%
No schooling (%)	13,5%	7,5%	14,6%	17,3%
Matric (%)	13,4%	20,3%	14,1%	15,4%

Source: StatsSA, 2011

When comparing the demographic data of the four municipalities shown in Table 2.8, OR Tambo District Municipality appears to be the most vulnerable, with Cacadu the least vulnerable. The demographic profile of each district impacts on drought risk and is a determining factor on how livelihoods cope with dry conditions. The demographic information for each quaternary catchment will be an important indicator for vulnerability related to dry periods.

Apart from demographic information, the following are discussed as part of the district profiles:

- General description
- Climate

- Economy
- Agriculture
- Water
- Ecology and biodiversity
- Disaster management
- Drought management
- Land reform. Successful land reform is a key element for sustainable food production in a future South Africa. Beneficiaries of new farms more often than not are not in a position to withstand pressures from exogenous shocks such as drought and part of the failure of the land reform program could be the impact of exogenous shocks such as drought. The coping capacity and vulnerability of land reform beneficiaries is unique and differs from those of established commercial farmers on the one end, and that of small-scale communal farmers on the other end of the scale. The land reform situation is therefore also reflected in this report.

Selection of the final three districts was made after discussions with, and recommendation from, the project's Advisory Committee. The following section discusses the profiles of the four district municipalities initially selected.

2.5.1 Amathole District Municipality (ADM)

Amathole is situated at the eastern coast side of the province and consists of eight local municipalities. The district covers 23 594 square km with about 60% urban and 40% rural. Buffalo City Metro is mainly an urban area and is not regarded as part of Amathole in the context of the drought risk assessment for this study. The land area of Amathole, excluding Buffalo City, is 21 229 square km. The local municipalities within the jurisdiction of the Amathole district municipality are the following:

- **Amahlathi** Municipality, comprising the towns of Stutterheim, Cathcart, Keiskammahoek and Kei Road, numerous peri-urban and rural settlements;
- **Nxuba** Municipality, comprising the towns of Bedford and Adelaide and surrounding rural areas;
- **Nkonkobe** Municipality, comprising the towns of Alice, Fort Beaufort and Middledrift, the smaller towns of Hogsback and Seymour, and numerous peri-urban and rural settlements;
- **Ngqushwa** Municipality, comprising the town of Peddie, the coastal town of Hamburg and numerous small peri-urban and rural settlements.
- **Great Kei** Municipality, comprising the town of Komga, the small coastal towns of Kei Mouth, Haga Haga, Morgan's Bay and Cintsa, and a number of rural settlements.
- **Mnquma** Municipality, comprising of the main town of Butterworth, the small towns of Ngqamakwe and Centani, and numerous peri-urban and rural settlements.

- **Mbhashe** Municipality, comprising the towns of Idutywa, Elliotdale and Willowvale, and numerous small peri-urban and rural settlements.

The map of the Amathole DM is shown in Figure 2.39.

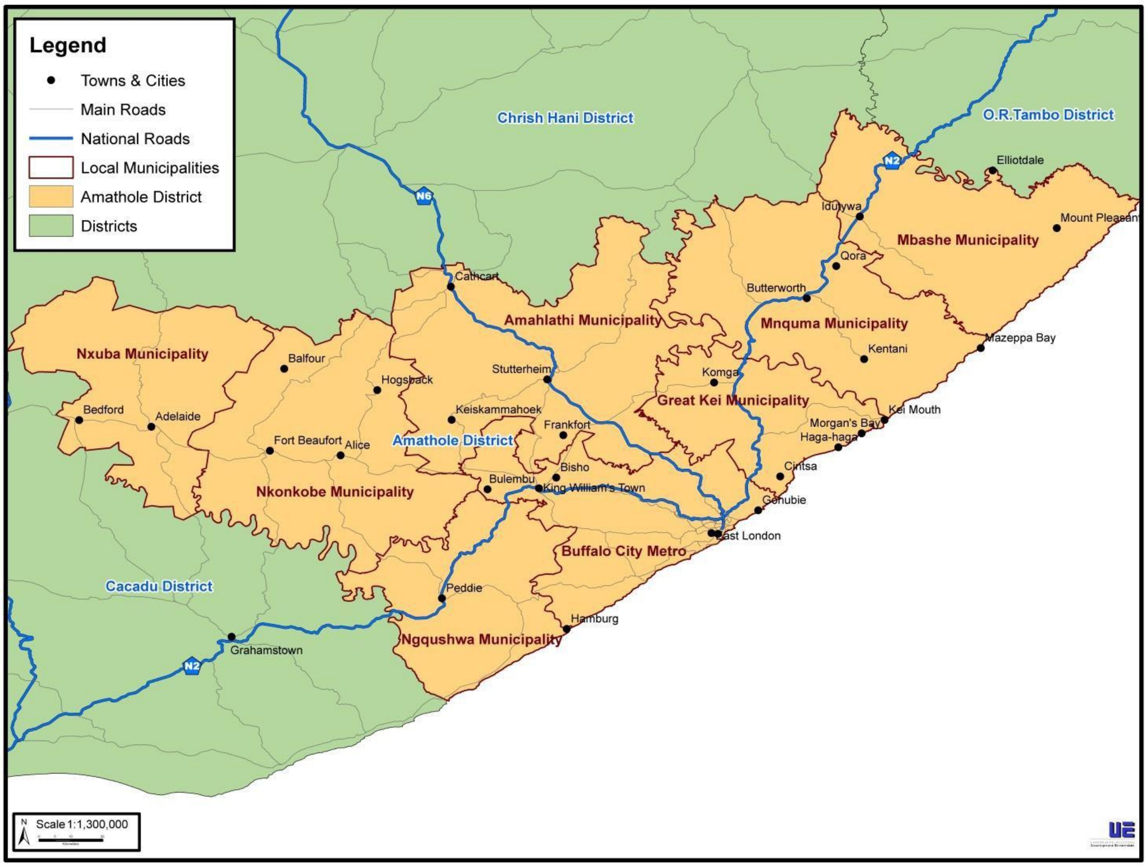


Fig 2.39: Amathole District Municipality
Source: Urban-Econ, 2011

2.5.1.1 Climate

The climate of the Amathole District varies from mild temperate conditions (14-23°C) along the coastal areas to slightly more extreme conditions (5-35°C) among the inland areas. The district is located in a summer rainfall area with mean annual precipitation that varies from 1 000 mm in the north-east coastal zone to 600 mm in the west. Winter snow is sometimes experienced on the higher mountains toward the northern part of the district. Updated weather data are not readily available at all quaternary catchments and it might be a challenge to analyse drought hazard in all catchments. The mean annual precipitation per quaternary catchment is shown in Figure 2.40. The arid western parts of the district are clearly visible.

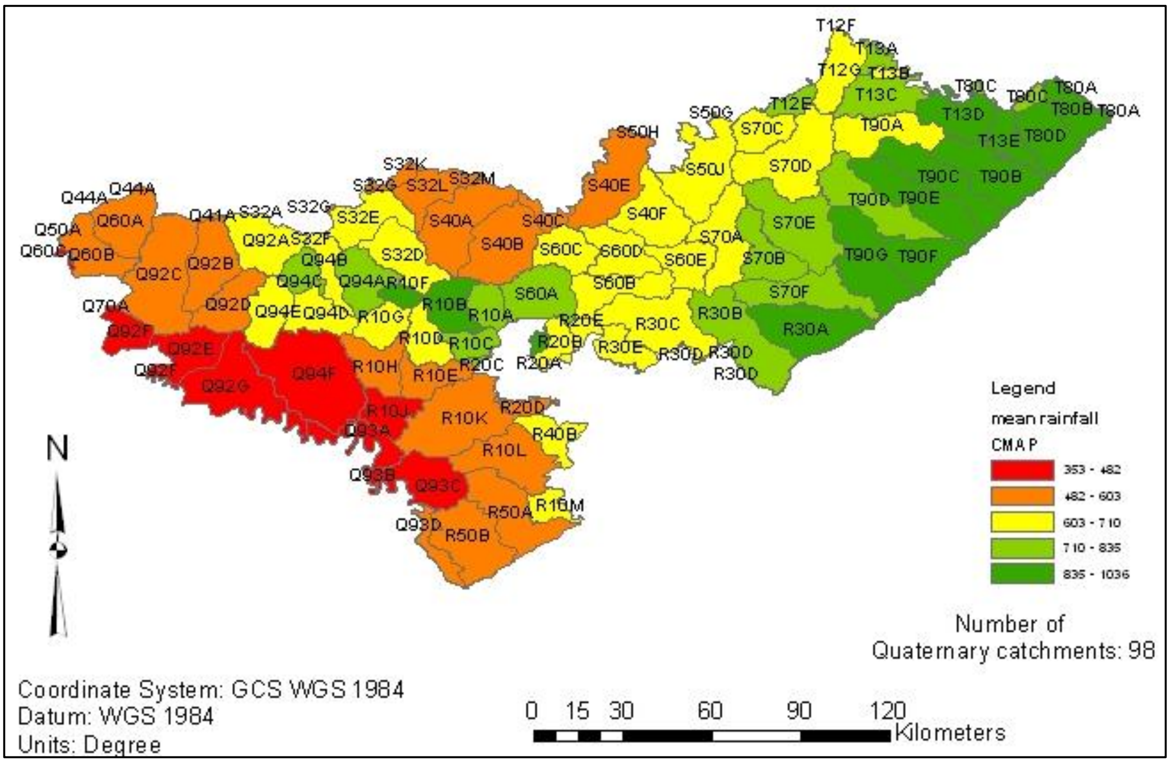


Fig 2.40: Amathole mean annual precipitation per quinary catchment

2.5.1.2 Economy

Amathole has the 3rd largest economy in the EC after Nelson Mandela Bay Metro and Buffalo City Metro, contributing 12% to the provincial economy. The major towns in Amathole are Butterworth, Idutywa, Peddie, Alice and Stutterheim. Manufacturing, trade, finance and the community service sectors dominate the district's economy and as a result of its central location in the province, it has good linkages with neighbouring districts. Agriculture contributes only about 7% to the GGP of the district, but the GGP does not reflect the real contribution from agriculture since the downstream and upstream impacts are not considered.

Amathole is characterized by a very poor rural community in the former homeland areas with unemployment of more than 45%, and with 55% of the rural population living below the minimum living threshold.

2.5.1.3 Agriculture

The main characteristics of the agricultural sector are the following (Amathole IDP, 2012):

- Land use patterns and land ownership are diverse, with communal ownership and land use in the former homelands of Ciskei and Transkei to private ownership and commercial farming.
- Agriculture is subsistence in most part of Amathole due to a number of constraints, especially the land ownership issue.

- The prospect for agricultural growth in the district is small because communal farmers lack funding, inputs and experience to farm beyond subsistence levels.

The focus of the district in respect of agricultural development is to create an enabling environment for subsistence as well as commercial agriculture to flourish through the provision of critical infrastructure. In spite of limited high potential agricultural land, a number of opportunities are exploited and still exist for agricultural development. Amongst others they are the following:

- **Livestock** (Sheep and cattle) are farmed together on most commercial farms, but there is a shift away from small stock to large stock, which is less profitable than small stock. Stock theft and increased labour costs are some of the major contributing factors for this shift. However, livestock production remains the main agricultural activity and has both a strategic and socio-economic value for Amathole. Goat farming is also an important sector because of its resilience amongst subsistence farmers.
- **Dairy farming** is a specialized sector and is located mostly in the coastal zone where irrigation for fodder exists. Market surpluses, the low profit margins and the high management demands limit expansion of this sector.
- **Game farming** shows a positive growth with commercial farmers shifting to game farming due to lower labour costs and managerial needs. Game farming has good potential for expansion and growth, but this is limited to the commercial sector due to challenges linked to land consolidation and high infrastructure investment costs.
- **Vegetable and irrigated crops** are medium to high-income crops, but require high managerial skills. Some projects already exist in the district, but potential exists for expansion and the creation of 24 000 new jobs.
- The primary field crop is **maize** and the less than 1% contribution from the province to the national yield is not a true reflection of actual production and the value of maize production in Amathole. Many livelihoods intercrop maize with beans and pumpkins and maize is a much-needed staple food for most rural livelihoods.
- Tunnel or hydroponic production dominates the production of **high value crops** such as cut flowers, tomatoes, but this is limited to the coastal zone.
- The potential for **pineapple** cultivation is sub-optimal along the Amathole coast and production is declining.
- A number of **poultry** projects have been implemented, but without great success. Market insecurity and high level of managerial needs are some of the limitations.

2.5.1.4 Freshwater in Amathole

The four major drainage systems in Amathole are the:

- Great Fish river catchment (Great Fish, Koonap & Kat Rivers)
- Great Kei River basin (Great Kei, Kubusi, Klipplaat & Gqnube Rivers)

- Mbhashe River basin, and the
- Amathole catchment (Keiskamma, Buffalo, Nahoon & Gqunube Rivers).

Pressures on the freshwater supply in Amathole are the following:

- Western region
    - Agriculture dominates the region
    - Irrigation return flow increases are responsible for sediment load and siltation of the Great Fish River
- Eastern region
    - Former Ciskei and Transkei – mainly communal land use
    - Largely under-developed and characterized by under-developed rural settlements
    - Major pressures include microbial contamination, solid waste pollution and increased sediment loads due to erosion at overgrazed landscapes
- Central region
    - Dominated by industrial and urban area of East London
    - Population growth and urbanization
    - Industrial waste
    - Effluent discharge.

2.5.1.5 Ecology and biodiversity

The Amathole District has a high diversity of plant species because of biogeographic complexity. Five biomes and 21 vegetation types are represented in the district (See Figure 2.41).

Medicinal plant species are present in abundance and pharmaceutical companies and traditional healers exploit these quite extensively. The majority of larger animal species are extinct from the area. Invertebrates, herpetofauna and amphibians face many pressures, primarily resulting from habitat destruction from human related pressures. Amathole comprises of 2.8% of South Africa's surface area, yet supports 15% of its species diversity. Many species and ecosystems are threatened as a result of increased pressure on natural populations and their habitats.

Not many protected areas exist in the district and the vegetation is not protected to the extent that is generally recommended. The few protected areas occurring in the district are extremely important for the protection of some plants and animals. Only the Eastern Cape thicket is conserved, with 16% of its surface in a conservancy area. The main impacts of this are (i) higher vulnerability to dry periods, (ii) water shortages due to alien vegetation infestation, (iii) habitat loss, (iv) habitat degradation, (v) fragmentation, (vi) alien infestation, and (vii) soil erosion.

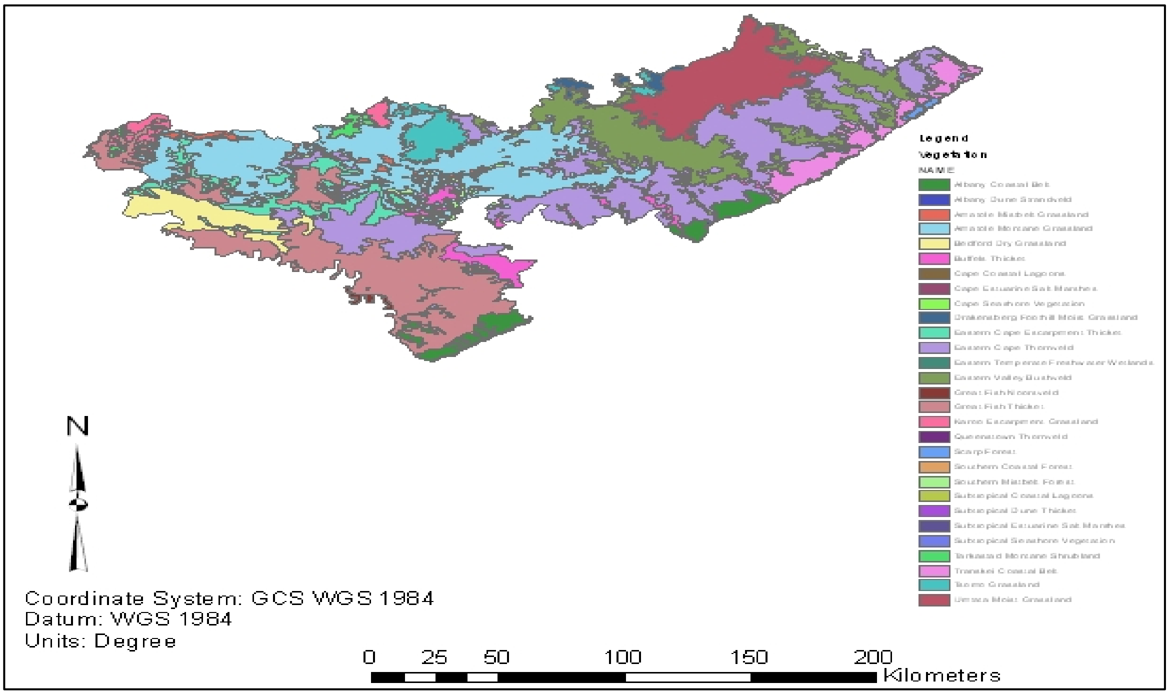


Fig 2.41: Vegetation types in Amathole

2.5.1.6 Disaster management in Amathole

The disaster management function in Amathole is functional with a newly built Centre and staff. In order to service the local municipalities, satellite centres were established at:

- Mnquma
- Amahlathi
- Mbhashe
- Great Kei
- Ngqushwa
- Nkonkobe
- Nxuba

Sufficient funding for disaster management and disaster risk reduction planning remains a challenge and the much-needed inter-departmental disaster management committee is still dysfunctional. Inter-departmental collaboration is essential, especially in the context of drought management. The lack of contingency plans for disaster response (in the case of this research project, a drought contingency plan) is of great concern and is at the core of previous problems of slow support and support coming too late, and lack of sufficient funding.

2.5.1.7 Drought planning in Amathole district

Drought is a regular phenomenon in Amathole and extended periods of drought were experienced recently especially during the period 2008 to 2010. Amathole was declared a drought disaster area during July 2009 and the municipality affected the worst was Nxuba local municipality. The Amathole IDP mentioned climate change and changing weather patterns as the causes of recent droughts and this research is challenging the hypothesis of an increase in drought occurrences as a result of climate change. As a result of the 2008 – 2010 drought, the district included elements of drought mitigation planning into the latest IDP. An example of a drought mitigation plan is the Nxuba groundwater exploration study funded by the Department of Water and Sanitation.

One of the main lessons learned by the district from the 2008-2010 drought is that the carting of water to drought stricken areas is too costly and not sustainable in the long run. As a result of that, Amathole District Municipality budgeted R78,55 million to source alternative water sources in its endeavour to improve water supply during dry periods. This is a good example set by the district to mitigate the impact of dry periods and to prevent dry periods to be classified as droughts. Disaster management at district level is jointly responsible for drought disaster response in conjunction with with the Department of Agriculture and Rural Development (DARD).

The municipality developed the following procedures during droughts (IDP, 2012):

- On-going publicity campaigns about the drought and conserving water;
- Undertake groundwater investigations in each affected area – this commenced in 2011/12 year;
- If groundwater investigation is successful, equip boreholes;
- If groundwater investigation is not successful or only partially successful, supplement with desalination in coastal areas;
- In inland areas, where groundwater is not an option, other surface water supplies should be investigated;
- Water re-use should be considered as an immediate quick-win solution in all drought affected areas with Waste Water Treatment Works (WWTWs), and it is further proposed that ultimately water re-use becomes part of the district's best practice at all WWTWs throughout the entire district as a means of reducing water usage and taking a long term water conservation approach;
- Water conservation and demand management (WCDM) initiatives should be implemented in all areas, and in this regard consultants have been appointed in seven identified towns to develop such plans for phased interventions. This is to include ensuring all consumers are metered and zone meters have been installed in billing areas. Special effort should be made to minimize high pressures where it occurs in water systems to reduce water losses through leaks. Leak detection must be practised and refurbishment of old/dilapidated water pipes and installations be prioritized to cut water losses. This would require that an aggressive preventative maintenance program and planning/budget be launched via better utilization of ADMs, WCDM programs and WMIS (Water Management Information System) hardware/software such as EDAMS

2.5.1.8 Land Reform in Amathole

Amathole received 505 land claims with numbers in different local municipalities as follows:

- Amahlathi LM – 68 claims
- Mnquma LM – 31 claims
- Mbhashe LM – 7 claims
- Great Kei LM – 10 claims
- Nkonkobe LM – 203 claims
- Ngqushwa LM – 127 claims
- Nxuba LM – 59 claims

From the 505 claims received, 402 were determined to be legitimate and are currently under investigation. Until now (February 2017) only 13 claims had been settled. Eighty-four farms were obtained through the Settlement and Land Acquisition Grant (SLAG) and a further 64 farms through the Land Redistribution for Agricultural Development (LRAD) program. Figure 2.42 illustrates the geographic locations of the land reform projects in Amathole District Municipality.

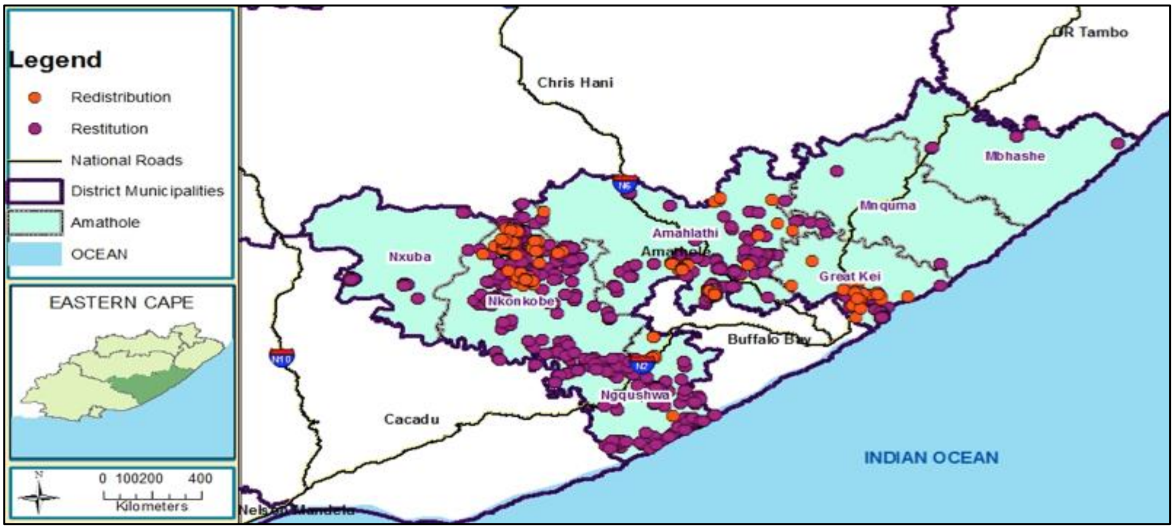


Fig. 2.42: Land reform projects in Amathole District Municipality
Source: Dept. of Rural Development & Land Reform, 2013

Land claims on commercial agricultural land have a direct impact on the vulnerability of farmers since the farmer, or current landowner, in most cases shifts to short term strategies and cuts down on maintenance of infrastructure.

2.5.2 Cacadu District Municipality (CDM)

Cacadu District Municipality (CDM) is, at 53 243 square km, the largest of all the district municipalities in the EC. CDM is located in the west of the EC and stretches from the Indian Ocean coast in the south to the Northern Cape and the Western Cape provinces' borders in the west with the Chris Hani and Amathole District Municipalities in the north. The district consists of nine local municipalities with two National Parks that fall outside the legislative and management powers of the local municipalities. These parks are the Addo Elephant National Park and the Tsitsikama National Park. The South African National Parks Board manages both parks.

The nine local municipalities, with main towns in each, are the following (CDM IDP, 2012):

- Camdeboo – Graaff-Reinet, Aberdeen, Nieu-Bethesda
- Blue Crane Route – Somerset-East, Cookhouse, Pearston
- Ikwezi – Jansenville, Klipplaat, Waterford, Wolwefontein
- Makana – Grahamstown, Alicedale, Riebeeck-East
- Ndlambe – Port Alfred, Kenton-On-Sea, Bushmans River Mouth, Alexandria
- Sundays River Valley – Kirkwood, Addo, Peterson, Glenconner
- Baviaans – Willowmore, Steytlerville, Rietbron, Vondeling
- Kouga – Jeffreys Bay, Humansdorp, Hankey, Patensie, St Francis Bay
- Kou-Kamma – Joubertina, Kareedouw, Louterwater

The CDM, together with local municipalities and main routes is illustrated in Figure 2.43.

Fig 2.43: Cacadu District Municipality
Source: CDM IDP, 2012.

Population density in CDM is low compared to the rest of the province. CDM covers approximately one third of the land of the EC, but only hosts 5,4% of the province's population with an average distribution of seven people per km^2. CDM is predominantly a rural commercial farming area and differs from the Amathole, Alfred Nzo and OR Tambo DMs in that there are no large areas of communal land such as the former homeland areas of Transkei and Ciskei. Communal land only exists around towns where municipalities own the land that is used by subsistence farmers in town. More than 50% of the population resides in the municipal areas of Makana, Kouga and Ndlambe.

2.5.2.1 Climate

Climates in Cacadu vary from mild conditions and moderate rainfall along the coast to harsh and arid conditions in the Karoo. The Tsitsikama forest in Kou Kamma municipality has a mean temperature of 23°C during summer and a winter mean temperature of 17°C while temperature in Graaff Reinet in Camdeboo municipality rise to mid-40°C with a mean summer temperature of 31,5°C and mean winter temperature of 19,4°C.

Rainfall varies from 1000 mm in the Tsitsikama forest in the most southern part of the district to less than 200 mm in the Karoo in the western part of the district. The eastern part of the district receives about 600 mm per annum with approximately 400 mm per annum in the central part of the Cacadu DM. The mean annual precipitation per quaternary catchment in CDM is shown in Figure 2.44. The arid western and central part is clearly visible on the map.

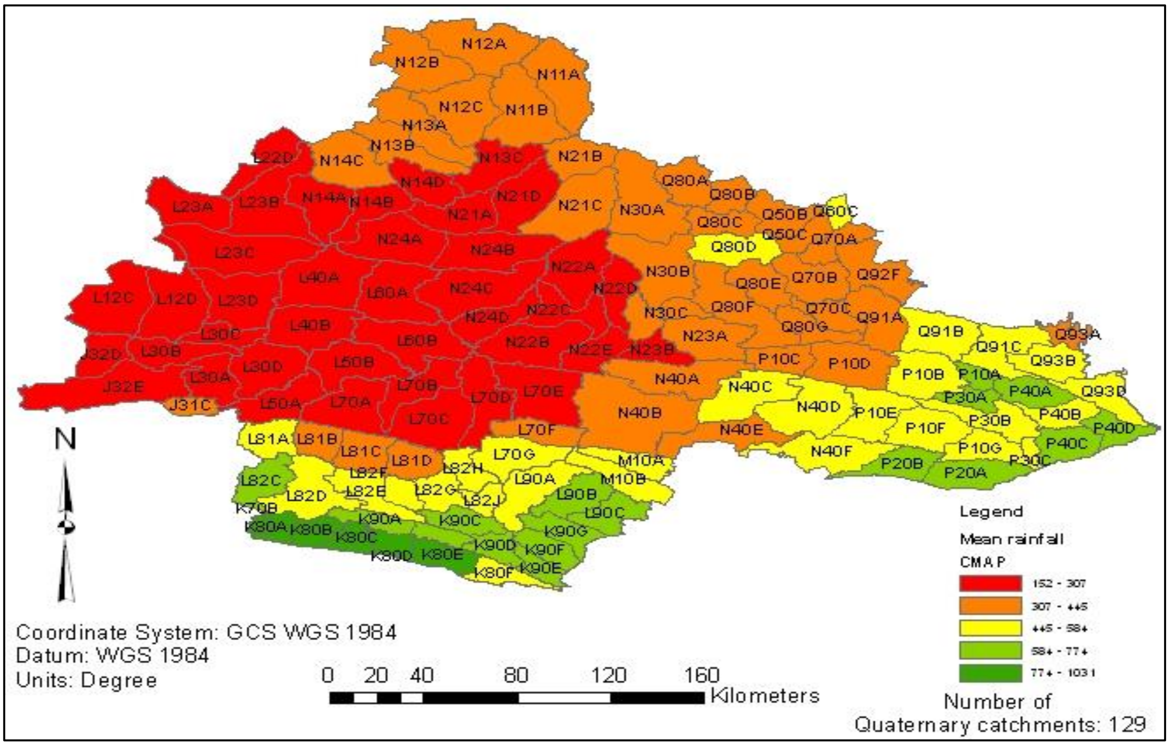


Fig 2.44: CDM mean annual precipitation per quaternary catchment

2.5.2.2 Economy in CDM

Agriculture remains the single most important economic driver in the CDM, contributing nearly R1 billion to the district's GGP, but its relative contribution to GDP remains small when compared to community services. The largest contributor to gross value added is community services followed by trade (which includes tourism), finance, agriculture, manufacturing and transport (See Figure 2.45).

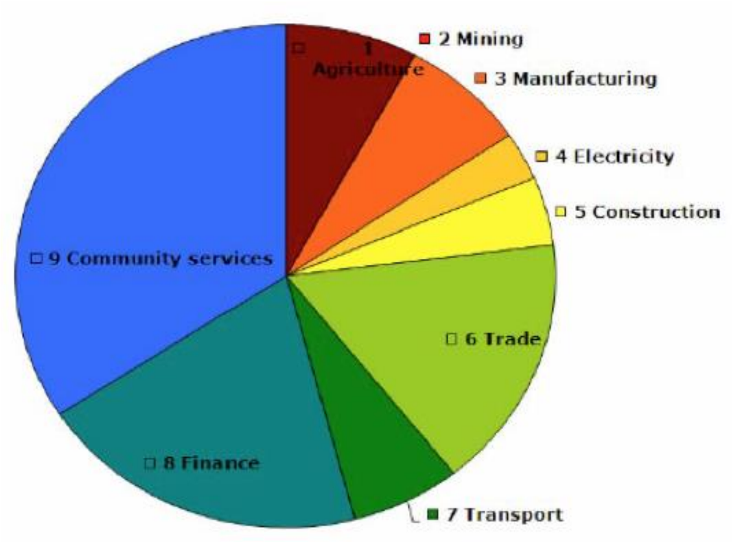


Fig. 2.45: CDM GVA sector composition (2010)
Source: CDM, IDP, 2012

Important to note, however, is that tourism depends also on agriculture through game farming and rural guesthouses and that this is not correctly reflected as a part of agriculture.

2.5.2.3 Agriculture in CDM

Owing to the diverse climate in the district, a wide array of agricultural commodities is produced. Most of the district is arid with little high potential land, except in the Langkloof and Sundays River valleys where farmers irrigate and produce high value crops. Most of the district, however, consists of extensive livestock farming. The main agricultural activities are listed as follows (Cacadu, 2011):

- Sheep (mutton, wool and hides)
- Goats (Chevron, mohair and hides)
- Cattle (beef, dairy and hides)
- Game (venison, trophies & tourism)
- Ostrich (meat, leather & feathers)
- Pork
- Fruit (citrus, deciduous fruit, pineapple and stone fruit)
- Vegetables (fresh and for processing)
- Chicory
- Grains (animal feed)
- Honey bush tea
- Chicken (meat & eggs)
- Fishing

The total area of permanent cultivation under irrigation adds up to approximately 39 600 ha (high value crops and feed and fodder for dairy cows), with temporary cultivation (mostly for animal feed and fodder) is at about 60 000 ha. Carrying capacity for extensive livestock varies from 10 ha per LSU in the south near the coastal region to 40-60 ha per LSU in the west. CDM is also the largest producer of mohair in the country, with more than 2,9 million kg of mohair produced annually; that is more than 50% of total mohair production in SA (Local Government Handbook, 2012). The coastal belt of the district, particularly the Kou-Kamma, Ndlambe and Kouga local municipalities, are the centre of the dairy industry in the EC and are responsible for producing more than 20% of total milk production in SA. Citrus production is concentrated in the Sundays River valley, with Kirkwood regarded as the citrus capital in the EC. Kirkwood is also surrounded by one of the largest citrus areas in SA with 12 000 ha of citrus orchards.

Agriculture is an important provider of employment with about 41% of formal employment opportunities in primary agriculture and 7% in related agro-processing industries, while tourism provides only 3% of total formal employment in the district.

2.5.2.4 Water in CDM

CDM depends predominantly on groundwater for human consumption as well as for agricultural activities. The low inland rainfall toward the west of the province results in sporadic dry periods which consequently dries up boreholes and disrupts water supply to towns and human settlements. As a result of the above, there is a competing demand for the scarce water resources between agriculture and the communities.

Information on major dams in CDM is summarized in Table 2.9.

Table 2.9: Water schemes in CDM

Major Dam	Major River	Municipality	Use
Churchill & Impofu	Kromme River	Kouga	Domestic & Irrigation
Loerie	Kromme River	Kou-Kamma	Domestic
Beervlei	Groot River	Baviaans	Flood Retention
Kouga	Kouga River	Kouga	Domestic & irrigation
Transfer scheme • Uitkyk scheme • Glen Melville dam	Orange River via Fish River into Sundays River	Blue Crane Sundays River Valley Makana	Domestic & irrigation Irrigation Domestic & irrigation

Source: CDM IDP, 2012.

All the local municipalities in the CDM also act as Water Services Authories (WSA). The three major dams, Churchill, Impofu and Loerie are situated in the Kouga and Kou-Kamma municipalities and predominantly serve the Nelson Mandela Metro, with limited supply also to Humansdorp, Jeffreys Bay and St Francis Bay. The transfer schemes were developed predominantly to serve the agriculture sector in the District. There is one water board in Ndlambe Municipality, the Albany Coast Water Board that services Bushmans River Mouth and Kenton-on-Sea.

2.5.2.5 Biodiversity in CDM

The biomes present in Cacadu are Nama-Karoo (826 466 ha), Albany Thicket (217 866 ha), Succulent Karoo (137 046 ha), Fynbos (133 749 ha), grassland (8 511 ha) and forests (147 ha). Ninety-eight per cent of the area is still covered with natural habitat, with only 2% where no natural habitat remains (BGIS, 2012). Formal land base protected areas consist of 10 reserves covering 4,5% of total land cover in the district, or 61 180 ha. The Addo Elephant National Park and the Tsitsikama National Park are not included as part of these reserves. Wetlands play an important role not only in the preservation of ecosystems, but they are an important drought risk reduction mechanism where available. There are 1 818 wetlands in the district covering a total area of 5 449 ha.

2.5.2.6 Disaster management

CDM has a functional disaster management section with four satellite offices at Kouga, Makana, Ndlanbe and Camdeboo local municipalities. CDM disaster management also established communications networks at Sundays River, Kouga, Makana, Ndlambe and Camdeboo municipalities. CDM does not have a well-developed disaster management plan that is supported by a disaster risk assessment (Mandisa, 2013).

Agriculture in the Langkloof experiences regular disasters in the form of floods and droughts and a real concern exists that the resources in the Langkloof are not utilised in a sustainable manner (Coetzee, 2013).

2.5.2.7 Drought planning in CDM

Drought is a regular phenomenon in CDM and severe drought conditions were experienced from 2008 to 2011. Of critical, and in the national, interest is the shortage of water during dry periods in the Nelson Mandela Bay Metro (NMBM). Although not included in this research, the linkage and cooperation between CDM and NMBM is of utmost importance since NMBM receives almost all of its water from the dams and the water catchment located in CDM. The drought risk assessment and subsequent drought management plan must therefore consider the water requirements of NMBM.

Water shortages are regularly experienced in Willowmore, Steytlerville (Baviaans municipality), Jansenville (Ikwezi municipality) Graaff-Reinet (Camdeboo municipality) and Port Alfred (Ndlambe municipality). The Paterson area (Sundays River municipality) has a particular water shortage problem in that groundwater exploration yielded no returns and the town experiences regular water crises, which are exacerbated by the influx of people.

CDM initiated the development and implementation of a water conservation and water demand management strategy that includes the additional exploration of groundwater. NMBM also developed a strategy to reduce water use. NMBM implemented a strategy committee that assisted with the development and monitoring of drought mitigation and prevention plans. The reconciliation strategy seeks to determine current water balances and to develop future water balance scenarios for a 25 year planning horizon (DWA, 2012).

Specific interventions implemented after the 2008-2011 dry period are the following (DWA, 2012):

- Prepare and implement an emergency drought action plan.
- Implement a drought public campaign to reduce water use.
- Maximize the water transfer during dry periods from the Nooitgedacht water transfer scheme that transfers water from the Orange-Fish-Sundays Rivers.
- Prepare to abstract the dead storage from the Impofu dam in cases of emergency.
- Impose water restrictions when required.
- Implement a drought punitive system for water wastage in times of water shortage.
- Investigate the re-use of treated water from the Fish Water Flats wastewater treatment plant to supply industrial water to industries.
- Increase the potential groundwater use.

CDM embarked on several rainwater harvesting projects and continues to explore potential ground water sources, but funding remains one of their biggest challenges.

2.5.2.8 Land reform in Cacadu DM

Being predominantly a commercial agricultural area, few land claims existed in CDM. The Department of Rural Development and Land Reform themselves do not have good records of land claims or land restitution in CDM. According to the Department of Rural Development and Land Reform (2013) only 161 farms were purchased with the PLAS grant scheme for the purpose of land reform. The location of the land reform projects in CDM is illustrated on the map in Figure 2.46.

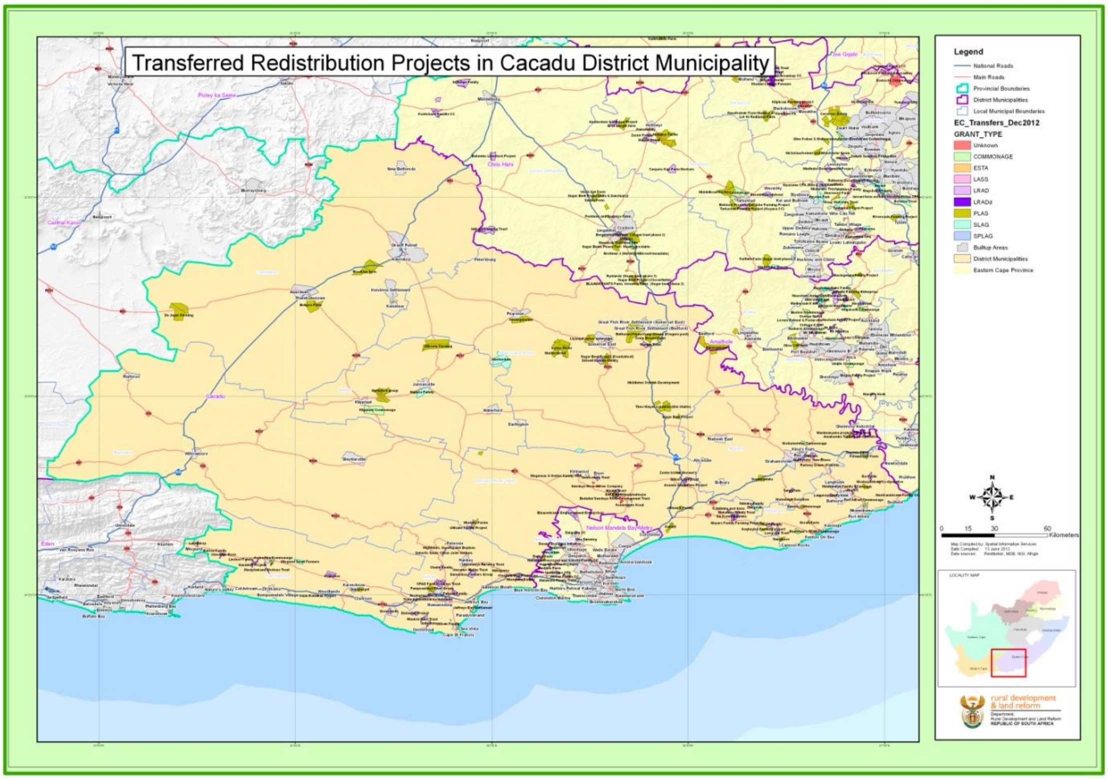


Fig. 2.46: Land reform projects in CDM
Source: Dept. of Rural Development & Land Reform, 2013.

2.5.3 OR Tambo District Municipality (ORTDM)

ORTDM is located along the north-eastern border of the EC and borders the Indian Ocean in the east. It is bordered by the Alfred Nzo District Municipality in the north, by the Joe Gqabi District Municipality in the northwest, by the Chris Hani District Municipality in the west and by the Amathole District Municipality in the southwest.

ORTDM consists of five local municipalities namely:

- Ingquza Hill
- Port St Johns (around the town of Port St Johns)
- Nyandeni
- Mhlontlo
- King Sabata Dalindyebo (Mtata)

ORTDM is classified as a Category C2 municipality meaning it is basically rural with about 80% of the geographic area having been part of the former Transkei and with 93% of the population residing in widely dispersed homesteads and small villages (IDP ORTDM, 2012) (See Fig 2.47).

Fig 2.47: OR Tambo District Municipality
Source: IDP OR Tambo, 2012

King Sabata Dalindyebo local municipality is the only municipality in the district with a reasonable core tax base due to economic activities such as businesses, reasonable markets and a reasonable productive agricultural sector, which is located in Mtata and surrounding areas. All the other municipalities are characterized by a rural, mainly subsistence economy. Settlements in these municipalities are small and people have very low income levels with few markets opportunities.

2.5.3.1 Demographics of ORTDM

The largest concentration of people is in the King Sabata Dalinyebo district municipality with a population density of 147 persons per km^2 and representing 31% of the total population in the DM. Most of these people live in and around Mtata, the capital of the district. The second largest concentration of people is in Port St Johns district.

The percentage of economically active people in the district is the lowest in the EC – together with Alfred Nzo District Municipality – with fewer than 50% of people between ages 15 and 65. That in itself increases vulnerability against external shocks, especially in rural areas. The deprivation index in the district illustrated on the map in Figure 2.48 is high, with Port St John’s local municipality the highest in the district.

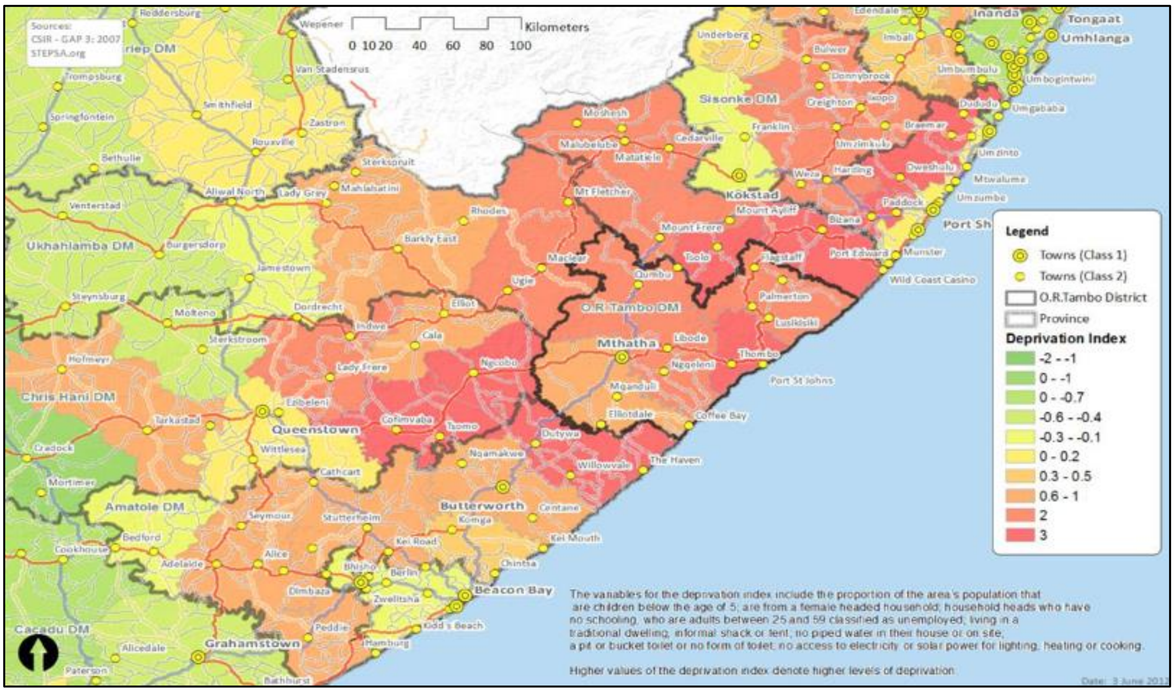


Fig 2.48: Deprivation index for ORTDM
Source: IDP ORTDM, 2012 (CSIR – GAP3, 2007)

Deprivation is an important index for vulnerability to drought and it includes factors such as (IDP ORTDM, 2012) the:

- Proportion of the area's population that are children below the age of 5;
- Proportion of the area's population that are from female headed households;
- Proportion of the area's population that are household heads with no schooling;
- Proportion of the area's population that are unemployed adults between ages 25-59;
- Proportion of the area's population that are living in a traditional dwelling, informal settlement or shack;
- Proportion of the area's population that have no piped water in their house or on site;
- Proportion of the area's population that have a pit or bucket toilet or no toilet;
- Proportion of the area's population that have no access to electricity, or solar power and heating.

The Human Development Index (HDI) as an indicator of poverty is lower in ORTDM than the average for the EC and much lower than those for SA as a whole. The per capita income in the district is about R15 000 per annum, which is much lower than in the rest of the EC, apart from Alfred Nzo local municipality. Illiteracy is also used as a social vulnerability indicator for drought and literacy rates in the district are very low, with only 37% in Port St John's and 62% in KSDLM, which is the highest in ORTDM. Seventy 5% of households in the district receive grants from government, which strangely enough might decrease vulnerability to drought since that provides an alternative income during dry periods.

2.5.3.2 Climate of ORTDM

Most of ORTDM receives more than 800 mm annually with 1200 mm at the coastal zones and 600 mm in some areas in the central part of the district (See Figure 2.49). Temperature is mild with a mean minimum of 14-19°C in January and 2-13°C in July and a mean maximum of 14-25°C in January and 19-21°C in July.

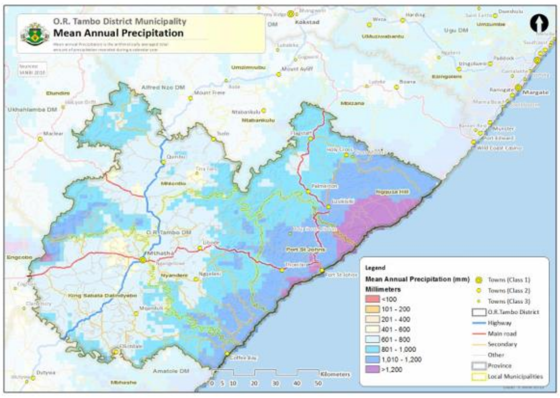


Fig 2.49: Mean annual precipitation in ORTDM
Source: IDP ORTDM, 2012

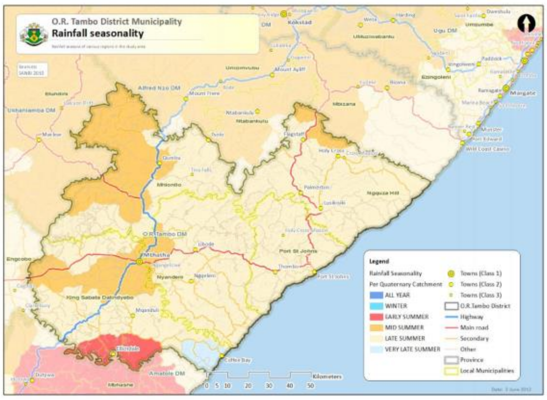


Fig 2.50: Rainfall seasonality in ORTDM
Source: IDP ORTDM, 2012

The inland areas are mainly a summer rainfall area where 80% of precipitation falls between October and March, while a much better annual precipitation distribution exists along the coastal areas (See Figure 2.50). The mean annual precipitation per quaternary catchment is shown in Figure 2.51. The number of quaternary catchments making up ORTDM is 53.

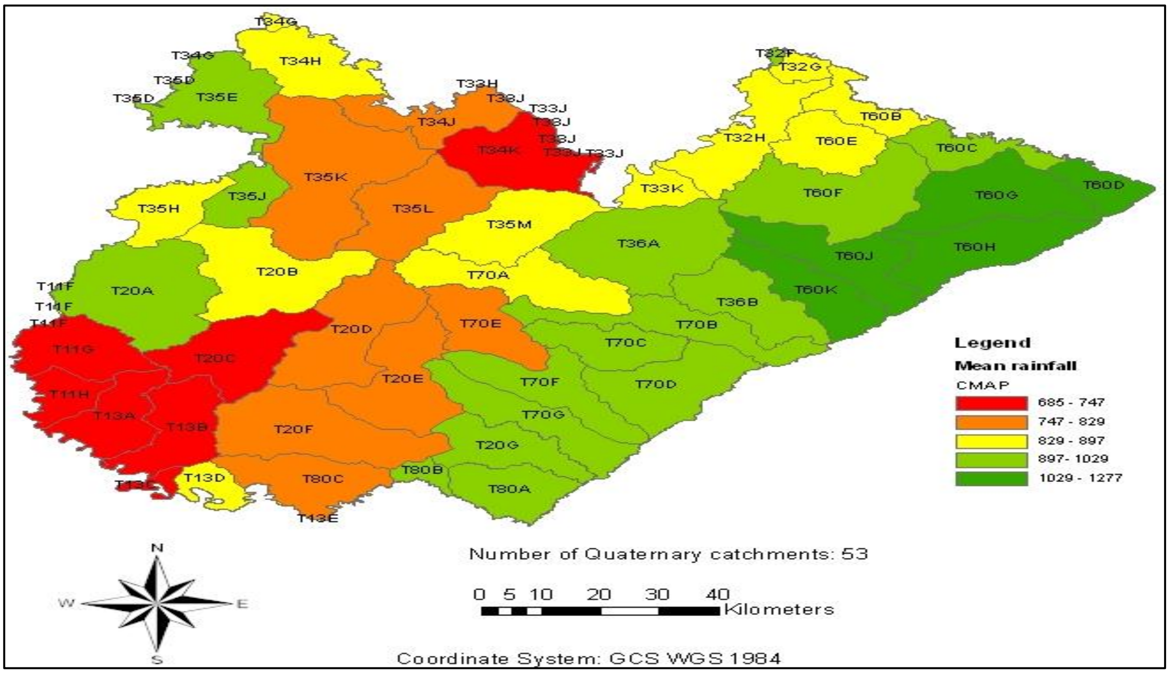


Fig 2.51: Mean annual precipitation in ORTDM per quaternary catchment

2.5.3.3 Economy of ORTDM

ORTDM contributes approximately 8% to the provincial GGP of the EC. The 8% compares well with other district municipalities such as Cacadu (8%), Amathole (9%), Chris Hani (6%), Joe Gqabi (2%) and Alfred Nzo (2%).

The main economic driver in ORTDM is the tertiary sector, which an overall focus on community services. Community services contribute half of the total economic activity in the district, with trade the second largest at 19%. No economic system can be sustainable when built on community services since all the income consists of direct remittances from government. ORTDM communities are thus highly vulnerable due to the lack of economic activities in the primary and secondary sectors.

Figure 2.52 illustrates the GVA per mesozone during 2007. Most GGP was generated in Mtata, followed by Lusikisiki, Flagstaff, and along the N2.

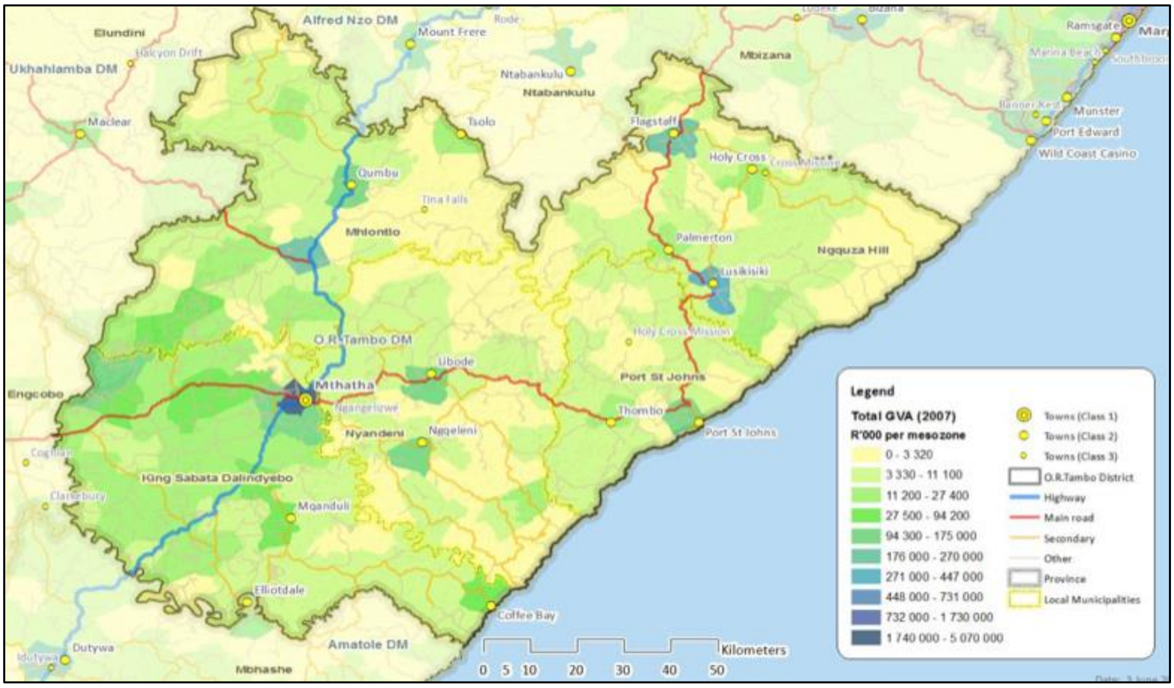


Fig 2.52: GVA per mesozone in OR Tambo District Municipality
Source CSIR Geospatial platform, 2007; IDP ORTDM, 2012

2.5.3.4 Agriculture in ORTDM

Agriculture in ORTDM is mainly subsistence livestock farming on communal land and contributes only 1,8% to the GGP in the district. The rich natural resource base in the district gives the district a competitive advantage for agriculture, yet this is not exploited due to largely historical factors that limit growth and development in the rural areas. In spite of the *"officially"* poor performance of agriculture, it remains the backbone of the rural livelihoods in the largely un-urbanized areas of the district. Agriculture remains important through its ability to provide for rural livelihoods, generating employment and fighting endemic poverty in the district.

Livestock farming in ORTDM represents the largest concentration of communal livestock farming in SA with 631 674 cattle, 732 478 goats and 1 225 244 sheep. The DM, together with the Department of Agriculture and Rural Development, introduced a number of successful livestock improvement programs, namely (IDP ORTDM, 2012) the:

- Beef development program;
- Iqhayiya sheep end wool production program, together with the Wool Growers Association; and the
- Lamhumilanga goat production program.

The above-mentioned programs seek to improve productivity and profitability by implementing the best agricultural practices and improved management principles, including better practices in animal feeding, health control, breeding and sustainable management of resources. The main stumbling blocks currently seem to be (i) the land tenure system, (ii) land claims, (iii) lack of infrastructure, (iv) limited access to irrigation water, and (v) poor coordination and integration of stakeholders (IDP ORTDM, 2012).

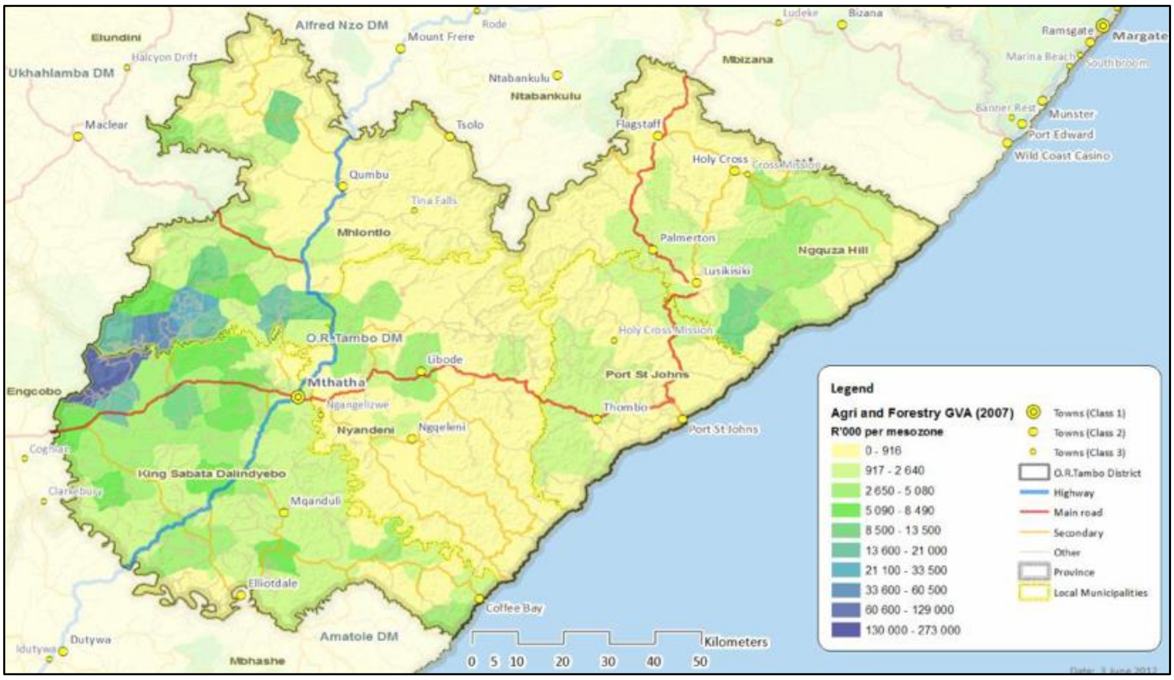


Fig 2.53: GVA per mesozone from agriculture and forestry
Source: CSIR-GAP, 2007

Gross value added (GVA) from agriculture and forestry is very low in ORTDM with less than R1 million per mesozone in the largest part of the district, except from a small high potential area in the west of the district where the GVA exceeds R100 million per mesozone (See Figure 2.53).

2.5.3.5 Water in ORTDM

ORTDM is the only district in SA with surplus water available for further development. The largest river is the Umzimvubu River with two smaller rivers, namely the Mtata and the Umthamvuna rivers as well as a number of smaller coastal rivers with small catchments stretching not more than 60 km inland. The smaller coastal rivers with their estuaries provide for the typical character of the Wild coast. Ecological water requirements are higher in the lower catchments of the three main rivers (See Figure 2.54)

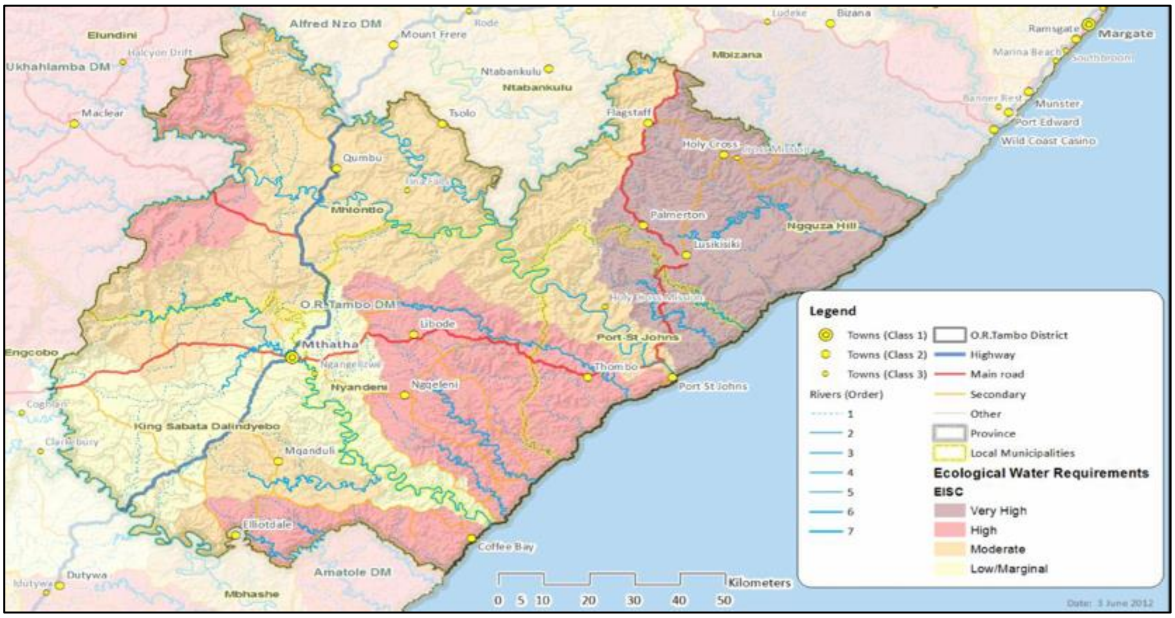


Fig 2.54: Ecological water requirements in ORTDM
Source: IDP ORTDM, 2012

In contrast to the other district municipalities, groundwater is not the main sources of water in ORTDM and groundwater vulnerability is very low. The map in Figure 2.55 illustrates the low vulnerability of groundwater in ORTDM.

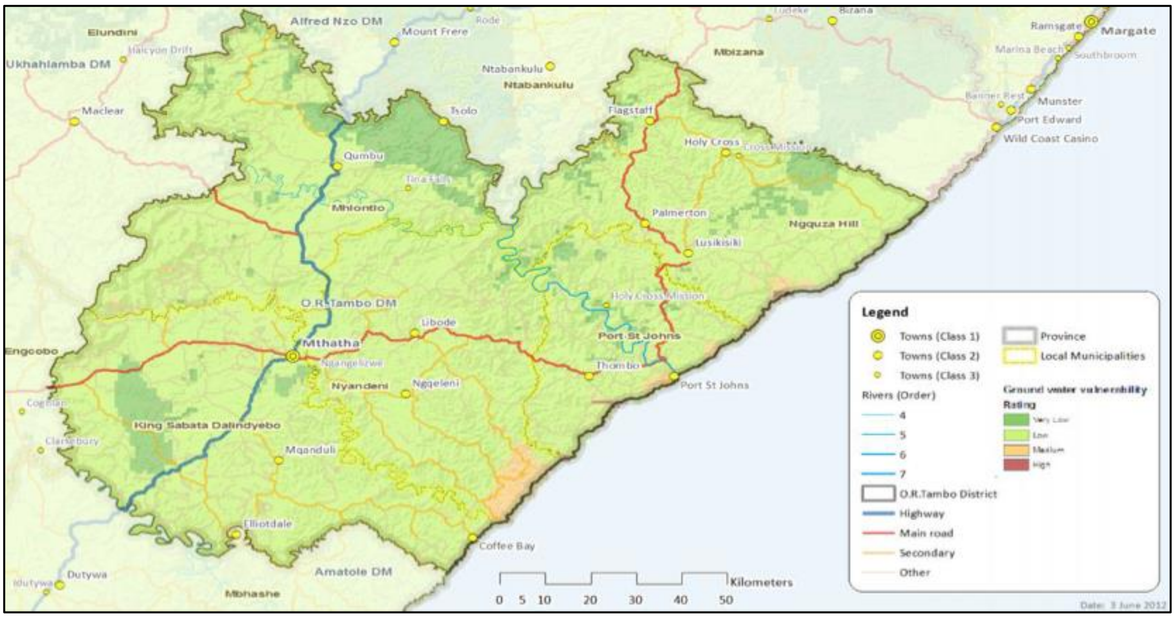


Fig 2.55: Groundwater vulnerability in ORTDM
Source: IDP ORTDM, 2012

2.5.3.6 Ecosystem status and biodiversity in ORTDM

ORTDM has a wide range of habitats consisting of (i) upland and coastal grassland, (ii) afromontane and coastal forest, (iii) valley thicket, (iv) thorny bushveld, (v) coastal forests, (vi) bush veld, and (vii) grassland of Pondoland. The ecosystem status is of concern since large areas, especially in the central part of the district, are critically vulnerable (See maps in Figure 2.56 and Figure 2.57). Ecosystem status is important in context of drought vulnerability and is therefore an environmental vulnerability indicator for drought risk.

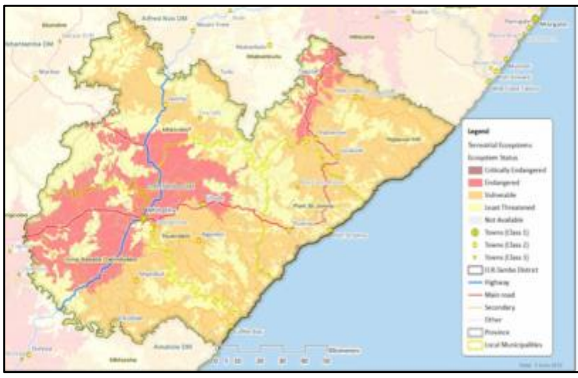


Fig 2.56: Ecosystem status in ORTDM
Source: IDP ORTDM, 2012

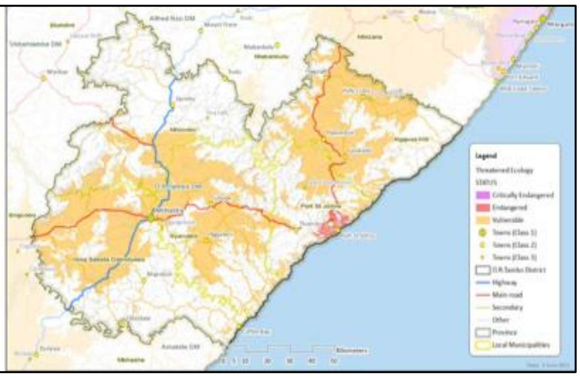


Fig 2.57: Threatened ecology on ORTDM
Source: IDP ORTDM, 2012

Environmental degradation is also a serious concern in ORTDM. Soil erosion as a result of overgrazing, uncontrolled movement of people as well as animals, while uncontrolled land use imposes limitations on the economic use of land.

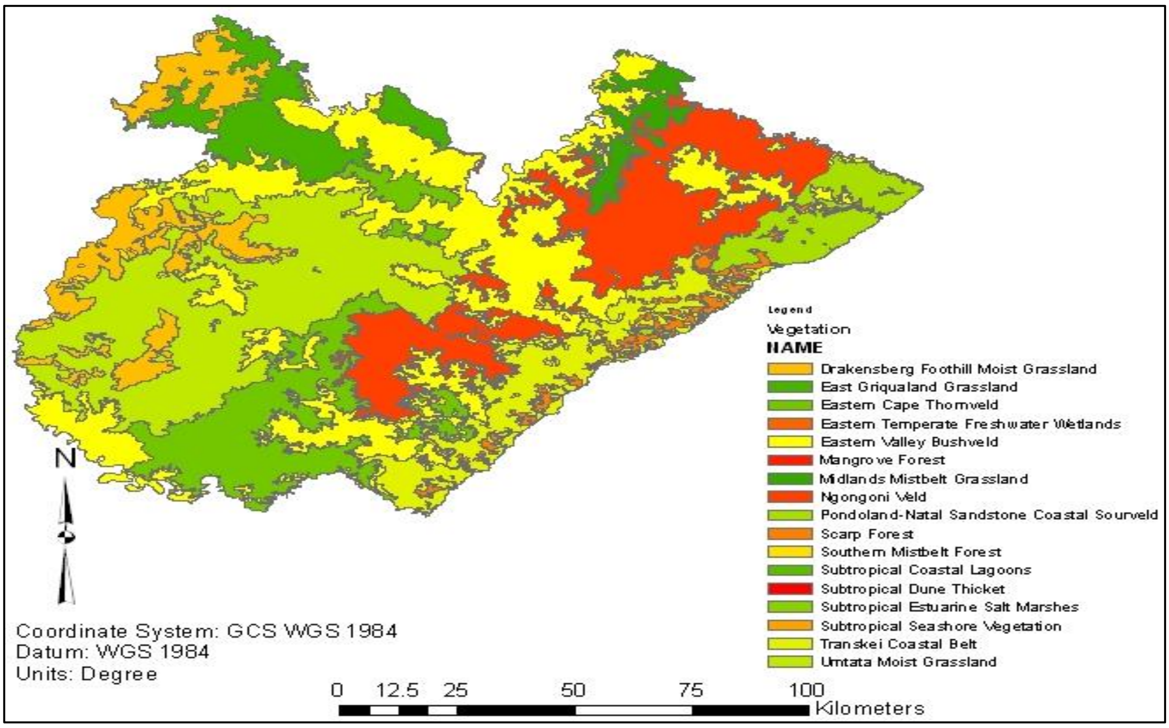


Fig 1.58: Vegetation types in ORTDM

2.5.3.7 Disaster management in ORTDM

ORTDM has a disaster management policy in line with national guidelines and a disaster management plan which was, however, not available upon request to the municipality.

2.5.3.8 Drought management in ORTDM

The Department of Agriculture and Rural Development largely handles drought management in ORTDM. Hlangu (2013), however, confirmed that a drought risk assessment was at that stage being conducted, but could not provide any information regarding the process. According to Hlangu (2013), the new district demarcation was hindering the completion of the risk assessment.

2.5.3.9 Land reform in ORTDM

ORTDM received 107 land claims of which 2 were urban land claims. Of the 107 claims, 22 had been settled at the time of writing (February 2017) while 85 were still under investigation. As illustrated in Figure 2.59, the claims are evenly distributed throughout the district and should not have a significant influence on the vulnerability of the agricultural sector. No land has been purchased in ORTDM under the PLAS grant.

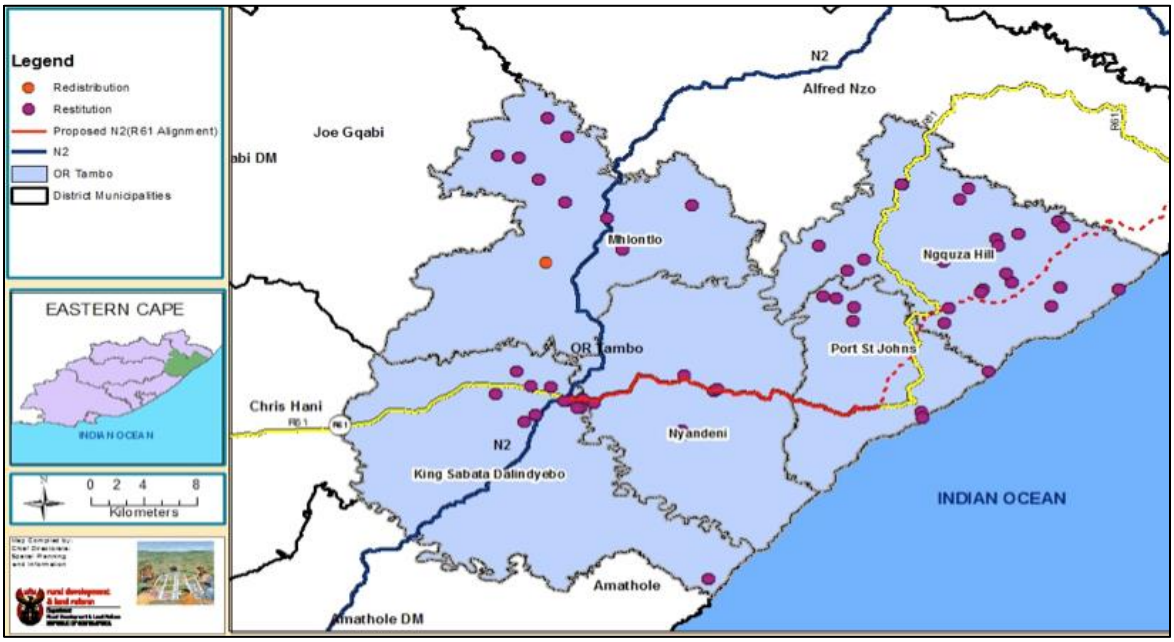


Fig 2.59: Land reform in ORTDM
Source: Department of Rural Development & Land Reform, 2013

2.5.4 Joe Gcabi District Municipality (JGDM)

JGDM covers an area of 2 564 705 ha and is bordered by Lesotho and the Free State to the north, the Northern Cape to the west, Chris Hani and Amathole District Municipalities to the south and OR Tambo District Municipality to the east. The landscape is very diverse; from the high Drakensburg Mountains at the Lesotho border to far and flat reaching plains to the west. The district consists of four local municipalities namely:

- Gariep (Burgersdorp, Steynsburg, Venterstad),
- Maletswai (Aliwal North, Jamestown),
- Senqu (Barkley East, Lady Grey, Sterkspruit, Rhodes, Rossouw), and
- Elundini (Maclear, Ugie, Mount Fletcher).

Maletswai and more specifically Aliwal North is the economic hub of the district with considerable agricultural and forestry activities in the Ugie region.

Figure 2.60 shows a map of JGDM and the four local municipalities.

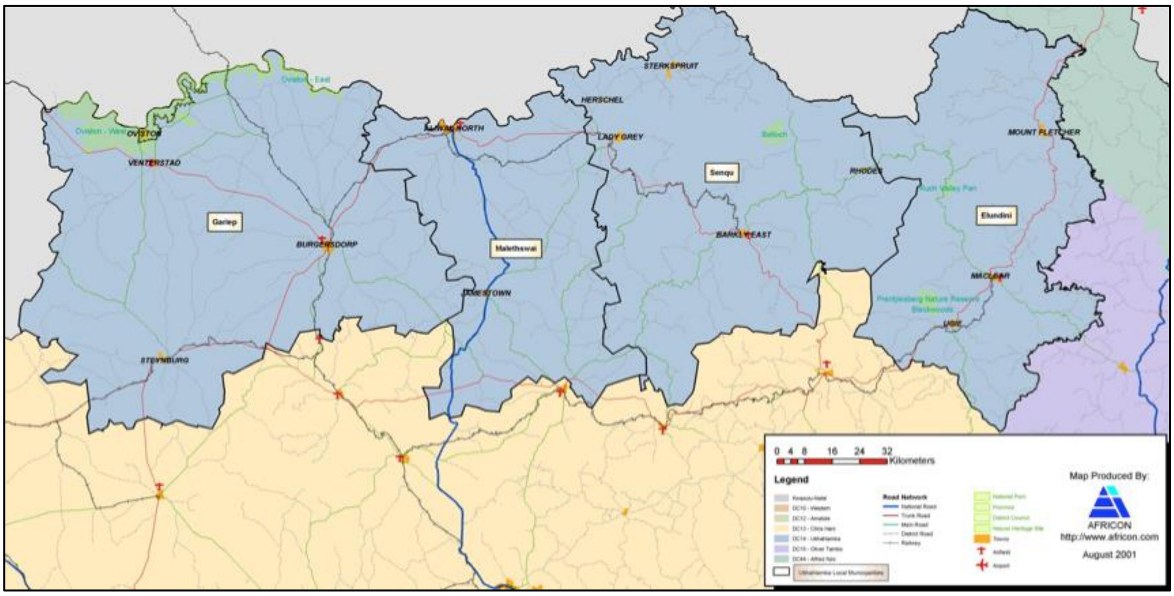


Fig 2.60: JGDM
Source: Africon, 2011

2.5.4.1 Demographics of JGDM

The number of people living in JGDM add up to 349 768, with the highest population density in Elundini local municipality with 138 141 and Senqu with 134 150 people (StatsSA, 2011). Education levels are an important vulnerability indicator for external shocks and 76% of the population had not completed grade 12, while 58% had not completed primary school or had no schooling at all.

2.5.4.2 Climate

The mean annual rainfall in JGDM ranges from about 800-1200 mm in high altitude areas to 300-400 mm in the western basin region. Most of the rain is the result of westerly troughs and cut-off lows in the upper atmosphere, with moisture supplied from the Indian Ocean in the lower levels of the atmosphere and from the sub-continent in the higher levels of the atmosphere. On the eastern side of the Drakensberg, rainfall is enhanced due to orographic lifting of moist air from the east. Most rainfall (75%) occurs in the summer months (November to April) in the form of thunderstorms.

Summer temperatures vary from cool in the high altitude areas in the east to relatively hot in basins towards the west. Daily maximum temperature, averaged for January, ranges from 24-32°C in the Gariep and Maletswai LMs and 18-26°C in Elundini and Senqu LMs. The area is known for its extremely low temperatures in winter, with below zero mean minimum temperatures except for small areas to the western edges of Gariep LM and eastern areas in the Elundini LM where the July mean minimum temperature is above freezing point. Most of the JGDM has a frost season length of 13-14 dekads (10-day periods), which increases to 16-18 dekads in the higher altitudes (within the Senqu and Elundini LM in the southern Drakensberg mountain range). The length of the frost season decreases to 8-12 dekads in the much lower altitudes in the Elundini LM. The frost season begins during 1-10 May in the higher lying lands (mountain ranges), but only during 21-30 May at the lower altitudes. The frost season comes to an end during 21-31 August in the lower lying regions in the Elundini LM and at the beginning of September in the rest of the DM, but only ends during the last dekad in October in the mountain ranges (Jordaan, 2010). The mean annual precipitation per quaternary catchment is shown in Figure 2.61. The variation from the high rainfall zone in the east to the more arid climate in the west is clearly illustrated.

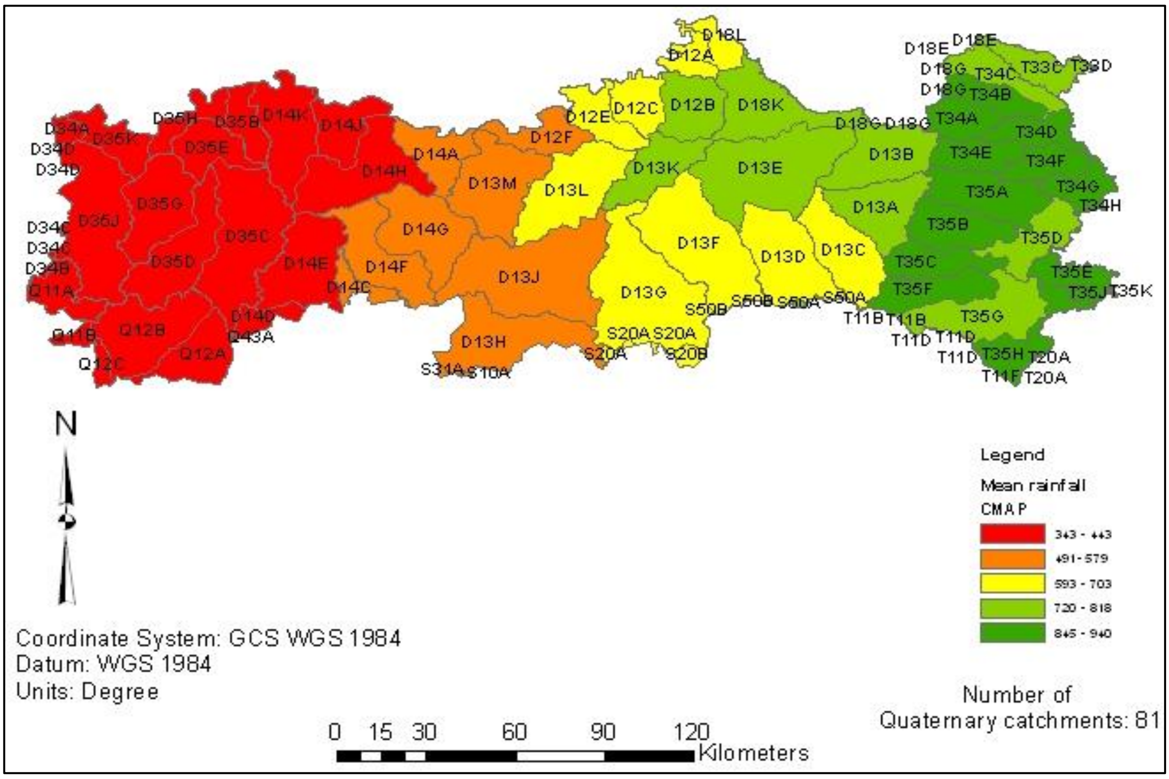


Fig 2.61: JGDM mean annual precipitation per quaternary catchment

2.5.4.3 Economy in JGDM

The GGP or GVA-R is highest in the tertiary sector, varying between 71% and 80% for the period 2007 to 2011. The secondary sector produces 14% while the contribution from the primary sectors, which includes agriculture, adds up to only 6% of the total GGP in the district. The tertiary sector consists mainly of government salaries and government grants and the high proportionate GVA from this sector is an indication of a highly vulnerable and unsustainable economy.

The agricultural sector plan for JGDM indicated the GGP for agriculture (2009 data) to exceed R1,4 billion and agri-business turnover from the small towns as R1,8 billion per annum. Businesses in JQDM indicated that about 72% of turnover is generated through agricultural related business, making agriculture the backbone of the economy of all the towns in JQDM (Jordaan, 2010).

About 46% of the population in JGDM is unemployed. In terms of employment the community sector (government) employed the largest percentage of people in the formal sector at 38%, followed by households at 19%, agriculture at 18% and trade with 11%. Of these sectors, agriculture has shown the highest, and rather dramatic, decline in employment over a seven year period, while community services had shown a steady increase in employment. Livelihood income is very low, with 95% of people earning less than R3 200 per month.

Forestry also contributes significantly to the economy of Elundini local municipality. About 55% of the land in Elundini is covered with plantations for commercial use and BG Bison in Ugie alone employs more than 2 000 people directly and indirectly in plantation operations, with 231 permanent staff and 60 contractors at their chipboard factory (IDP JQDM, 2011).

2.5.4.4 Agriculture in JGDM

The main commodities produced in JGDM are wool, mutton, and meat (from cattle) followed by grains (maize, soybeans, dry beans, wheat) in the Elundini municipality, ostriches in the Gariep municipality and game farming in Gariep and Maletswai municipalities. Commercial agriculture in JGDM is very stable, with few land transactions occurring due to the low risk nature of farming. Farmers spent most of their income in businesses within the district if one compares their gross income of R1,45 billion with spending of R1,37 billion at businesses within the district. It is therefore clear that the economy of all towns depend heavily on agriculture (Jordaan, 2010). Irrigation farming is not widely practised in JGDM, with a concentration of irrigation at the following locations (Coastal & Environmental Services, 2004):

- Orange river: Gariepdam to Aliwal North 4 900 ha;
- Teebus spruit – Fish outlet: Approximately 2 200 ha;
- Jozana's Hoek dam: 35 ha;
- with a large number of individual farmers irrigating small pieces of land from groundwater as supplemented fodder production for animals.

Subsistence agricultural is practised on commonages and traditional land in the former Transkei (Herschel/Sterkspruit and Mount Fletcher area). Although official data do not reflect the income generated from subsistence agriculture, it is quite substantial in the areas with a large number of hectares of traditional land. Apart from the former Transkei, most part of JGDM is characterized by commercial agriculture and also forestry in the Elundini area. The main farming activities on commonages and traditional land are sheep, goats and cattle farming. The contribution of these sectors is seldom reflected in official statistical data, but thousands of families depend on income from this sector. In the communal farming areas of the Elundini and even Senqu local municipalities, maize production is very important from a food security perspective. Owing to the high rainfall in Elundini the potential for maize production is very high, but current production activities are such that low yields are obtained in the most instances. Rainfall in Senqu is somewhat low for successful maize production, yet some commonage farmers plant some maize with varying degrees of success, but mostly with very low yields. In most cases commonage farmers do not have access to input capital with which to buy inputs, as well as there being an absence of mechanization. The Massive Food

Program and ASGiSA has contributed much to increase production outputs the past few years, but also with varying degrees of success, especially once farmers are expected to fund a larger percentage of inputs themselves (Jordaan, 2010). Forestry plantations in Joe Gqabi add up to 25 487 ha, exclusively in the eastern local municipality of Elundini and it represents 20% of forest plantations in the EC.

2.5.4.5 Water in JGDM

Freshwater is a key component for both humans and animals and occurs in varying degrees of shortage and abundance in different regions of the district. Groundwater is the primary source of water in the more arid rural regions, especially in Maletswai, Gariep and Senqu local municipalities. The district traverses three major water management areas (WMA), namely the:

- Umzimvubu to Keiskamma WMA;
- Upper Orange WMA, and
- A small portion of the Fish to Keiskamma WMA.

The JGDM is drained by three main river catchments, namely the:

- Senqu/Orange river catchment with a mean annual runoff of 4 12 mm^3/annum, the
- Umzimvubu river catchment (with the Tsitsa, Tina and Kinira tertiary catchments feeding the Umzimvubu river) with mean annual runoff of 2 897 mm^3/annum, and the
- Kraai river catchment with mean annual runoff of 956 mm^3/annum

The largest suppliers of water to the JGDM (apart from groundwater sources) are (i) the Gariep dam, (ii) the Orange/Fish tunnel and (iii) the Holohlatsi dam. The Southern Drakensberg Mountains along the boundary of the Elundini LM form a watershed that separates the eastern and western parts of the Joe Gqabi district. The watershed along the easterly boundary of the Kraai catchment, along the escarpment above the towns of Maclear, Ugie and Elliot, separates flow to the Atlantic Ocean via the Orange from flow to the Indian Ocean via the Umzimvubu River. The Umzimvubu River enters the sea at Port St John's, and is considered the largest undeveloped river in South Africa. The natural habitats of the catchment are critical for the regulation of water supplies. Rainfall is intercepted by natural grasslands and wetlands, so that it infiltrates into the ground and is gradually released through the rest of the year, thereby maintaining baseflows during the dry months.

The Kraai River has its origins in the magisterial district of Barkley East at the southernmost end of the Drakensberg, south of Lesotho. The Kraai is a tributary of the Orange River and flows westwards from the junction of the Bell River and the Sterkspruit at Moshesh's Ford to join the Orange near Aliwal North. The Kraai catchment rises in the Herschel District at altitudes of up to 3 000 m on the basaltic rocks of the watershed that forms the boundary between South Africa and Lesotho.

2.5.4.6 Ecosystems status and biodiversity in JGDM

JGDM is characterized by a large diversity of land features and vegetation species. The western part of the district is arid and semi-arid with typical flat Karoo landscapes while the northern and eastern parts are mountainous, associated with unique high altitude species diversity and wetlands. The western and more arid parts of the district are dominated by Karoo escarpment shrub land, dry grassland, besemkaree koppies scrubland and eastern upper Karoo vegetation. The mountainous areas are covered by Southern Drakensberg and Lesotho Highland Basalt grasslands as well as Zastron moist grassland and Senqu Montane shrub land in the north (See Figure 2.62).

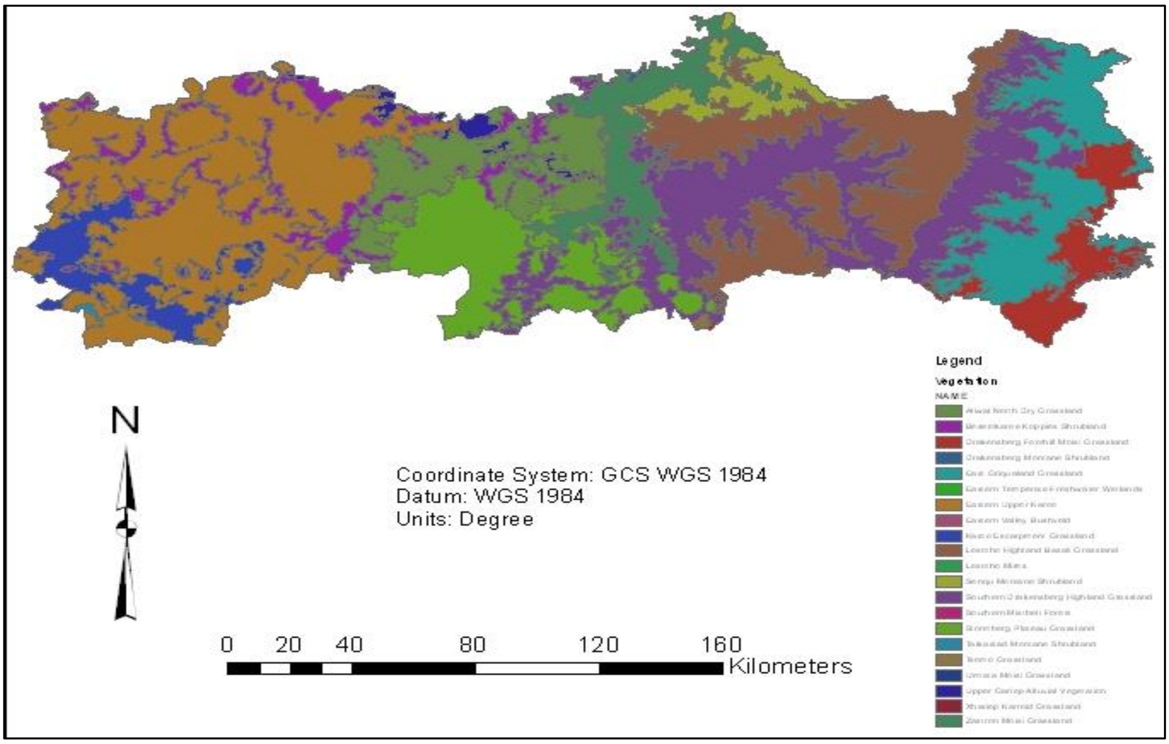


Fig 2.62: JGDM vegetation types

2.5.4.7 Disaster and drought management

The JGDM has developed a generic disaster management plan and framework, but a detailed risk assessment had still not been completed at the time of writing . The disaster management centre is located in Barkley East, with satellite offices in each of the local municipalities. No detailed drought management or contingency plan is available and droughts are dealt with as an *ad hoc* activity. The Department of Agriculture and Rural Development with its regional office in Aliwal North remains the primary actor in the management of agricultural drought support and planning, while the Department of Water Affairs (DWA) also supports the district with funding in support of projects to alleviate water shortages. During 2012, for example, DWA assisted the district with R25,7 million for drought relief.

2.5.4.8 Land reform in JGDM

The total number of restitution claims in JGDM is 116. The number of farms purchased and owned by the Department of Rural Development and Land Reform through the Pro-active Land Acquisition Grant (PLAS) program is 77, with 11 farms obtained under the SLAG program and 11 farms under the LRAD program. The land reform projects illustrated in Figure 2.63 are evenly distributed through the district and are too few to impact on drought vulnerability in a quaternary catchment. Vulnerability of individual farms might differ because of the lack of experience and knowledge of the new land occupiers.

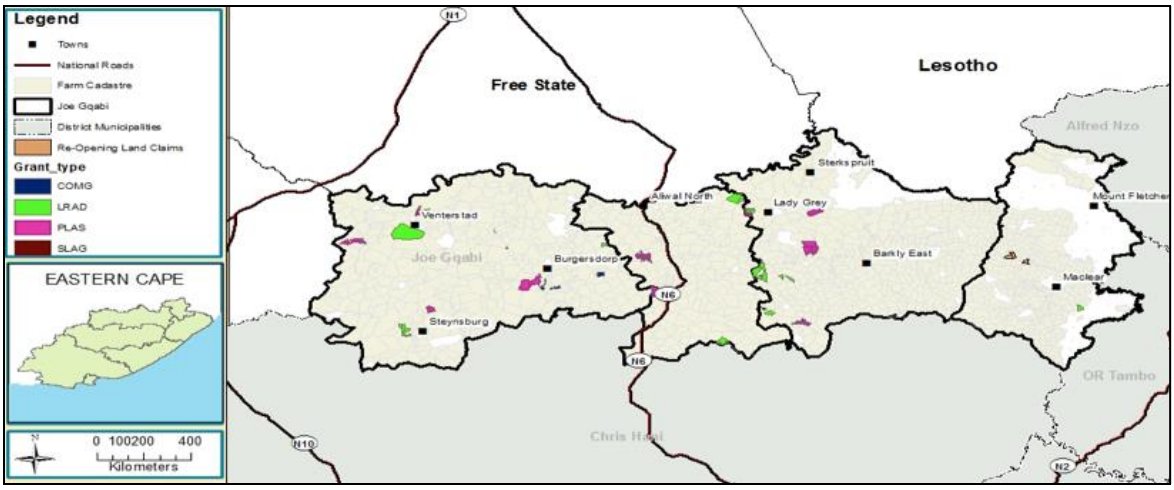


Fig 2.63: Land reform projects in JGDM
Source; Dept. Rural Development and Land Reform, 2013

2.6 Conclusion

The description of the study area exposed most of the indicators required for vulnerability and coping capacity assessment. The description of the study area relied heavily on current information and the gaps will be addressed in the vulnerability and coping capacity assessment sections. The detailed description of the hazard or the meteorological data per quaternary catchment will be dealt with in the hazard assessment section.

Based on the available data and the comparison of the four selected districts discussed in this chapter, it was recommend that the research should focus on (i) Joe Gqabi District Municipality, (ii) OR Tambo District Municipality, and (iii) Cacadu District Municipality.

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3 Drought Risk Assessment, Vulnerability and Resilience: Literature Review

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Executive Summary

Drought is undoubtedly one of our worst natural enemies – its beginning is subtle, its progress insidious and its effects can be devastating. The main objective of this research is to propose drought risk adaptation and coping strategies based on drought risk assessment for the rain fed farming sector in three Eastern Cape district municipalities of Cacadu, Joe Gcabi and OR Tambo. This includes both commercial and communal subsistence farmers.

A thorough literature review provided for a better understanding of what was done locally and internationally on drought risk, vulnerability, resilience and coping capacities. It also served as a guide to identify relevant methodologies used by other researchers for similar projects.

Drought risk is a function of vulnerability to drought, the frequency of occurrence, and the severity of drought conditions. One of the main challenges in drought risk assessment is the identification of all the indicators and the weighting of these indicators in relation to each other. Indicators for social, economic and environmental vulnerability as well as coping capacity and adaptation were identified and evaluated in the context of their relevancy to the livestock and crop production sectors in the proposed study area.

The vulnerability and coping capacity indicators proposed in this report are not exhaustive and further indicators might be added as a result of forthcoming fieldwork and research during the next phase of the project.

3.1 Introduction

Drought is undoubtedly one of our worst natural enemies – its beginning is subtle, its progress insidious and its effects can be devastating. Drought may start any time, last indefinitely and attain many degrees of severity. It can occur in any part of the world, with an impact ranging from slight personal inconvenience to endangered nationhood (Houman *et al*., 1975). Animal and food production are vital agricultural activity outcomes, and even a superficial survey shows that losses incurred from an extended drought can amount to many hundreds of millions of rand. Direct losses result from pasture deterioration, livestock deaths and reduced crop yields, while a complete list includes reduced returns of most agricultural products (FAO, 2013). Further losses include transporting emergency food supplies for humans and animals, and establishing emergency water supplies. Estimates of indirect losses are more difficult to evaluate, but would include losses from crops not planted and production from animals not conceived. Included would be losses due to abandonment of land, changes in land use following drought, and administrative cost resulting from the agro-economic planning for alternative land use. Primary losses are borne by the agricultural and livestock industries, but the cost of drought ultimately spreads over the entire Eastern Cape Province when the government makes relief grants to primary industries, assists with fodder transport and livestock care, constructs emergency reservoirs, and when general prices rise following the shortage or import of commodities.

Drought is widely perceived as a hydro-climatic hazard, but in reality droughts are socio-environmental phenomena, produced by mixtures of climatic, hydrological, environmental, socio-economic and cultural forces (Kallis, 2008). Drought risk is a function of vulnerability to drought, the frequency of occurrence, and the severity of drought conditions and its impacts. One of the main challenges in drought risk assessment is the identification of all the indicators and the weighting of these indicators in relation to each other. Indicators for social, economic and environmental vulnerability as well as coping capacity and adaptation were identified and evaluated in the context of their relevancy to the livestock production sector in the proposed study area.

The vulnerability and coping capacity indicators proposed in this chapter are not exhaustive and further indicators are discussed in later chapters.

The objective of this chapter is to review the literature on drought vulnerability and resilience. Risk assessment is sometimes confused with hazard assesment and this chapter puts the relation between vulnerability, resilience and hazard assessment into context. Indicators for social, economic and environmental vulnerability as well as coping capacity and adaptation are identified and evaluated from the literature in the context of their relevancy to the livestock and crop production sectors in the study area. This provided for a better understanding of what has been done locally and internationally on drought risk, vulnerability, resilience and coping capacities. It also served as a guide to identifying relevant methodologies used by other researchers for similar projects. Additional indices more specific to the the research area are identified and discussed in later chapters.

The discussion in this chapter relies on a comprehensive literature review for the social, economic and environmental vulnerabilities and coping strategies as well as the methodology for drought risk assessments. In addition to the literature study, expert and local knowledge about farming and drought in the Eastern Cape were sourced in order to determine the relevancy of potential indicators for drought risk in the study area.

3.2 Drought Risk Assessment Methodology

Drought risk is a function of vulnerability to drought, the frequency of occurrence, and the severity of drought conditions (Knutson *et. al.,* 1998). Following the notion that risk assessment starts by evaluating vulnerability, potential impacts across drought types are discussed. Although risk management is often assumed to be of paramount importance to crop and livestock producers (Barry, 1984; Hardeker *et al*., 1997), very little information on how livestock producers perceive and manage drought risk is available (Jordaan, 2011). What risks matter to livestock producers, what tools they perceive as being effective in managing those risks, and what sort of risk management education is of interest to them, are key questions. These and many more questions need answers.

Drought disaster risk to the livestock sector indicates the potential threat and direct endangerment to livestock production. A drought disaster is not only the result of climatic elements such as precipitation, temperature, aridity, etc. Features such as landform, soil type, land use structures, vegetation composition, regional economic development, management systems, early warnings and a number of other indicators also determine drought risk. The extent of drought disaster risk for livestock production is mainly decided by variables such as frequency, duration and intensity of dry periods, spatial extent of damage caused by drought (i.e., the area affected by drought) and regional livestock production level (Zhao & Yao, 1992; Zhang 1995). Beef cattle producers perceive severe drought and cattle price variability as primary risk factors, with the potential to affect farm income.

Many of the tools used by producers to manage drought risk are enhancements of basic management procedures that have been carefully planned to reduce the likelihood of an adverse event. Examples of these risk management tools include reducing pasture stocking pressure when a severe drought is expected. Reduction in stocking rates was revealed as cattle producers' most important drought risk management tool (Hall *et al.,* 2003). Planning a forage reserve is often cited in the literature as essential to a drought management strategy, as is balancing herd size with nutrient availability and pasture sustainability (Jordaan, 2011).

Despite the apparent effectiveness of available livestock risk management tools, researchers described lower preference for such tools by livestock producers compared to crop producers (Ward *et al*., 1999). One possible reason is differing levels of risk across livestock and crop enterprises. Alternately, lower preference may imply that livestock producers perceive these risk management tools to be somehow inadequate. Also, it may be that producers simply either lack the required training to use these tools effectively or the motivation to adopt a risk management tool, given their perception of its utility. The corollary to this observation is that a greater variety of structured risk management tools and training targeted at livestock producers may be required for a significant increase in usage to occur.

Drought risk assessment can be defined as the process of identifying, quantifying, and ranking the vulnerabilities in a drought scenario (Jordaan, 2011). It involves the following:

- Assess potential drought hazard threats to the livestock producers, population, infrastructure, environment, etc.;
- Vulnerability assessment (socio-economic and institutional analysis);
- Estimate time of exposure (climate forecast); and
- Define capacities and measures to be taken.

The disaster risk assessment methodology as stipulated in the Disaster Management Act (South Africa, 2002) is shown in Figure 3.1. This model was used as a framework for calculating drought risks. Stage one provided valuable information for the phase one assessment and included a drought hazard and vulnerability assessment, a literature study and desk review.

In the case of drought, the main determinant for hazard assessment is water deficit for normal production because of too little precipitation and evapotranspiration being too high. These factors were assessed by means of historical meteorological data, on-site inspections of affected areas or sectors, modelling of impacts and contributions from focus groups and stakeholders. Vulnerability depends on the region's environmental and social characteristics and is measured by the ability to anticipate, deal with, resist, and recover from the drought. This background helps in bridging the gap between identifying the impact severity and the policy development process by focusing on the causes of this vulnerability, rather than the actual impacts (Knutson *et al.,* 1998).

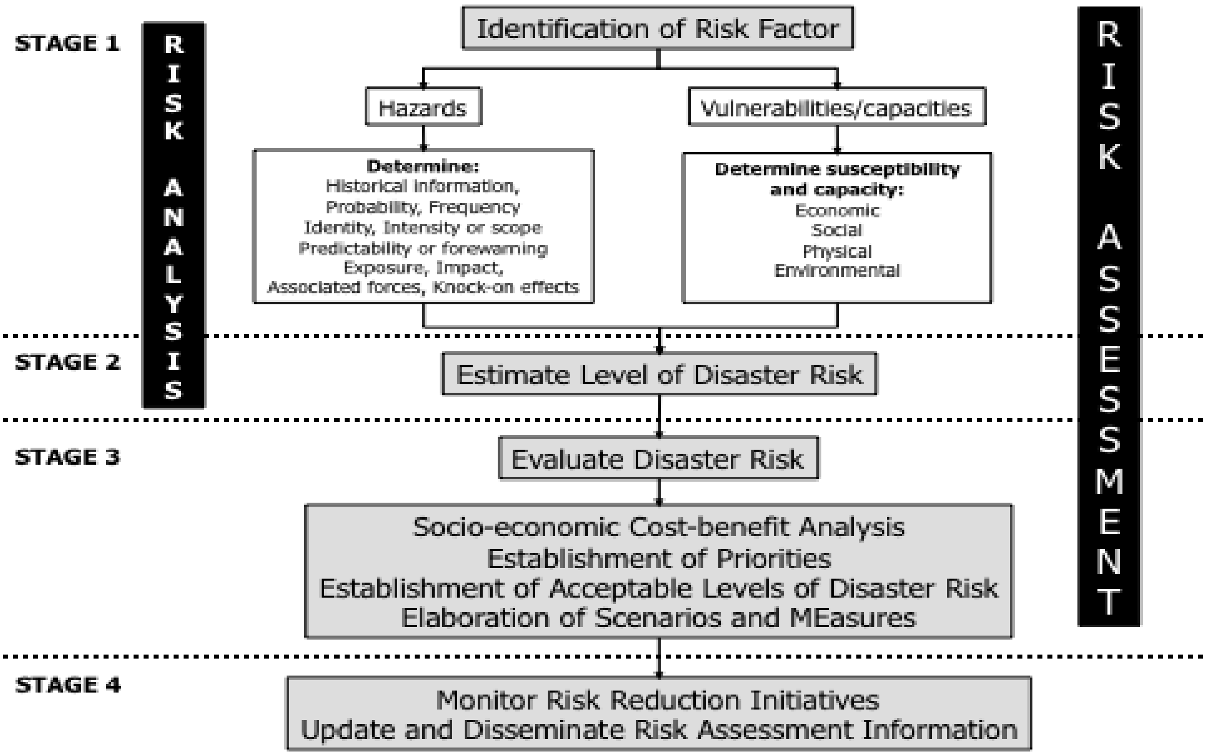

Fig 3.1: Disaster Risk Assessment Methodology
(Source: NDMF, 2005)

Common drought impacts are categorised as (i) economic, (ii) environmental, and (iii) social. Economic impacts are wide-ranging and frequently include agriculture losses in crops and livestock, industrial losses in timber and fishery production, location-specific declines in the tourism and recreation industry, and the decline in relevant food production. Commonly observed environmental impacts include damage to animal and plant species, soil erosion and depletion, loss of wetlands, increased incidence of wildland fires and overall biodiversity losses (Commission on Water Resource Management, 2003). Social impacts also vary considerably, with the most pressing being health related problems including nutrition depletion, indirect increases in vector-borne disease concentrations, and ultimately loss of human life (CWRM, 2003). Impact priorities depend on economic costs, extent of impacted areas, immediacy, public opinion, size of impacted populations, and the ability of the impacted areas to recover. The following should be noted concerning the livestock and crop production sectors for the study area:

- **Economic vulnerability** to drought refers to the vulnerability of the economy of communities, towns, districts and different sectors in the study area to droughts. Direct economic loss during extreme droughts can be calculated by, for example, production losses of wool and mohair (kg/unit animal), meat production (kg/ lamb or calves weaned), progeny (number of animals born), mortality (number of animals died) or additional feed and fodder purchases. Intangible elements such as progeny in the following season are not visible immediately during and immediately after the drought disaster, but have a huge impact on farm profitability. Other intangibles include loss of markets due to under-supply during extreme droughts, creating opportunities for other suppliers to enter the market, or consumers might move to alternative products when prices become too high during periods of under supply (NDMC-US, 2006; Jordaan, 2011). Other economic impacts of drought disasters include the possible loss of jobs, resulting in lower than normal turnover in small towns and communities (ECLAC, 2009; Jordaan, 2011). The economy of most towns in the EC depends on the agricultural sector, therefore droughts impact on businesses in those towns.
- **Environmental vulnerability** to drought refers to the susceptibility of the environment, and more specifically the vegetation, to the impact of a severe drought. Severe droughts could result in soil degradation through wind and soil erosion, bush encroachment and the extinction of certain species. Locusts in combination with drought could damage the vegetation cover to such an extent that it takes many years to recover to its original state (NDMC-US, 2006).
- **Social vulnerability** to drought refers to the vulnerability of farmers, farm workers and the local community to the negative impacts of a severe drought. Severe drought may cause high stress levels, affecting the health of farmers and their families as well as the farmers' sound decision making potential (NDMC-US, 2006). Furthermore, drought may result in job losses for farm workers and ultimately affect the local community due to the economic slowdown of small towns.

After generating a priority list of impacts, the bulk of the vulnerability assessment can be conducted. The vulnerability assessment's focus is to identify the causes of the prioritized drought impacts, hence bridging the gap between impact identification and the policy formulation phase of drought risk assessment (CWRM, 2003). Knowing that a particular sector is vulnerable to drought impacts is only one component of understanding drought risk. Establishing drought event frequency is the other key component.

Coping capacity, adaptation or resilience are as important as vulnerability and are thus included as major indicators for drought risk reduction.

3.2.1 Risk Equation

Different frameworks and equations for drought risk exist (Wisner *et al.,* 2004). Zhang (2004) modelled risk assessment of drought disasters for maize production in the Songliao Plain of China using a method of quantitative risk analysis (QRA). Typically, QRA techniques are used to obtain a better understanding of the risk posed to people who work in hazardous materials facilities, and to aid them in preparing effective emergency response plans (Heinrich *et al.*, 1980; Luo, 1987). QRA is based on contrasting the assessed environment with the reference environment. A work environment risk assessment is then undertaken by assigning marks to each factor according to class.

Jordaan (2006) proposed an adjustment to the Wisner *et al.* (2004) equation that will be used for this study as:

$$R = \left(\frac{H}{C_H}\right) \times \left[\frac{\sum V_{econ}V_{env}V_{soc}}{\sum C_{econ}C_{env}C_{soc}}\right] \qquad (1)$$

where:

R	= Disaster risk for drought
H	= Probability of a hazard with a certain magnitude
C_H	= Capacity or factors that impact on the magnitude of the hazard
V_{econ}	= Economic vulnerability
V_{env}	= Environmental vulnerability
V_{soc}	= Social vulnerability
C_{econ}	= Capacity to deal with economic vulnerability
C_{env}	= Capacity to mitigate and limit environmental vulnerability
C_{soc}	= Capacity to mitigate and limit social vulnerability.

However, Gbetibouo & Ringler (2009) emphasized the lack of consistency in the methodologies to calculate drought impacts as well as the lack of available data that can be used as vulnerability indicators. Jordaan (2011) also mentioned the identification and weighting of vulnerability indicators as amongst the main challenges in drought risk assessment. To calculate vulnerability, this study will adopt Jordaan's (2011) approach and it is calculated as follows:

$$V = \sum_{i=1}^{3} = wi\ Vi \qquad (2)$$

$$V = f\,(V^{env}V^{soc}V^{econ}) \qquad (3)$$

where:

V^{env}	= Environmental vulnerability to drought hazard
V^{soc}	= Social vulnerability to drought hazard

V^{econ} = Economic vulnerability to drought hazard

w_i = Weight of vulnerability indicator *i.*

Another common tool used in agricultural drought risk assessment is the drought index, applied either as an individual index or in combination with other indices. For example, Easterling *et al.* (1988) combined the Moisture Anomaly Index (MAI) and Palmer Drought Severity Index (PDSI) values to reflect crop moisture sensitivities. Thompson & Wehmanen (1979) employed the Green Index Number (GIN) derived from remotely sensed data to detect agricultural vegetative water stress. The GIN is defined as the percentage of pixels in a segment with a green number greater than 15. Walker (1989) designed a physiological-based composite drought index as a function of the balance between cumulative water supply and transpiration demand.

No single drought index can work in all circumstances. There is a tendency to evaluate drought severity using several indices or variables. Wilhite (2000) pointed out that it is important to use appropriate and reliable drought indices in decision-making. Consulting more than one index before making a decision is therefore necessary and important. One of the main challenges in drought risk assessment is the identification of all the indicators and the weighting of these indicators in relation to each other. Meteorological drought impact is a key indicator to vulnerability, but methodologies to calculate this are not consistent, and databases for assessing the impact are not readily available (Gbetibouo & Ringler, 2009). In the absence of quantitative and reliable analyses of estimated losses, drought impacts tend to be underestimated. Executing cost-benefit analyses from such data underestimates the benefit of mitigation. This study should provide and apply a rigorous methodology for drought risk assessment.

3.3 Drought Vulnerability

Vulnerability is expressed by the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of drought hazards, including land degradation and desertification (ISDR, 2007). Coping capacity, on the other hand, has to do with the capacity of farmers to deal with drought periods or to direct their management in such a way that they avoid disaster droughts. Another term that reflects coping capacity is resilience.

The concept of vulnerability is of paramount importance to the study of human–environment interaction (Wu *et al.,* 2002). In spite of the absence of a commonly agreed definition, two major viewpoints in defining vulnerability appear (Hassen, 2008). Cutter (1996) viewed vulnerability as a condition that exists within individuals or communities prior to the occurrence of the hazard. The second major viewpoint suggests differential vulnerability to hazards, which leads to differences in extent of losses incurred (Wu *et al.*, 2002). Adger & Kelly (1999) state that the second perspective of vulnerability is associated with the assessment of social vulnerability of people and communities to hazards.

While the term ‘vulnerability’ has no universal or commonly agreed definition, it has developed into becoming a fundamental concept in understanding factors within communities that facilitate a hazard to develop into a disaster (Cutter *et al.,* 2003; Hassen, 2008; Tapsell *et al.,* 2010; Zarafshani *et al.,* 2012). Cutter *et al*. (2003: 242) loosely define vulnerability as a “*potential for loss*”. Wisner *et al*. (2004: 11) view it as “*the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural disaster*”. UNISDR (2004) defines it as “*The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards*”. Vulnerability, as defined by Adger & Kelly (1999), concerns individuals and social groups. It is the condition of individuals, or groups, or communities concerning their capability to deal with external stress.

Of particular interest to this study is the view held by Bogardi & Birkmann (2004) of vulnerability as being a function of exposure and susceptibility of a population group to a hazard event, as well as their capacity to withstand or cope with the impacts thereof. These definitions generally refer to vulnerability as the condition of a system prior to the occurrence of a hazard. According to them vulnerability is not fixed, but is dynamic. A person can be extremely vulnerable at one point in time and become less vulnerable at another point. Even those people who may not be vulnerable at some point could later become vulnerable as a result of such factors as aging, illness or disability, which have nothing to do with natural hazards. Vulnerability, as discussed above, refers to defencelessness, to damage, injury or harm, and is viewed as a dynamic process, which changes with time (Cutter *et al.,* 2003; Smit & Wandel, 2006; Tapsell *et al.,* 2010). The review of literature led to a recognition of vulnerability as a concept that encompasses various types or facets or components (Tapsell *et al.*, 2010).

Drought vulnerability assessments describe who and what are exposed to the threat (drought identification), the differential susceptibility (the potential for loss, injury, harm, adverse impacts on livelihoods), and impacts of that exposure. Vulnerability and resilience are key to any disaster risk assessment and should always be assessed in relation to a specific hazard (Ribot, 1996; Wisner *et al.,* 2004; Dwyer *et al.,* 2004; National Drought Mitigation Centre, 2011).

Vulnerability assessment requires a model with a structural framework and objectives for analysis (Fekete, 2010). The Progression of Vulnerability model provides an excellent framework for the explanation of vulnerability to hazards. However, this model does not clearly explain adaptation, coping capacity and resilience. Models such as the sustainable livelihood framework (DFID, 2011), the vulnerability framework model by Turner *et al.* (2003), the disaster risk reduction framework (UN/ISDR, 2004), and the BBC conceptual framework proposed by Bogardi *et al*. (2005) all attempted to explain the vulnerability’s complexity and resilience to external shocks, both to humans and the ecology or environment. The BBC framework revealed the relationship between hazard and vulnerability in a risk reduction perspective (Birkmann, 2005; Bogardi *et al.,* 2005; Tapsell *et al.,* 2010).

Of all these models, the BBC conceptual framework was preferred for this study. Apart from the significant inclusion of the social dimension of vulnerability, the BBC model is also preferred for its promotion of proactive action in risk reduction. It demonstrates the necessity of intervention strategies prior to the occurrence of a disaster (Bogardi *et al.,* 2005). The model clearly identifies the three components of vulnerability as exposure, susceptibility and coping capacity (Fekete, 2010). It does not focus only on the deficiencies of the exposed population and their losses, but also on their capacities and the potential within society to reduce their vulnerability to disaster before it strikes them (Bogardi *et al.,* 2005; Fekete *et al.,* 2009; Fekete, 2010). Fekete (2010) pointed out that the BBC model revealed how social, economic and environmental spheres interact with each other. The social sphere is *"nested within"* the environmental sphere and linked with the economic spheres, as shown in Figure 3.2.

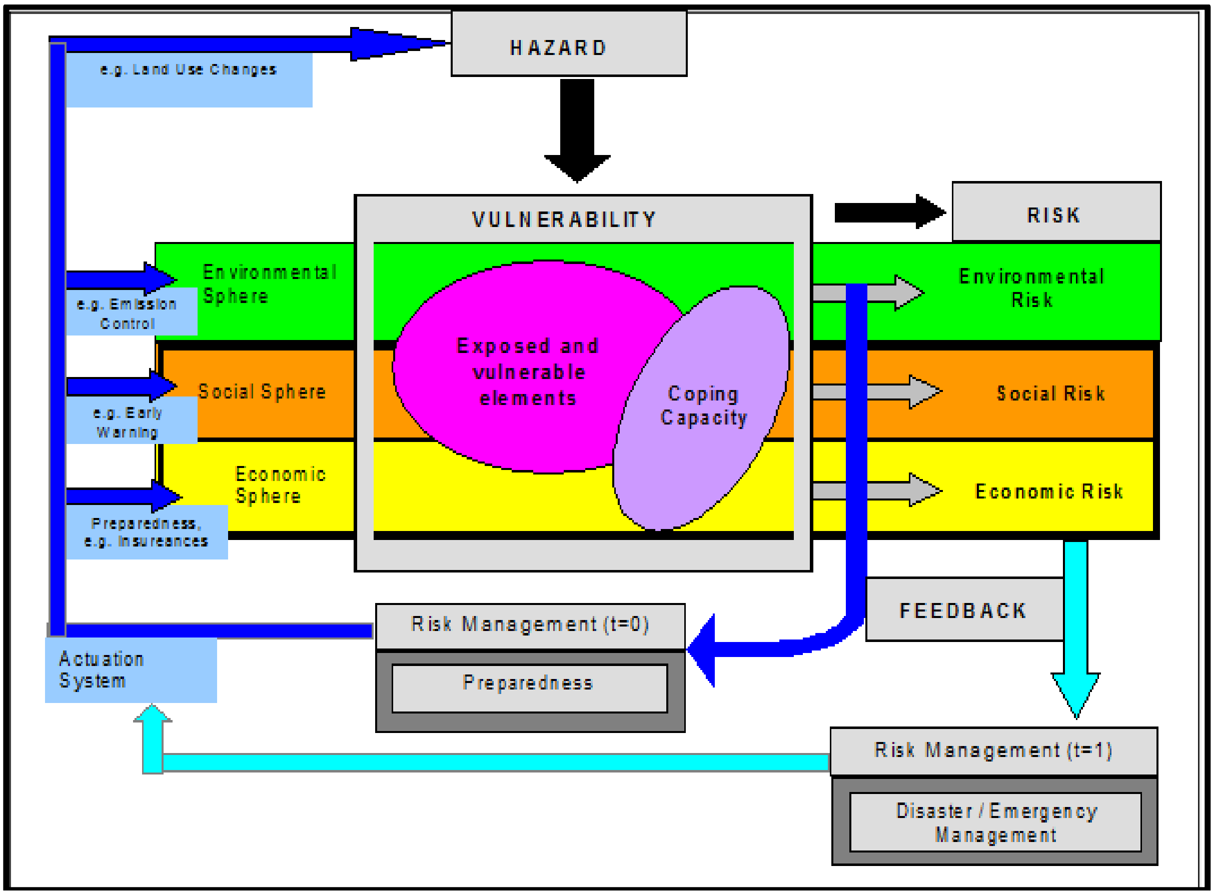

Fig 3.2: BBC Model incorporating exposure, susceptibility and coping capacity
(Source: Bogardi et al., 2005)

The goal of this research is not only to identify the risk factors (who and what is vulnerable), but also the driving forces that shape vulnerabilities in the three research areas of the Joe Gcabi, OR Tambo and Cacadu districts in the Eastern Cape. These tasks are both qualitative in their approach and they are quantitative in nature, providing numerical estimates of population exposures of both commercial and communal livestock farmers and rankings of vulnerability.

This study focused on the following three components of vulnerability to drought in the research areas:

- **Economic vulnerability** to drought refers to the vulnerability of the economy of communities, towns, districts and different sectors in the study area. Direct economic loss during extreme droughts can be calculated by, for example, production loss of wool and mohair (kg/unit animal), meat production (kg/ lamb or calve weaned), progeny (number of animals born), mortality (number of animals died) or additional feed and fodder purchases. Intangible elements such as progeny in the following season are not visible immediately during and immediately after the drought disaster, but have a huge impact on farm profitability. Other intangibles include loss of markets due to under-supply during extreme droughts, creating opportunities for other suppliers to enter the market, or consumers who might move to alternative products when prices become too high during periods of under-supply (NDMC-US, 2006; Jordaan, 2011). Other economic impacts of drought disasters include the possible loss of jobs, resulting in lower than normal turnover in small towns and communities (ECLAC, 2009; Jordaan, 2011). The economy of most towns in the Eastern Cape depends on the agricultural sector, therefore droughts impact on businesses in those towns.
- **Environmental vulnerability** to drought refers to the susceptibility of the environment, and more specifically the vegetation, to the impact of a severe drought. Severe droughts could result in soil degradation through wind and soil erosion, bush encroachment and the extinction of certain species. Locusts, in combination with drought, could damage the vegetation cover to such an extent that it takes many years to recover to its original state (NDMC-US, 2006).
- **Social vulnerability** to drought refers to the vulnerability of farmers, farm workers and the local community to the negative impacts of a severe drought. Severe drought may cause high stress levels, affecting the health of farmers and their families as well as the farmer's sound decision making potential (NDMC-US, 2006). Furthermore, it may result in job losses for farm workers and ultimately affect the local community due to the economic slowdown of a small town.

3.3.1 Vulnerability Assessment

Vulnerability assessment is the process by which the susceptibility of '*elements at risk'* to a drought hazard is estimated, and includes an analysis of the underlying causes of their vulnerability (Kafle & Murshed, 2006). Dunning & Durden (2011) define vulnerability analysis as measuring the correlation that exists between social factors and vulnerability to hazards. It provides a framework for isolating socio-economic and environmental causes for drought (Khoshnodifar *et al.,* 2012). Drought vulnerability assessments describe who and what are exposed to the threat (drought identification), the differential susceptibility (i.e. the potential for loss, injury, harm or adverse impacts on livelihoods), and impacts of that exposure. Vulnerability and resilience are key to any disaster risk assessment and should always be assessed in relation to a specific hazard (Ribot, 1996; Wisner *et al,.* 2004; Dwyer *et al.,* 2004).

Although there are various definitions of vulnerability, there is agreement among experts that in order to conduct a vulnerability assessment, there is need to first define the conceptual framework to be applied (Rygel *et al.,* 2006; Fekete, 2010). Consequently, Birkmann (2006) notes that because of the complex nature of vulnerability, indicators are needed to facilitate an estimation of vulnerability. The notion of using indicators has been supported by many practitioners such as Cutter *et al*. (2003), Adger *et al.* (2004), Dwyer *et al.* (2004), Rygel *et al*. (2006), Birkmann (2006), Tapsell *et al*. (2010), Wongbusarakum & Loper (2011) and Jordaan (2011).

The goal of this research was not only to identify the risk factors (who and what are vulnerable), but also the driving forces that shape vulnerabilities in the three research areas of the Joe Gqabi, OR Tambo and Cacadu districts. These tasks were both qualitative in their approach and quantitative in nature, providing numerical estimates of population exposures of both commercial and communal livestock farmers and rankings of vulnerability

Briefly defined, vulnerability indicators are variables to identify and assess drought conditions. Hammond *et al.* (1995) define indicators as "*quantifiable constructs that provide information either on matters of wider significance than that which is actually measured, or on a process or trend that otherwise might not be apparent*". Indicators are recognised as useful measuring tools in measuring trends and conditions to be used for policy decisions, especially when it is not easy to measure the phenomena directly (Cannon, 2003; Damm, 2010; Jordaan, 2011). Indicators help us to understand where we are, where we are going and how far we are from the goal. It must be a sign, number, a graphic, clue, a symptom or a pointer that something is changing. The United Nations International Strategy for Disaster Reduction (UNISDR, 2005) highlights the importance of social, economic, and environmental vulnerabilities to disasters and promotes policy, planning and action with a focus on these spheres of disaster hazard impact.

Drought is one of the most difficult hazards and/or disasters to understand and to define. Therefore there are different definitions for drought. Drought risk indicators are both qualitative and quantitative in nature and they include several scientific disciplines. Critique against the use of the risk equation proposed in this study includes that drought risk is difficult to define, and that some of the drought indicators and triggers may lack scientific justification. Nevertheless, sound indicators and triggers are important to detect the onset of drought conditions, to monitor and measure drought events, and to reduce drought impacts.

3.3.2 Selecting Vulnerability Indicators

Policy-makers and decision-makers make life-changing decisions based on information presented as indicators and therefore the need for indicators to be (i) transparent; (ii) robust; (iii) representative; (iv) replicable; (v) comparable; and (vi) easy to understand (Dercon, 2001; Cannon, 2003). Moldan & Dahl (2007), on the other hand, state that the quality of indicators are measured by (i) purpose and appropriateness in scale and accuracy; (ii) measurability; (iii) representation of the occurrence concerned; (iv) reliability and feasibility; and (v) communicability to the target audience. Damm (2010) groups the requirements for indicators into three groups, namely (i) standard criteria; (ii) participatory-relevant criteria; and (iii) practitioner-relevant criteria. The following sub-criteria are allocated to the different groups:

- Standard criteria: These have to be
  - *Validated for accuracy* in order to provide a true reflection of the issue under assessment and must be developed in a consistent analytical framework, with data having to be verified, being scientifically robust and collected according to approved methodologies;
  - *Relevant* to the specific topic and goal;
  - *Reproducible* within defined and acceptable limits for data collection over time and space;
  - *Sensitive* towards a broad range of conditions and outcomes within an appropriate time frame and geographic area; and be
  - *Fully transparent* in order for others to understand.
- Participatory-relevant criteria: These have to be
  - *Understandable* in order for users to grasp the indicators; and
  - *Easy to interpret,* since users are in most cases not subject matter experts and indicators should thus communicate the message to the common user.
- Practitioner-relevant criteria: These have to ensure
  - *Data availability*, which is probably the first criterion to be evaluated by the practitioner, as without data no indicator can be developed;
  - *Cost effectiveness*, with indicators being more accepted when data are simple and easy to collect; and
  - *Policy relevance*, which indicates the usefulness of an indicator, and with policy relevant indicators monitoring key outcomes, progress, processes and provide relevant information.

It is not practically possible to include all aspects of social, economic and environmental indicators related to the study, hence the need to select indicators that will be assessed. The BBC framework will form the basis for identifying locally developed social, economic and environmental indicators, which are appropriate (Adger *et al.,* 2004; Wongbusarakum & Loper, 2011). The indicators selected are directional and relative to drought in the research area of the Cacadu, O.R. Tambo and Joe Gqabi districts in the Eastern Cape and allow for comparisons between the two farming systems as well as helping to identify where and how to intervene in order to reduce drought risk. Thus the indicators selected include the three components of vulnerability, which are exposure, susceptibility and coping capacity of the target population to drought.

Adger *et al.* (2004) provide a selection procedure for indicators that involve two general approaches: the deductive and inductive approaches. The deductive approach is based on the selection of indicators on a theoretical understanding of relationships and follows identification of the processes under study and how they are related. The most suitable indicators will be assigned values and weights (Adger *et al.,* 2004). The inductive approach, on the other hand, usually makes use of empirical content that is used to build an indicator model for the particular phenomenon being studied (Adger *et al.,* 2004). This study will make use of both. Preliminary study tours to the research area provided the observable social, environmental and economic processes that could be involved in vulnerability and resilience. All indicators in this study were selected based on relevance, availability, ease of understanding, ease of collection, comparability, literature and preliminary study tour observations. Jordaan (2011) also emphasised the importance of indicator relevance to drought.

3.3.3 Social Vulnerability

There is no one single definition of social vulnerability, or resilience, among authors and each one uses the term with a different meaning (Adger, 1999). Blaikie *et al.* (1994) and Hewitt (1997) define social vulnerability as the susceptibility of social groups to potential loss from hazard events or society's resistance to hazard. Wisner *et al.* (2004) described vulnerability as the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life, livelihood, property and other assets put at risk by discrete and identifiable events, in nature and in society.

According to Hewitt (1997), social vulnerability derives from the activities and circumstances of everyday life or its transformations. It is the condition of a given area with respect to hazard, exposure, preparedness, prevention and response characteristics to cope with specific natural hazards. It is a measure of the capability of this set of elements to withstand events of a certain physical character (Weichselgartner, 2001). The product of social inequalities is defined as the susceptibility of social groups to the impacts of hazards, as well as their resiliency or ability to adequately recover from them. Susceptibility is not only a function of demographic characteristics, but also of more complex constructs such as health care provision, social capital and access to lifelines (Cutter & Emrich, 2006). Yarnal (2007) argued that social vulnerability emanates from social factors that place people in highly exposed areas, affect the sensitivity of people to that exposure, and influence their capacity to respond and adapt.

Tapsell *et al*. (2010) and Cutter *et al*. (2003) stated that most approaches to vulnerability assessments have used indicators to stand for characteristics and attributes of which there is a universal consensus amongst practitioners and researchers concerning key factors that determine social vulnerability. There are specific characteristics of vulnerable populations that are believed to have an influence on the kinds of problems and needs that practitioners will be faced with (Tapsell *et al*., 2010).

3.3.3.1 Demographic factors

This indicator seeks to answer the question "who is vulnerable to drought?" Within the same community, different groups are likely to experience the impacts of drought differently. According to Wongbusarakum and Loper (2011) "*demographically vulnerable groups are those that, because of their particular demographic or social characteristics, are more vulnerable than others in the broader community*". The ADPC (2000) mentioned the marginalised as "*the weaker section or groups or part of a society that has been pushed to the limits of subsistence*". Demographic characteristics such as gender, ethnicity or race lead to different exposure levels to drought (Wongbusarakum & Loper, 2011; King & MacGregor, 2000; ADPC, 2000; AJMC, 2006; Rygel *et al*., 2006).

Age: The elderly tend to be more susceptible to drought hazards (King & MacGregor, 2000; Vincent, 2004; Clark *et al*., 1998 cited in Rygel *et al*., 2006) because of lack of physical and economic resources to prepare for and respond to hazards (Ngo, 2001; Rygel *et al.,* 2006), although this does not apply to all eldely. ADPC (2000) reported that the Asian culture respects the elders, however, the physical and economic realities show them as being marginalised. The post Bhuj Earthquake of Gujarat assessment revealed that those over 60 years were the worst affected by the disaster. Those who are ethnically or racially in the minority are also usually marginalised, lacking access to natural and social resources such as education, credit and insurance which increases their susceptibility to drought hazards (ADPC, 2000).

Gender: Gender is a key demographic characteristic that influences social vulnerability (Cutter *et al*., 2009). Women mostly depend on men for economic resources. They have no land ownership or inheritance rights, no decision making powers, less education, lower wages (ADPC, 2000) and, for example women in Nicaragua, lack land ownership rights which exclude them from accessing credit (Segnestam 2014). Most women, especially widows and single mothers, live in poverty (Cutter *et al.,* 2009) making them more susceptible to drought impacts. According to ADPC (2000) these attributes are more important when in combination than as a single category. It is important to note that these groups of people are not vulnerable due to a lack of strength for survival, but they lack access to resources as well as having no political voice to influence any change (ADPC, 2000). Information on demographically vulnerable groups helps policy-makers understand the characteristics of a community and plan appropriate intervention strategies.

3.3.3.2 Initial well-being

Initial well-being indicates the capacity of households or communities to cope with impacts of hazards by assessing the initial nutritional as well as health status of the community prior to the impact (Cannon, 2000). The healthcare spheres of vulnerable populations can be divided into three groups: physical, psychological and social – such as the chronically ill, those with disabilities, mental problems, those who are suicidal and suffering from chronic depression (Rygel *et al.,* 2006). Vincent

(2004) also discusses HIV/AIDS as a Sub-Saharan Africa pandemic that further threatens the initial well-being and demographic resilience of a community. It debilitates the working capacity, transforms demographic structure, increases household workloads, diverts the limited resources into health care provision and increases poverty (Vincent, 2004; Granados, 2012). Considering that the HIV prevalence rate in the productive age (15 – 49 years) of South Africans that stands at 17.9% (UNAIDS, 2012), initial well-being is an important vulnerability indicator to drought in the Eastern Cape.

3.3.3.3 Social dependence

The Heinz Center for Science, Economics and Environment (2000) and Rygel *et al.* (2006) both argued that people who rely completely on social services for their survival are already poor and marginalised and in disaster situations they need support. People who live in poverty suffer more as a result of disaster impacts. They have lower preventative, mitigation or recovery measures to prevent them from the negative impacts of disasters. Their losses are more devastating relative to their wealthier counterparts. Vincent (2004) pointed out that the bulk of Africa consists of nations of low and middle development status characterised by high dependency ratios. The way a community perceives risk, its capacity to prepare for the drought, communication and warning systems, the nature and extent of impacts, response, recovery and reconstruction are all influenced by the community's poverty and dependency status (Fothergill & Peek, 2004).

3.3.3.4 Education levels

A study conducted by Jacob & Jepson (2009) on social vulnerability of fishing communities in the Gulf of Mexico revealed that the less resilient communities had an average level of education that was lower than average. High education level is an important resiliency indicator, which is supported by the second Millennium Development Goal (MDG) that promotes universal primary education by 2015 (South Africa-MDGs, 2013). The less the proportion of educated people in a community (or the level of education) the more vulnerable that community is to adverse hazard impacts as they have less political participation and access to resources (Granadosm 2012).

Education empowers farmers to contribute to the socio-economic health and resiliency of communities to drought by providing skilled labour and sharing knowledge and experiences (Drought Policy Review, 2008; ANTA, 2003, 2004 cited in Aslin & Russelm 2008; Bureau of Rural Sciences, 2008b). Education and training is critical in the prosperity of communities. Oliver (2010), cited in Jordaan (2011), argued that there was a significant difference in educational level between commercial and communal farmers in the drought risk assessment study conducted in the Northern Cape province of South Africa.

3.3.3.5 *Cultural values, beliefs and customs*

Commitment to some cultural values, beliefs, attitudes or customs can determine the social vulnerability or resilience of a community to drought (King & MacGregorm 2000; Iglesias *et al.,* 2007). Canon (2008) argued that some of the behavioural processes that people exhibit, or why they do not do what authorities want them to do, are locked in their cultural and religious beliefs. For example, during the preliminary study tour of the study area, extension officers in Aliwal North, Stekspruit (Joe Gqabi) and Willowmore (Cacadu) alluded to some local cultural practices that increase vulnerability of livestock farmers to drought; for exmple, keeping livestock during droughts for cultural rituals (Jordaan, 2011). They end up making greater losses because the livestock either die or they have to sell poorly conditioned animals at reduced prices. An understanding of such practices will contribute to the development of relevant intervention strategies for drought risk reduction.

3.3.3.6 *Lack of access to resources*

Equity concerning access to resources is critical as a social indicator to drought because financial, material, natural and social resources are important in resilience for drought hazard events. Equitable access to resources such as land and water enable farmers to irrigate as well as to move and expand their settlements and agricultural activities where need arises, thereby reducing their susceptibility to the impacts of drought (Dwyer *et al.,* 2004; Jordaan, 2011; Zarafshani *et al.,* 2012). The equitable distribution of these resources in farming communities is, therefore, pivotal in coping with drought impacts (Adger & Kelly, 1999; Wongbusarakum & Loper, 2011).

The gap between those who have access and those without is perceived to be increasing, leading to increased collective vulnerability to climate related hazards as resources are concentrated within the reach of a few people, leaving the greater part of society exposed to stresses (Adger & Kelly, 1999).

This indicator is closely related to poverty because it reduces the poor peoples' access to essential resources, leading to increased vulnerability to drought impacts (Adger & Kelly, 1999). People in rural areas generally have poor access to health services, affecting their health well-being, as is the case in rural Australia where inhabitants are affected by distance, fewer health professionals and facilities for the population (Adger, 2004; Australian Institute of Health and Welfare, 2008a, 2008c).

3.3.3.7 *Lack of external support*

This indicator measures the presence of government and non–governmental organisations (NGO) and officials as well as community leaders who can organize drought risk reduction and its effectiveness (ADPC, 2000; Wongbusarakum & Loper, 2011). A strong institutional background is essential for the promotion of resilience in the face of hazard events. Information is easily disseminated to the public and the facilitation of emergency preparedness and pre-disaster planning, all of which reduce baseline vulnerability (Vincent, 2004). The effectiveness of especially government organisations can be undermined by political meddling and corruption. The supposed equitable access to resources and distribution is impeded, leading to increased vulnerability for particular sectors of society (Vincent, 2004).

As reported by Jordaan (2011) during the 2010 drought, commercial farmers in the Northern Cape province requested drought relief worth in excess of R300 million which was just ignored by the National Department of Agriculture. Even when drought support is given to small-scale farmers it is usually inadequate and late (Smit, 2011, cited in Jordaan, 2011). Jordaan (2011) further noted that in rural towns and villages, there are no organised institutions that support communities in drought, hence they depend on municipalities which unfortunately are having a poor record of service delivery.

3.3.3.8 Lack of preparedness strategies

According to the International Federation of Red Cross (2000), a drought hazard can easily develop into a disaster when the exposed population has no plans of how to get out of harm or what measures to take. The community may lack awareness about their vulnerability, what measures to take, drought related information and early warning systems – be it traditional knowledge or access to media and other communication systems (IFRC, 2000; ADPC, 2006; Wongburasukum & Loper, 2011).

According to ADPC (2006) a disaster risk reduction plan is critical in determining the resiliency of a community to hazards as well as having early warning systems (EWS) for the community, which increases the capacity to reduce drought impacts. A community's preparedness for drought events may also include raising vulnerability awareness levels that reduce vulnerability by helping the community define their acceptable level of risk (ADPC, 2006).

3.3.3.9 Security and safety

Security or safety is a crucial social vulnerability indicator to drought in the Eastern Cape Province. When farmers and their farms are attacked or threatened, they abandon the farming industry, leaving people more vulnerable to drought impacts. Zimbabwe is one good example where white farmers and several of their black African farm workers lost their lives as a result of violent farm invasions. Although among the major producers of wheat and maize that feed the nation, white commercial farmers were forced to flee the land for dear life, leaving an estimated half of the population threatened by famine (Swarns, 2002; CBSNEWS, 2008).

Among the challenges that South African farmers face are stock theft as well as farm attacks. In the year 2011/12 alone almost 31 000 cases of stock theft were reported in South Africa, and the Eastern Cape was ranked the highest in stock theft in the country (Majavu, 2013). Lobaldo (2002) reports that out of the 40 000 white farmers in South Africa more than 1 200 had been murdered between 1994 and 2002, and more than 6 000 farms had been attacked. Insecurity in the farming industry –

whether due to stock theft or racially or politically associated farm attacks – has and will lead to farmers leaving the industry, leading to loss of experience and skill as well as increased susceptibility to drought impacts.

3.3.3.10 Classification of some social indicators

Social vulnerability for each of the quaternary catchments was measured based on the Likert scale from 1 to 5, as follows:

Vulnerability		**Coping Capacity**	
1:	Not vulnerable at all	1:	Not coping at all
2:	Slightly vulnerable	2:	Slightly coping
3:	Moderately vulnerable	3:	Moderately coping
4:	Very vulnerable	4:	Cope well
5:	Extremely vulnerable	5:	Cope extremely well

See Table 3.1 for the index classification.

Table 3.1: Classification and indexing for social vulnerability indicators

Indicator	Index	Description	Statement of Measure	Relationship with Vulnerability	Data Source
Demographic factors Age	1	<10% of population is above 65 years	Proportion of population above 65 years old	The older farmers are the more vulnerable to drought	Survey/ SAStats Observation
	2	11% - 20% of population is above 65 years			
	3	21% - 30% of population is above 65 years			
	4	31% - 40% of population is above 65 years			
	5	>41% of population is above 65 years			
Gender participation	1	Men and women equally make critical farming decisions	Level of gender equality in agricultural activities	The less gender balanced a community is the more vulnerable it is to drought impacts	Survey
	2	Decision making not equal, but no effect on production			
	3	Women do farm work; men make decisions			
	4	Women have limited role in farming decisions			
	5	Women have no say; has damaging effect on production			
Initial well-being HIV or AIDS	1	<5% households with a member with HIV or AIDS	Proportion of population with HIV or AIDS	The more people living with HIV or AIDS the greater the vulnerability	Survey/SAStats
	2	6% - 15% households with a member with HIV or AIDS			
	3	16% - 30% households with a member with HIV or AIDS			
	4	31%- 50% households with a member with HIV or AIDS			
	5	>51% households with a member with HIV or AIDS			
Social dependence	1	<20% on social grant	Proportion of population on social grant	The greater the dependent population the more vulnerable to drought	SAStats
	2	21% - 40% are on social grant			
	3	41% - 60% are on social grant			
	4	61% - 80% are on social grant			
	5	>80 % on social grant			
Low education levels	1	>50% with tertiary education	Proportion of population with formal education	The more educated the community the less vulnerable to drought	Survey/SAStats
	2	>20% with tertiary education & >80% matriculated			
	3	>80% matriculated			
	4	50% - 80% matriculated			
	5	>50% not matriculated			
Lack of access to resources	1	>81% of population have access to resources	Proportion of population that has access to social services	The less the resources are equitably distributed the greater the vulnerability	Survey/SAStats
	2	61% - 80% have access to resources			
	3	41% - 60% have access to resources			
	4	20% - 40% have access to resources			
	5	<20% of population has access to resources			
Security/safety	1	All farmers feel very secure from farm attacks	Extent of security/safety among farmers	The less the farmers feel secure/safe the greater the vulnerability	Survey/SAStats
	2	>60% farmers feel secure from farm attacks			
	3	40% - 60% farmers feel secure from thefts and farm at			
	4	10 – 40% farmers feel secure from farm attacks			
	5	>90% farmers have been robbed, not safe at all			

3.3.4 Environmental/Ecological Vulnerability

The use of the correct terminology is particularly important in the context of drought risk assessment since the spheres of socio, environment (ecology) and economy are intimately intertwined. Drought risk assessment in this study is focused on extensive livestock agriculture and crop production in the EC province. Socio-ecological, in the context of this study, therefore describes the relationship between people who depend on, and utilise the natural resources in the arid and semi-arid ecosystem; or more specifically, the relationship between farmers, farm workers, landowners and people living in rural towns where agriculture is the primary resource base on the one side and the ecosystem on the other side.

The most common term used to describe ecosystems is "*environment*". The South African National Disaster Management Framework (NDMF, 2005) and the UNISDR (2004) named the spheres to be considered in the vulnerability or impact assessment as (i) social; (ii) economic; (iii) environment; and (iv) infrastructure[4]. The social dimension[5] of vulnerability is unambiguous, but environment can mean many things. An environment is the whole of surrounding things. The Business Directory, for example defines environment as "*the sum total of all surroundings of a living organism, including natural forces and other living things, which provide conditions for development and growth as well as of danger and damage.*" The Mirriam Webster Dictionary has a more comprehensive explanation for environment, namely: *"(i) the circumstances, objects, or conditions by which one is surrounded (ii) the complex of physical, chemical, and biotic factors (as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival, and (iii) the aggregate of social and cultural conditions that influence the life of an individual or community. An environment is what surrounds a thing or an item. The environment is the surrounding. It could be a physical element - physical environment, that includes the built environment, natural environment - air conditions, water, land, atmosphere etc or it could be human environment - people surrounding the item or thing. This is also known as the social environment and includes elements like the spiritual environment, emotional environment, home, family etc. The environment is a fluid dynamic thing*".

The literature groups environment into categories from the micro-scale to the macro-scale as follows: (i) physical environment; (ii) natural and physical environment; (iii) social, natural and physical environment; (iv) behavioural, social, natural and physical environment; and (v) total environment (Crutzen, 2002; UNISDR, 2004). The different spheres of environment are illustrated in Figure 3.3.

[4] in many cases infrastructure can be grouped as part of economics.
[5] it has to do with people, livelihoods, community, social structures, etc.

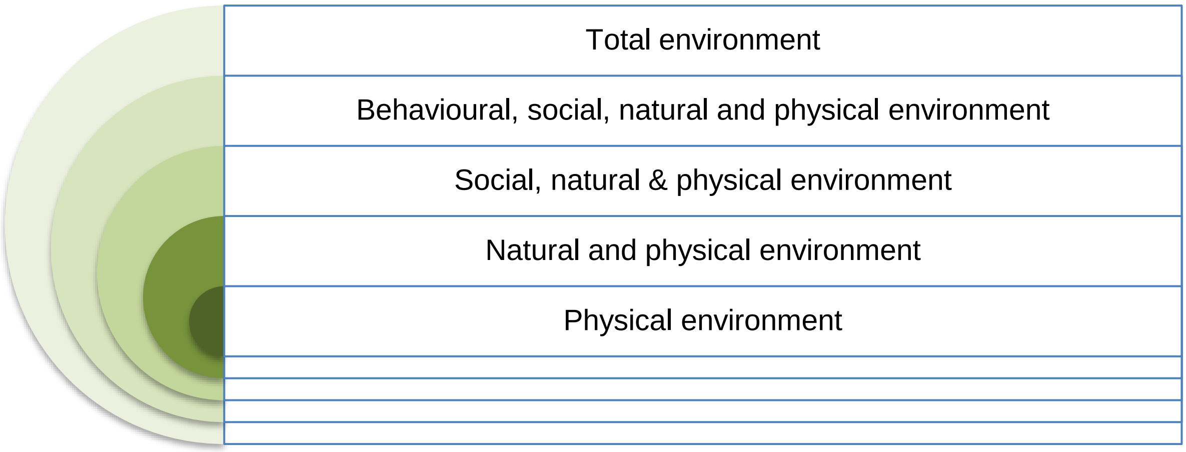

Fig 3.3: Spheres of environment
(Source: Tietenberg, 2001, adapted by Jordaan, 2011)

The challenge in the context of drought risk assessment in this study is what to assess. Is it the total environment or part of the total environment? Damm (2010) uses the term “ecology”, which is a sub-classification of “environment”, instead of “environment”. The term “environmental” is more commonly used in risk assessments, and is also the term used to describe the environmental aspects in the drought risk assessment. One can therefore assume that in the context of this study environmental vulnerability > ecological vulnerability.

The missing link in most of the above-mentioned arguments is the economic impacts of vulnerability. People utilise natural resources or the ecology not because they are altruistic; they utilise and interact with ecological systems because they can produce from that. Farmers interact with the ecological environment because they produce food and products, make profits and better their standard of living. Anyone who believes that people interact with the ecology purely to preserve it is out of touch with reality. The UN expert group on vulnerability recognises the integration between environment and economic vulnerability. They conclude that the environment (ecology) can induce economic vulnerability and therefore recommend the analysis of ecologically induced economic vulnerability either as part of ecological vulnerability or as part of economic vulnerability (Guillaumont, 1999). First, however, one needs to understand the link between the environment/ecology and the economy.

The environment in its broader context is viewed as a composite and very special asset that provides services. Our very existence depends on the environment and, as is the case with other assets, it needs to be protected to prevent undue depreciation of the value of the asset. Tietenberg (2003) describes the environment as a closed system that provides the economy with, (i) **raw materials**, which are transformed into consumer products through production processes; and (ii) **energy,** which fuels this transformation. Apart from raw materials and energy, services are provided directly to consumers. Examples are the air that we breathe, food and drinks, protection and shelter, clothing and amenities for which no substitute exists such as the beauty of nature and the enjoyment people get from nature.

The broader definition of environment allows one to view the relationship between the environment and the economy as a closed system, as illustrated in Figure 3.4 (Tietenberg, 2003).

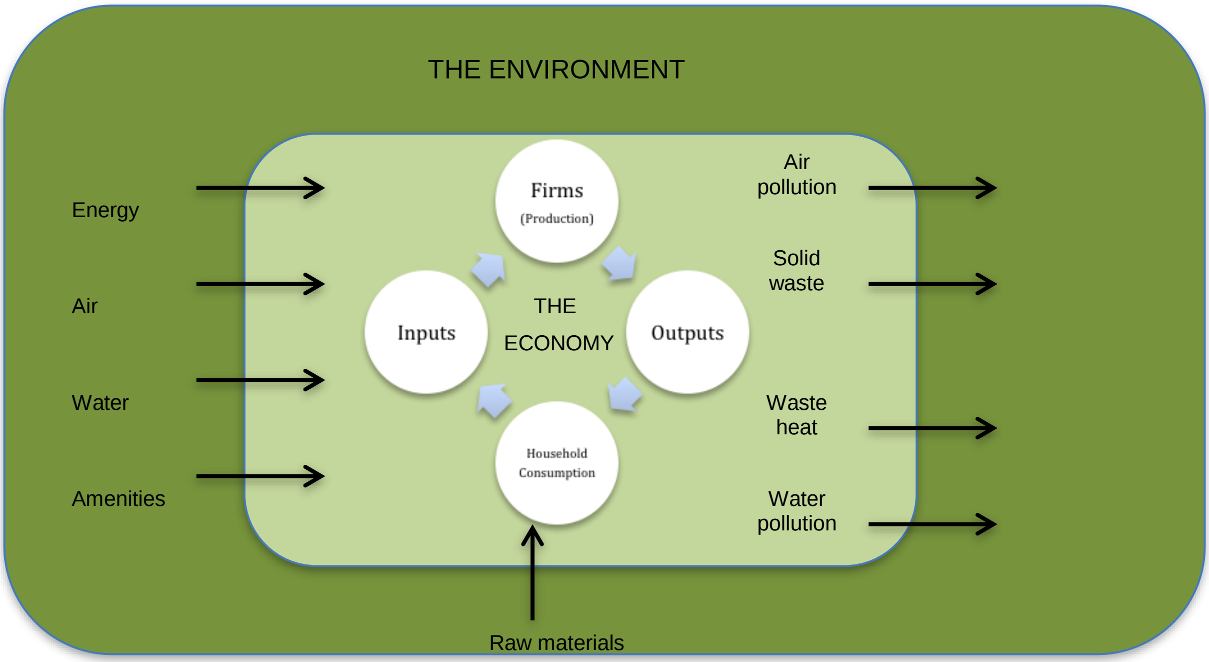

Fig 3.4: The economic system and the environment
(Source: Tietenberg, 2003)

The human-environment-economy link is absolutely intertwined and the components cannot be separated from each other in the agricultural sector. The study of risk assessment in the agricultural sector requires the integration of socio-environmental-economic sciences. That brings forth the issue of sustainability. One cannot value the environment without considering the sustainable use thereof; especially in view of increased population growth and socio-economic demands placed onto the natural resource base. People and scientists have different opinions of sustainability and what is needed for sustainable use of resources. Snyman (1998), for example, defines sustainable animal production on semi-arid and arid rangelands as follows: "*the rangeland ecosystem must be managed in such a way that output never exceeds input and losses, especially erosion must be limited, while output such as animal products (meat and fibre) must remain economically viable.*"

Economists group the different sustainability criteria into three groups, namely (i) weak sustainability; (ii) strong sustainability; and (iii) environmental sustainability (Tietenberg, 2003). According to Tientenberg (2003) the meanings of the different sustainability criteria are as follows:

- **Weak sustainability** implicates the use of resources by current generations to such an extent that future generations will be able to achieve the same level of well-being. Weak sustainability implies that the total value of capital stock (natural plus physical capital) should remain the same. Individual components of the aggregate could decline in value as long as other components have increased in value to leave the net aggregate value unchanged. Hartwick (1977) demonstrated that a constant level of consumption could be maintained if all scarcity rent were invested in capital, implying that that level of investment would be sufficient to assure the maintenance of the total capital stock – today known as the *hartwick rule*. It implies that the current generation could use *natural capital* (environment, natural resources such as coal etc.) as long as they replaced the value of the *natural capital* with *physical capital*. The principle and the test for sustainability is that we should keep the principle value of the aggregate constant at minimum, or increase the value.

- **Strong sustainability** has the same sustainability objectives as weak sustainability, but places more emphasis on preserving *natural capital* (as opposed to total capital in weak sustainability), under the assumption that natural and physical capital offer limited substitution possibilities. Economists realise the weakness in the weak sustainability criterion and the need for a stronger focus on natural capital that drives future well-being; hence the term strong sustainability.
- **Environmental sustainability** assumes the maintenance of the physical flow of individual resources, not merely the value of the aggregate. The implication of this criterion, for example, is that all species and the number of species should be maintained – a criterion supported by environmentalists and environmental activists.

The implication of the different sustainability criteria is important in the case of comparable disaster risk assessment since the level of risk to the environment is determined by the criteria applied. If one applies the natural sustainability criteria, the risk will be higher than the strong and weak sustainability criteria. The same applies when using strong versus weak sustainability criteria.

The selection of environmental indicators is a complex process because of the multi-functional nature of environmental indicators (Kurtz *et al*., 2001). Indicators were selected based on criteria described in Section 2.3.2. Environmental vulnerability is linked to the physical environmental features of the landscape. These are factors such as soil (depth, type, potential), topography, morphology, land use, biome and vegetation type, and land cover, the latter including land degradation (Snyman, 2005; Hoffman *et al.,* 2009; Fouche, 2011; Jordaan, 2011; Snyman, 2013).

3.3.4.1 Land degradation

Land degradation is subject to being one of the most serious environmental indicators of drought vulnerability of our time (Wessels, 2005). Nkonya *et al*.(2011) described land degradation as an extensive phenomenon influenced by natural and socioeconomic factors. UNEP (1994) and Elwell (1996), cited in Eiswerth (2003), defined land degradation as the reduction or loss of the biological or economic productivity of land resulting from land uses or animal and human activities. According to Fullen & Mitchell (1991), cited in Jordaan (2011), farmers who graze their sheep and goats on semi-arid steppe land are one of the main contributory factors to the enlargement of China's deserts. While Nkonya *et al.* (2011) accepted that land degradation is attributed to dry land ecosystems as well as occurring in temperate climates. China, for example is a country with large areas of land degradation (Jordaan, 2011; Mitchell & Harris, 2012).

Desertification is land degradation in arid, semi-arid and dry sub-humid areas resulting from factors such as climatic variations and human activities (UNEP, 1994). Nkonya *et al.* (2011) described desertification as the diminution or destruction of the biological potential of land, which can ultimately lead to desert-like conditions. It is an aspect of the widespread deterioration of ecosystems and has diminished or destroyed the biological potential – that is, plant and animal production – for multiple use purposes at a time when increased productivity is needed to support growing populations in the quest of development. Land degradation and desertification are often used in a similar way, but land degradation is preferred to avoid confusion with the effects of drought.

Land degradation affects food security, international aid programs, national economic development and natural resource conservation strategies (Wessels, 2005). It includes diverse processes ranging from changes in plant species composition to soil erosion, but fundamentally describes circumstances of reduced biological productivity of the land. The South Africa's National Report on Land Degradation (NRLD), directed attention to severe land degradation in the former homelands, which are communal areas.

These communal areas are generally characterized by large number of human populations, overgrazing, soil erosion, excessive wood harvesting and increases in unpleasant plant species (Hoffman & Todd, 2000). Most of these areas are predominantly populated by black South Africans, engaged in the production of crops and livestock, mainly for own consumption or for sale on local or informal markets. In these communal areas, the land is owned by the State. In contrast, commercial areas consist of land that is privately owned by farmers who market their produce through the formal commercial sector (Hoffman & Todd, 2000). Livestock densities in communal areas tend to be 2-4 times higher than the recommended stocking rates and twice those of commercial farms (Shackleton, 1993; Meadows & Hoffman, 2002).

Communal homelands in the Eastern Cape Province of South Africa are widely regarded to be severely degraded (State of the Environmental Report - EC, 2009) and the existence of adjacent, non-degraded areas with the same soils and climate, provide a unique opportunity to test regional land degradation monitoring methods (Wessels, 2005). According to an Eastern Cape Provincial Fact Sheet (1997), the communal areas are significantly more degraded than the commercial farming areas. Thus districts such as OR Tambo and Joe Gcabi have the highest soil degradation index. Cropland, grazing land and forest areas are all affected by gully and sheet erosion. The Soil Degradation Index (SDI) incorporates the severity and rate of soil degradation for all land use types, adjusted for the percentage area of each land use type in the magisterial district. The Combined Degradation Index (CDI) is the sum of the total SDI and Veld Degradation Index (VDI) for each magisterial district. In communal areas where mixed herds of cattle and goats limit bush encroachment, deforestation and loss of plant cover due to overgrazing are of greater concern than bush encroachment.

3.3.4.2 Overgrazing

According to Rayburn (2000), overgrazing is a shortage of pasture to livestock. Meteer (2014) describes overgrazing as the failure to match animal grazing to forage growth and production. Rayburn (2000) stressed that overgrazing can increase soil erosion. It reduces soil depth, soil organic matter, and soil fertility damaging the land's future productivity. Warren & Redfearn (2013) stated that drought and dry soil conditions could have indirect impacts on soil due to an increased likelihood of overgrazing.

Overgrazing reduces ground cover (litter) and increases the likelihood of crusting during rainfall events. This decreases water infiltration and can prolong plant recovery following a drought, or at the very least limit recovery from drought conditions (Warren & Redfearn, 2013). Overgrazing can be caused by having too many animals on the farm or by not properly controlling their grazing activities. Overgrazing can leave grass vulnerable to drought and cause drought conditions even during normal years with average precipitation (NDMC, 2014). It is clear that overgrazing damages the environment (Rayburn, 2000), and NDMC (2014) mentioned that overgrazing intensity has a dramatic impact on the reduction of perennial plant cover.

Continuous overgrazing can have an effect on forage yields to be severely reduced or even eliminated. This will result in less, or no, feed for the animal. The roots of the plant that depend on the green leaves to scavenger sunlight and nutrients will be starved. This results in less root base and makes the plant very susceptible to drought (Meteer, 2014). Under drought conditions when plants are rested and allowed to build up energy reserves, there will be compensatory growth by pasture plants when rainfall finally comes.

3.3.4.3 Soil and wind erosion

Soil erosion has been recognised as one of the biggest problems in agriculture, more especially in developing countries (Meijer, 2013). Soil erosion is one form of soil degradation along with soil compaction, and loss of soil structure. It is a naturally occurring process on all land (Wall *et al*., 2014). Nelson (2005) defined soil erosion as the wearing away of the earth's surface. Soil erosion is a two-phase process comprising detachment and transport of soil particles and materials by the action of water or wind, with each contributing a significant amount of soil loss each year in the Eastern Cape (Eiswerth, 2003; Wall *et al*., 2014).

A key cause of soil erosion in southern Africa is the extent and timing of torrential storms that generally commence in October at the onset of the growing season. While these events assist rain fed subsistence farmers, the agricultural practices associated with rain fed farming can hasten soil erosion (Eiswerth, 2003). Through direct observation and familiarisation that was carried out in the study area, it was observed that foot paths at the edge of agricultural fields resulted in soil erosion as well. A clear evidence of accelerated erosion was seen within these areas (Joe Gcabi, OR Tambo and Cacadu districts).

Wall *et al.* (2014) stated that soil erosion by water is controlled by the following factors, namely, rainfall intensity and runoff, soil erodibility, conservation matters, vegetation, and slope gradient and length (Meijer, 2013). Most of the soil is eroded after harvest, especially on sloped land (Pic 3.2). Soil erosion does not only decrease the food production and fibre, but also has a deleterious effect on water, air quality, wetlands and global warming among other environmental problems (Clark II *et al*., 1986).

Soil erosion by wind is affected by factors such as the soil surface roughness, vegetation cover, unsheltered distances and climate (Meijer, 2013; Wall *et al*., 2014). Human activities cause soil erosion and render the soil less productive in several ways, including leaving soil bare after harvests, overgrazing rangelands, and clearing forests on steep slopes or with large clear-cuts (Nelson, 2005). Meijer (2013) stressed that tillage significantly affects a soil's susceptibility to erosion. Tilling is the turning-over of soil before planting. It creates more pores for air and water, but makes soil more susceptible to erosion.

Pic 3.2: Soil erosion (Maclear and Mount Frere area)

Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks (Wall *et al.,* 2014). According to Eiswerth (2003), when rainfall variability becomes high, droughts are generally frequent, making sustainable agriculture all the more challenging and increasing the potential for accelerated soil erosion. Soil erosion and salinisation are problems in croplands, particularly in commercial farming areas.

3.3.4.4 Land use

The way we use our land can have an effect on vulnerability to drought (Biazin & Sterk, 2013; National Drought Mitigation Center [NDMC], 2014). Land use is an important factor contributing to the condition of the land, since land use impacts on land cover, which in turn affects the condition of the land (Jordaan, 2011). Biazin & Sterk (2013) believe that land use is characterised by the arrangements, activities and input the community undertake in a certain land cover type to create changes or sustain the land. Land use characteristics are affected mostly by human activities that impact on the distribution of ecosystems, energy (latent and sensible heat) and mass fluxes (water vapour and gases), causing the land patterns to have either suppressed or enhanced convection and atmospheric circulation that affect the formation of cloud and precipitation.

According to Cheng *et al*. (2011) land use includes lakes, rivers, forests, wetlands and agriculture. The EC has diverse land use; rural and urban settlements, productive areas, and natural areas. In Figure 2.5 it is shown that about 64% of the land in the EC is used for livestock farming, including beef cattle, sheep, goats and game.

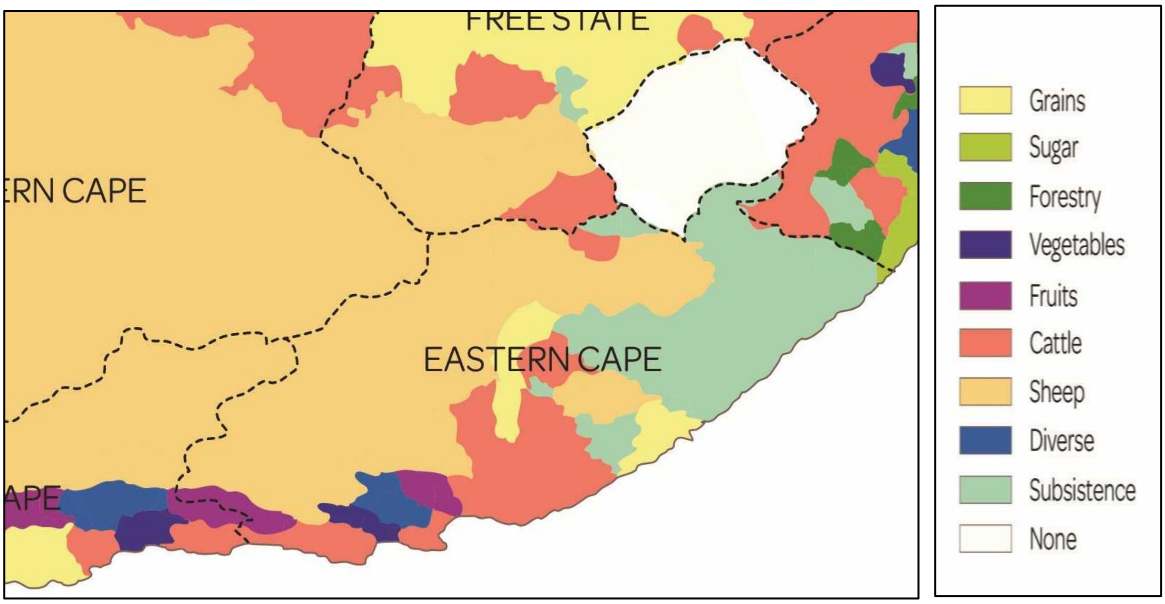

Fig 3.5: Land use in Eastern Cape

Crops are farmed on 20% of the land and include maize, vegetables, pineapples and citrus. Commercial forestry makes up 5% of land use and only 1% of land is set aside for conservation (Eastern Cape Provincial Fact Sheet, 1997; Eastern Cape SOER, 2009).

According to the Eastern Cape Provincial Fact Sheet (1997), the area of land used for crops and grazing decreased slightly during the period 1988-98. Land degradation was partly responsible for this. Factors such as the droughts of 1982/83 and early 1990s, violence and stock theft in the communal areas, increased production costs, lack of support for communal farmers and the collapse of agricultural infrastructure. Jordaan (2011) mentioned that most of the land used for livestock farming is utilised by commercial livestock or game farmers, with emerging, subsistence and small-scale farmers utilizing land at all communal areas. The Eastern Cape SOER (2009) reported distinctive rural settlements that are predominantly complex, with the communal settlements that are prevailing in the former Transkei and Ciskei areas.

3.3.4.5 Groundwater supply

Lloyd (1981) claimed that droughts impact on both surface and groundwater resources and can lead to reduced water supply, deteriorated water quality, crop failure, reduced range productivity, diminished power generation, disturbed riparian habitats, and suspended recreation activities, as well as affecting a host of economic and social activities. Groundwater resources describe water stored within pore spaces and fractures in underground rocks. Groundwater is considered advantageous by Titus *et al*. (2002) due to its high microbiological quality, arising from its location below ground and the natural protection this affords. The recharge to groundwater is essentially event based and is dependent on a large number of factors such as total rainfall, the distribution and intensity of rainfall events, connectivity to streams and rivers, soil type and land use (van der Heijde *et al.,* 1985).

Regardless of the challenges, groundwater (from springs, boreholes and dug wells) is considered raw material for improved rural water supplies on a very widespread basis, with current levels of dependency put at over 75% in Sub-Saharan Africa (Foster *et al*., 2008). Groundwater resources have a critical social function and its importance cannot be overstated because groundwater development for community water supply has far-reaching benefits in terms of reducing health hazards and improving socio-economic opportunity. The most significant aspect of groundwater behaviour in relation to drought is the time lag between changes in recharge and responses in groundwater levels and well yields (Calow *et al.,* 1997). This contrasts with the relatively "flashy" behaviour of surface water sources. The result is that, while some wells and boreholes may respond relatively quickly to rainfall variations, responses and problems in others may take months or even years to emerge, perhaps after several years of low rainfall (Calow *et al.,* 1997).

Peters *et al.* (2005) derived the deficit and duration of droughts from the time series of recharge and groundwater discharge using the threshold level approach. The analysis of the distribution of these droughts shows that for droughts with short return periods, the deficit in the groundwater discharge is smaller than in the recharge. For droughts with longer return periods, the deficit in the groundwater discharge is larger than in the recharge.

The time lag between a meteorological drought and its impact on a groundwater source is likely to depend on many different factors, which include the severity and duration of the drought episode, the design and siting of the groundwater well or borehole, physical characteristics of the aquifers, etc. (Peters *et al.,* 2005). According to the FAO (2003) degradation of groundwater resources may take place as a result of over-abstraction, water level declines and vulnerability to declines in groundwater levels.

3.3.4.6 Classification of selected vulnerability indicators

Ecological vulnerability for each of the quaternary catchment was measured based on the Likert scale from 1 to 5, as follows:

Vulnerability		**Coping Capacity**	
1:	Not vulnerable at all	1:	Not coping at all
2:	Slightly vulnerable	2:	Slightly coping
3:	Moderately vulnerable	3:	Moderately coping
4:	Very vulnerable	4:	Cope well
5:	Extremely vulnerable	5:	Cope extremely well

Table 3.2 provides an index classification for ecological vulnerability indicators.

Table 3.2: Classification and indexing for ecological vulnerability indicators

Indicators	Index	Description			
Overgrazing	1 2 3 4 5	Zero overgrazing <10% land overgrazed 10-20% land overgrazed 20-30% land overgrazed > 30% land overgrazed	% of affected grass cover	As grazing pressure increases the land is more vulnerable	Observation and survey
Soil erosion	1 2 3 4 5	100% excellent, no soil erosion >80% excellent, no soil erosion > 60% good, no soil erosion > 60% of the land is eroded > 80% of the land is eroded	% of soil eroded in a period of 30 years	The greater the extent of soil erosion the greater the vulnerability	Survey and observation
Land degradation	1 2 3 4 5	No land degradation Moderate degradation High degradation Very high degradation Severe degradation	Level of degradation over a period of 30 years	The more degraded the land the more vulnerable	Observation, survey and GIS
Land use	1 2 3 4 5	Very well planned Well planned Moderately planned Poorly planned No planning at all	Extent of land use planning	The less well planned the land is, the greater the vulnerability	Municipality and Observation
Groundwater supply	1 2 3 4 5	80% of groundwater supply with reliable water in the farm 50% of groundwater supply with reliable water 30% of groundwater supply with reliable water 10% of groundwater supply with reliable water No groundwater supply during drought	% of available water in recharged areas	The higher the groundwater supply the greater the coping capacity	GIS

3.3.5 Economic Vulnerability Indicators

Unlike sociological and environmental vulnerability assessments, which in most cases are accomplished through qualitative methods, the major advantage of economic vulnerability assessments is that some of the indicators are quantifyable by means of cost estimates. Cost assessments of the potential impact of hazardous events, in combination with cost-benefit analysis, provide crucial information for policy development and risk reduction planning (Logar & Van den Berg, 2011).

The link between the ecology and the economy is discussed in the literature, but economic vulnerability entails much more than ecologically induced impacts. Although not a new concept in economics, economic vulnerability became *"fashionable*" because of the turmoil in the international economy and political instability in developing states (Guillaumont, 1999). Briguglio *et al*. (2008) define economic vulnerability as "*the exposure of an economy to exogenous shocks, arising out of economic openness*", while economic resilience is defined as "*the policy-induced ability of an economy to withstand or recover from the effects of such shocks*". Guillaumont (1999) defines economic vulnerability as vulnerability to unforeseen shocks of any kind, or a susceptibility to exogenous shocks. Schneiderbauer and Ehrlich (2004) link economic vulnerability to poverty and the lack of resources at household and community level, while development is used as a measure of economic vulnerability at country level. Economic vulnerability at country level is well documented in the literature from both empirical and conceptual perspectives (Briguglio, 1995; 2003), but vulnerability at household and community level is more focused on the socio-economic vulnerability aspects with emphasis on social vulnerability. Briguglio *et al*. (2009) define economic vulnerability as an exposure of an economy to exogenous shock due to economic openness, while economic resilience is defined as the policy-induced ability of an economy to recover from the impacts of such exposures. Economic resiliency is the ability to (i) recover quickly from exogenous shocks, and (ii) to withstand the effect of any exogenous shock.

United Nations Environment Programme (UNEP, 2004) maintains that poverty, low income levels, high dependence on rain fed systems, poor planning and management of agricultural water supply and irrigation systems, high population density and other factors that inhibit population mobility and implementation of traditional coping mechanisms, and inexperience of communities to cope with drought are the societal characteristics that maximize vulnerability to drought. Wilk *et al*. (2012) identified small-scale farmers as being more vulnerable than commercial farmers because they encounter difficulties to finance the high input costs of implements and improved seed varieties and are constrained by limited customs of long term planning, agricultural techniques for water and soil conservation and limited access to knowledge. The small-scale farmers suffer most because of low adaptive capacity, high dependence on natural resources, inability to detect the occurrence of extreme hydrological and meteorological events due to low technology adaptation, lack of skills, illiteracy, and low level of awareness and lack of capacity to diversify (Maponya *et al*., 2013).

The methods developed by Dellal & McClarl (2010) on the economic impacts of drought on agriculture in the Turkish agricultural sector were applied to determine economic impacts of drought at regional and national level for that country's agricultural sector, and four economic indicators, namely production, price, trade and welfare were used with the 2008 conditions in Turkey to identify the effects of drought.

Economic vulnerability is, to a large extent, at the core of most vulnerability factors since social vulnerability in many cases is influenced by the economic well-being of livelihoods and communities. In the context of this assessment one should recognise the high level of dependency on the natural resources such as grazing and water supply, since the negative impact on grazing and water supply have a direct impact on production output and therefore on productivity and profitability. The farmers are in the "*first line of defence"* from the drought impact, and they are the ones (whether it be individuals or companies) that directly lose income and profits. The loss of income to farmers causes stress and farmers who, in most cases, have to lower their standard of living in order to survive. Furthermore, it could impact on the income streams or job security of farm workers and the economies of smaller rural towns which depend on the economic well-being of the agricultural sector.

The economic impact of drought differs from most of the other vulnerability indicators used in this research in the sense that the actual economic cost of drought can be calculated, provided the availability of tangible and reliable quantitative data. Economic vulnerability indicators are both tangible as well as intangible. In the context of this study, tangible and quantitative data were not readily available. Data for wool and meat production only covered one serious drought. Scale is also a problem since available data on wool production is published according to the original magisterial district borders, while the risk assessment is conducted at the scale of tertiary catchments. The scale of the risk assessment at a provincial level does not necessitate the use of detailed quantitative data. Micro-scale and district level risk assessments, though, would require the use of detailed quantitative data such as wool production and meat production data during droughts. The use of production loss functions could also be useful at micro- and meso-scale risk assessments. Owing to the lack of detailed data and the terms of reference for this study, only a few selected economic vulnerability indicators were used.

The selection and evaluation of economic vulnerability indicators was assessed by experts, extension officers, farmers and from the Principal Investigator's own experience. In the final analysis, in accordance with Adger (2004), arbitrary decisions were made on the final selection of indicators. Current indicator selection was based on criteria described in Section 2.3.2.

3.3.5.1 Lack of access to resources

According to Sen (1991), Norton & Alwang (1993), Baily & Pomeroy (1996), Adger *et al*. (1998), Alwang *et al.* (2001) and Wilk (2012), access to resources is regarded as one of the main factors contributing to vulnerability. Scholarly work such as that by Wilhite & Svoboda, (2000), Backeberg & Viljoen (2003), van Zyl (2006) and Ngaka, (2012) has revealed that access to, and use of, early warning information are critical components to drought planning as they support farmers' decision making. This statement proved that access to information as an indicator was crucial, because if the farmer does not have adequate access to and utilisation of timely, accurate, relevant and free information the famer's vulnerability to cope with drought will increase.

Travis (2013) used early warning as an indicator to track, dashboard and warn about changes in business conditions and illustrated the use of hybrid time series/early warning systems for major water resource reservoir. Wilhelmi & Wilhite (2002), Brat (2003), Vasquez-Leon *et al*. (2003), Kesharvarz *et al.* (2011), Maponya *et al.* (2013), Zarafshani *et al*. (2013) and Shiferaw *et al*. (2014) concluded in their studies in Fars province in Iran that indicators such as lack of access to enough agricultural water were among the most important indicators that increase farmers' vulnerability to drought. Khoshnodifar *et al*. (2012) and Zarafshani *et al.* (2012) found that farmers' ability to cope with drought depended on access to a variety of resources, such as land ownership, access to finance (equipment and machinery) and bank credit/loans, education level, social networking, water etc. Some authors (e.g. Scoones, 1998; Ellis, 2000; Wilk, 2012) divided the above variables into three parameters of social, economic and technical.

During a field trip to the research area in EC province, extension officers alluded to the fact that land ownership and size were the major problems with most of the farmers. This is challenging because there is a high demand for land. Infrastructure put in place by government to assist communal farmers was vandalized, causing farmers to graze on a small piece of land with overgrazing, soil erosion and land degradation as a result. All these factors that were identified increase farmers' vulnerability to drought in the area. The study conducted by Zarafshani *et al.* (2012) showed that small farmers with limited resources could not use their land in coping with drought.

3.3.5.2 Unemployment

Unemployment is an important economic indicator as it affects farmers and the community at large. Communal farmers are more vulnerable during drought because almost all their livelihood income is from farming and with high unemployment rates, opportunities for alternative jobs are scarce. Commercial farmers, on the other hand, do not compete in the same market for alternative jobs and they are in a better position to secure alternative income due to their generally higher levels of education and experience. Paavola (2008) revealed that one of the main factors influencing farmers' vulnerability was income. During drought farmers' income decreased and this make it difficult for them to mitigate the adverse impact of drought.

The Development Bank of South Africa (2013) report showed that the unemployment rate for the Eastern Cape Province had increased by an annual average rate of 28.8% in the previous decade and that the youth unemployment rate was 37.3%. According to their figures, the youth unemployment rate was higher than the aggregate unemployment rate. The report highlighted that this was due to the inability of the labour market in the province to create sufficient jobs that would absorb even the young people looking for employment.

3.3.5.3 Diversification of agricultural enterprise

Regional diversification was one factor that Alwang (2001), Erkson & Silva (2009) and Dercon (2007) found to influence the economic vulnerability of people. During drought, farm workers and people living in towns/villages can explore alternative source of income (Jordaan, 2011). On-farm diversification is also important factors when drought is experienced (Dercon, 2007; Shafid & Azamkakar, 2008; Jordaan, 2011; Shiferaw *et al.,* 2014), where farmers depend on alternative enterprise income during drought. Normally, farmers diversify their production systems by employing activities that are less sensitive to drought and diversify their cropping practices using mixed cropping, growing different cultivars at different sowing dates on farm plots and combining less productive drought-resistant cultivars with high yielding, but water-sensitive, crops (Dercon, 1996; Ellis, 2000; Shirefaw *et al.,* 2014).

Farmers can shift to goat and ostrich production since extension officers indicated that it has potential. There are EPWP programs, forestry, informal trade, art gallery centres, construction of roads, brick making, property renting and/or tourism that can be used to obtain other source of income.

According to Shafid & Azamkakar (2008) and Wilk (2012), access to finance allows farmers to diversify into other off-farm activities that can boost their incomes for back-up in difficult times. Zarafshani *et al*. (2012) and Maponya (2013) emphasised that crop diversification was good where the rainfall distribution was below normal. Livelihood diversification such as poultry and home garden vegetable production can increase small-scale farming’s resilience (Wilk, 2012; Shiferaw *et al.,* 2014).

3.3.5.4 Price sensitivity of products

Many researchers have proven that the price of products increases at the onset, during and after drought periods (Dellal, 2010; Jordaan, 2011; The National Drought Mitigation Centre, 2014). The livestock sector, however, experience a decrease in livestock prices at the onset of drought due to an oversupply of livestock, but an increase in livestock prices at the end of a drought period due to increased demand from farmers who need to replace livestock numbers after drought (Jordaan, 2011). Ding Ya *et al.* (2010) emphasised that crop failures and production losses due to drought were not being felt by farmers alone, but were passed on to consumers through increased prices. Dercon (2007) stated that the reaction of different products to drought conditions ultimately depended on the market. For example, drought affects the quality of livestock and also farmers are willing to sell their animals, thereby increasing supply and forcing down the price.

Preliminary research in the study area concludes that land prices are not much affected by droughts due to the interest in agricultural land by the government for land reform, and by professional people and companies who are not solely dependent on agriculture as the main source of income. Feedlots also play an important role to smooth and stabilise prices during droughts.

3.3.5.5 Financial safety nets

From the study conducted in the Northern Cape Province by Jordaan (2011) it was found that the lack of financial safety nets increase farmers' vulnerability to cope with drought disasters. Availability of reliable financial safety nets, on the other hand, support resiliency and is an important indicator for resilience. These safety nets could include government grants, insurance, disaster relief programs, loans, government subsidies and community funds (Ding Ya *et al.,* 2010; Resnick, 2012; Ngaka, 2012; Khoshnodifar, 2012; Wilk, 2012). Hellmuth *et al.* (2009), cited in Shiferaw *et al*., 2014), argued that in developing countries the risk transfer approach (insurance) has played an important role in mitigating climate risk.

Safety nets unfortunately also have some unintentional negative consequences. According to Zarafshani *et al.* (2012), farmers are economically vulnerable to drought due to government support programs such as social grants, which promote a dependency syndrome. Ngaka (2012) and Hosseini *et al.* (2009) also concluded that government hand-outs increased farmers' dependency, thus leading to unsustainable farming practices. Azadi & Filson (2009) rightfully suggested that agricultural extension programs should focus on small famers before the onset of a drought. Jordaan (2014) also concluded that United Nations and NGO handouts in Karamoja, Uganda, should carry part of the blame for the dependency of people in that region.

Relly & Schimelpfenning (1999) noted that resilience building to drought depended on the capacity of farmers to explore off-farm income or diversify on-farm activities. Eakin (2005) and O'Brien & Vogel (2003) highlighted that in order for farmers to manage climate risks, access to affordable insurances, credit and endorsement must be available. In South Africa most communal or small-scale farmers have no access to these services and depend mostly on Government support (Jordaan, 2011).

3.3.5.6 Debt ratio

The Department of Agriculture and Rural Development (2011) stated that the debt ratio represented the level of debt to assets for a farm. It is a good indicator of the level of financial risk associated with the farm. Small-scale farmers tend to start their business with off-farm income (loan/credit) and one finds that during drought this makes it difficult for them to repay their debt. In this case the farmer will be more vulnerable to the drought as more money will be needed to proceed with the farming business. According to Ding Ya *et al.* (2010) during the historic drought of 2007, many businesses in the southeast United States where forced to close locations, lay off employees or even file for bankruptcy.

3.3.5.7 Classification of selected economic vulnerability indicators

Economic vulnerability for each of the quaternary catchment was measured based on the Likert scale from 1 to 5, as follows:

Vulnerability		**Coping Capacity**	
1:	Not vulnerable at all	1:	Not coping at all
2:	Slightly vulnerable	2:	Slightly coping
3:	Moderately vulnerable	3:	Moderately coping
4:	Very vulnerable	4:	Cope well
5:	Extremely vulnerable	5:	Cope extremely well

Table 3.3 provides an index classification for economic vulnerability.

Table 3.3: Classification and indexing for economic vulnerability indicators

Lack of access to resources	1	Land, water, inputs, equipment, finance, tractors, information, resource	Proportion of farmers that have access to resources	The less the resources they have the more the vulnerability	Survey
	2	Access to 60% of above			
	3	Access to 40% of the above			
	4	Access to 20% of the above			
	5	Access below 10% of the above			
Unemployment	1	>20% unemployed	% of population without formal employment	The higher the % of unemployment the more vulnerability	SA Stats and Survey
	2	20 – 29% unemployed			
	3	30 – 39% unemployed			
	4	40- 50% unemployed			
	5	< 50% unemployed			
Price sensitivity of products	1	Increase in product prices as a result of drought	The likelihood of getting higher prices	The more the increase in price of products the more vulnerability	Corporative/ private company/ questionnaire
	2	Can expect different response to prices during drought, other markets determine product prices. Drought has no influence.			
	3	Can expect different response to prices during drought. Drought has no influence.			
	4	Product prices might decrease due to over-supply resulting from drought.			
	5	Product prices will definitely be lower during drought due to over-supply and poor conditions of animals			
Production output	1	Better than normal production output during drought	% of production output during drought	The more production output decrease the greater the vulnerability	Survey
	2	Normal production output during drought			
	3	Slight decrease in production during drought			
	4	At least 25% loss in production during drought			
	5	More than 50% decrease in production output during droughts			
On farm diversification	1	Practised on farm diversification (fodder banks, drought resistant crops, crop mixing, change to different enterprises)	Indication that on farm diversification is practised	The less/no change on farm practice the greater the vulnerability	Survey
	2	Apply 3 of above			
	3	Apply 2 of above			
	4	Apply 1 of above			
	5	Not practised on farm diversification – only 1 activity			
Debt ratio	1	No debt	% of farmers struggling to pay debt	The more the farmers struggle to pay debt the greater the vulnerability	Banks/ Survey
	2	10% of the farmers struggle to pay debt			
	3	30% of the farmers struggle to pay debt			
	4	50% of the farmers struggle to pay debt			
	5	More than 50% of the farmers struggle to pay debt			

Market access	1	Good market and open access through different channels	Indication of market availability	The less the market accessibility the greater the vulnerability	Survey
	2	Good market but limited access			
	3	Only 1 regular buyer and far from main centra			
	4	Only 1 irregular buyer			
	5	No market			

3.4 Drought Resilience

As with vulnerability, there is no single definition for resilience or capacity – partly due to the complexity of social systems as well as different theories and perspectives on society and disasters (Manyena, 2006; Zhou *et al*., 2009). Jacob & Jepson (2009) argue that while vulnerability measures exposure and susceptibility, resilience on the other hand, measures hardiness and flexibility. These two concepts seem to be on opposite ends of the balance of community well-being, yet they fully depend on how each measure is expressed. A measure that integrates both resilience and vulnerability, would provide a better perception of community well-being. Moreover, resilience, just like vulnerability, is not static. Communities hold certain levels of both (ADPC, 2006; Tapsell *et al.,* 2010) and can either reduce or increase either.

The concept of resilience was originally derived from the field of ecology, where it was understood as the ability to bounce back and return to a stable state in which some entity (e.g., individual, household, or community) existed before a disturbance (Constas & Frankenberger, 2013). Holling (1973), in the field of ecology, is often mentioned as one of the first to introduce the concept of resilience in a paper titled "*Resilience and Stability of the Ecological Systems*". He defined resilience as follows: "*the persistence of relationships within a system is a measure of the ability of the system to absorb change in the face of extreme perturbation and yet continue to persist*". Manyena *et al*. (2012) ascribed the original concept of resilience to the Latin word "*resilio*", implying to "jump or bounce back". In the context of social systems, there is an aspect of learning or adaptation implied by resilience by which, as the system recovers, it "*bounces back*" stronger and is better able to address future disasters (Peacock *et al.,* 2010).

An alternative approach views resilience as a factor of vulnerability and vice versa (Manyena, 2006, Zhou *et al*., 2009; Tapsell *et al.,* 2010). A network of ecology scientists, called the Resilience Alliance, in arguing that if something is not very resilient it is very vulnerable and that the opposite is also true, supports this view. However, this argument has been termed "*circular reasoning, myopic and very simplistic*" (Manyena, 2006). The question is: *"Are the two concepts opposites, or is one a factor of the other?"* An understanding of this relationship affects the application of resilience in vulnerability analysis. Villagran (2006) adopted a flip-side approach to the relationship between the two concepts, where "*high levels of vulnerability inversely implies low levels of resilience, and vice versa*". Both vulnerability and resilience can be defined by use of characteristics of a group. Cannon (2008, cited in Tapsell *et al*., 2010) suggesting that the two concepts are on the same continuum, with capacity and/or resilience as the opposite of vulnerability (Manyena, 2006; Hassen, 2008; Jordaan, 2011). This study will make use of this view, i.e. where high levels of vulnerability inversely imply low levels of resilience and *vice versa.*

FLOOD (2005) defined resilience as the capacity of a community or society, potentially exposed to hazards, to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase capacity for learning from past disasters for better future protection and to improve risk reduction measures. It is the ability of a system, community, or society to react to and recover from the damaging effects of hazards. According to Villagran (2006), resilience is an intrinsic ability of a system, an element, or a community to resist the impact of a natural or social event. Resilience is the capacity for renewal, reorganisation and development (Folke, 2006).

The Asian Disaster Preparedness Centre (2006) discusses a resilient community as one that has capacities in three phases before, during and after hazard event:

- Phase 1: The ability to absorb the shocks of hazard impacts, so that they do not become disasters (thus to reduce the probability of failure);
- Phase 2: The capacity to bounce back during and after a disaster (thus to reduce the consequences of failure);
- Phase 3: The opportunity for change and adaptation following a disaster (thus to reduce the time needed for recovery as well as patterns of vulnerability).

Resilience, when viewed as "*bouncing back*" (ADPC, 2006) is significant. As stated above already, Manyena *et al*. (2012) noted that the original concept of resilience derived from the Latin word "*resilio*", meaning to "jump back" or "bounce back". This refers to ability of people and society to recover within the shortest possible time, with minimal or no assistance at all. The "*bounce back*" notion differentiates resilience from vulnerability. However, it is argued that this notion of resilience assumes that communities return to the pre-disaster structures and institutions; hence the new concept of resilience as "*bouncing forward'* (Manyema *et al*., 2012). Thus, resilience may be viewed as "*the intrinsic capacity of a system, community or society predisposed to a shock or stress to bounce forward*" (Manyema *et al*., 2012).

UNISDR (2007) defines resilience as the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need. The UNDP (2013) defines building resilience as: "*a transformative process of strengthening the capacity of women and men, communities, institutions, and countries to anticipate, prevent, recover, adapt and/or transform from shocks, stresses, and change"* (UNDP, 2013). USAID (2012) states resilience to be: *"the ability of people, households, communities, countries, and systems to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth*".

There are commonalities in the different definitions of resilience. A frequently used definition of resilience is *“the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change”* (Adger, 2000). According to DFID (2011), resilience is: *“the ability of countries, communities and households to manage change, by maintaining or transforming living standards in the face of shocks or stresses - such as earthquakes, drought or violent conflict – without compromising their long term prospects*” (DFID, 2011). This definition connects resilience with long term development.

3.4.1 The Concept of Resilience in the Field of Hazards and Disasters

There has been considerable work done in applying the concept of resilience in conjunction with natural hazards and disasters. Mileti (1999) suggests building a disaster resilient community as a new approach to dealing with natural disasters. There is a need, therefore, for a change in the disaster risk reduction work culture, with stronger emphasis being put on resilience rather than just vulnerability (Manyena, 2006). A great deal of work on resilience has focussed on the capacity of disaster-affected communities to ‘*bounce back’* or to recover with little or no external assistance following a disaster. Timmerman (1981) linked resilience to hazard vulnerability and defined resilience as the measure of a system’s/sub-system’s capacity to absorb and recover from a hazardous event.

Distinct communities are exposed to different hazards, vulnerabilities and capacities depending on their location. A community’s resilience to a particular hazard is therefore its capacity to grow through the disaster, and this is determined in part by the capability by which the social system organises itself to increase its capacity for learning from past disaster for better future protection and to improve risk reduction measures. The suggested measurement of resilience in the Hyogo Declaration is “*the degree to which the social system is capable of organizing itself to increase capacity for learning from past disasters for better future protection and to improve risk reduction measures”* (Siembieda *et al.,* 2010).

Subsequent to the work of Timmerman’s (1981), many definitions of the concept of disaster resilience have emerged in the hazards/disasters field; however, there is no single agreed-upon definition of disaster resilience. Table 3.4 puts forward a succinct listing of the many definitions available. On the concept of resilience, there are common fundamentals shared between ecological and hazard/ disaster perspectives. Common themes that emerge from these definitions of resilience include (i*) that an ecosystem is commonly the unit of analysis,* (ii) *that resilience may be defined as either the ability of systems to absorb changes and yet maintain themselves, or the ability to rapidly bounce back from some form of impact,* (iii) *that shift focuses on the capacities of a system to (a) resist or absorb impacts and (b) be able to maintain or return, more or less, to the same form, function, structure or qualitative state* (Peacock *et al.,* 2010) (iv) *that it implies the capacity to learn, plan for, and communicate about possible disruptions,* (v) *that it has the ability to self-organize and to be self-*

reliant in times of crisis, (vi) *and that it embraces strong social connectedness that serves as a "core engine" for responses* (Frankenberger *et al.,* 2013).

Table 3.4: Selected definitions of disaster resilience

Paton *et al.* (2000)	Resilience describes an active process of self-righting, learned resourcefulness and growth. The concept relates to the ability to function at a higher level psychologically, given an individual's capabilities and previous experience.
Bruneau *et al.* (2003)	It is the ability of social units (organizations, communities) to mitigate hazards; it contains the effects of disasters when they occur, and the ability to carry out recovery activities in ways that minimize social disruption and mitigate the effects of future earthquakes… Characteristics of a resilient system include: 1) Reduced failure probabilities; 2) Reduced consequences from failures, in terms of lives lost, damage and negative economic and social consequences; and 3) Reduced time to recovery (i.e. restoration of a specific system or set of systems to their "normal" level of performance).
Walter (2004)	Resilience is the capacity to survive, adapt and recover from a natural disaster. Resilience relies on understanding the nature of possible natural disasters and taking steps to reduce risk before an event, as well as providing for quick recovery when a natural disaster occurs. These activities necessitate institutionalized planning and response networks to minimize diminished productivity, devastating losses and decreased quality of life in the event of a disaster.
Paton & Johnston (2006)	Resilience is a measure of how well people and societies can adapt to a changed reality and capitalize on the new possibilities offered.
Maguire & Hagan (2007)	Social resilience is the capacity of social entity, e.g. a group or community, to bounce back or respond positively to adversity. Social resilience has properties of resistance, recovery and creativity
Wilbanks (2008)	A community "that anticipates problems, opportunities, and potentials for surprising; reduces vulnerabilities related to development paths, socio-economic conditions, and sensitivities to possible threats; responds effectively, fairly, and legitimately in the event of an emergency; and recovers rapidly, better, safer, and fairer

The definitions of resilience all try to typify when a system experiences a shock, stress, or disturbance and what pathway it follows. Those who collapse, or recover but are worse off than before, are not resilient, and are likely to fall deeper into vulnerability. Those who bounce back, or bounce back better, can be said to be on a pathway of resilience (UNDP, 2013). The concept of resilience has gained popularity because it holds the promise of bridging the operational gap between humanitarian aid and development assistance, and because it highlights the need to build the capacity of individuals, households, and communities to withstand and/or adapt to a broad array of risks (Constas & Frankenberger, 2013).

3.4.2 Human Resilience, a Process or an Outcome of Adaptation?

Researchers looking at resilience have sought to understand why it is that some people recover from disasters, or manage to avoid negative outcomes, and others not (Kolar, 2011). It is important to understand the concept of resilience, since it explains the individuals' and/or community's, or sector's behaviour/reaction towards adaptation to drought risk and thereby enhances planning, mitigation and development. It also helps to explain the phenomenon of resilience which explains why individuals, communities or countries succeed notwithstanding the fundamental hazards to their development, progression and survival – Japan being a country is a good example in this regard.

There are many diverging approaches towards human resilience and its relationship with risk, resulting in endeavours to define and operationalize resilience. The different conceptualizations of resilience have different inferences on how it is explored and presented. The fundamental arguments in operationalizing resilience, however, focus on whether resilience is defined as a process or an outcome of adaptation (Kolar, 2011). Norris *et al.* (2008) and Newman (2004) explain resilience as a process rather than an outcome, involving positive learning, adaptation, anticipation and improvement in basic structures, actors and functions. Mancini & Bonanno (2009) discussed resilience and conclude that it is an outcome-based approach, thereby defining resilience as *"a stable pattern of low distress over time".* Olsson *et al.* (2003) also noted that an outcome-focused approach understands resilience as characterized by "*particular patterns of functional behaviour*" in the presence of risk. They also stressed that resilience can be conceptualized as a "*dynamic process of adaptation to a risk setting that involves interaction between a range of risk and protective factors from the individual to the social".*

3.4.3 Relationship between Vulnerability, Resilience and Adaptive Capacity

The concept of resilience sheds light on the relationship between risk and vulnerability. Risk is defined by Miletti (1999) as *"the probability of an event or condition occurring"*, subsequently it is able to be reduced through physical, social, governmental, or economic means, thereby reducing the likelihood of damage and loss (Siembieda *et al*., 2010). Several authors address the connection between resilience and vulnerability and they attempt to answer whether resilience and vulnerability are the two opposites, or whether one is the outcome of another. The debate has been extensive as to whether, and how, these two concepts are distinct from one another. Many authors take the view that vulnerability measures exposure, susceptibility and sensitivity of a household or community to a disturbance, while resilience is concerned with the capacities of households and communities to resist or recover from a disturbance, showing their *"hardiness and flexibility"* (Jacob & Jepson, 2009; Frankenberger *et al*., 2013). Siembieda *et al*. (2010) state that vulnerability is the absence of capacity to resist or absorb a disaster impact. Changes in vulnerability can then be achieved by changes in these capacities.

Gallopı´ns (2006) identified the conceptual linkages between vulnerability, resilience and adaptive capacity. He modelled the components of vulnerability, where he made it clear that vulnerability was the overreaching concept and that resilience is considered a subset or component of a system's capacity of response. He further defined a system's capacity of response to relate to the ability of the system to adjust to a disturbance, moderate the effects, take advantage of any available opportunities and cope with the consequences of any system transformations. Bhamra *et al.* (2011) and Gallopı´ns (2006) both identify vulnerability as the capacity to preserve the structure of a system, while resilience refers to the capacity to recover from disturbances, while maintaining that resilience is a subset element of vulnerability (Figure 3.5).

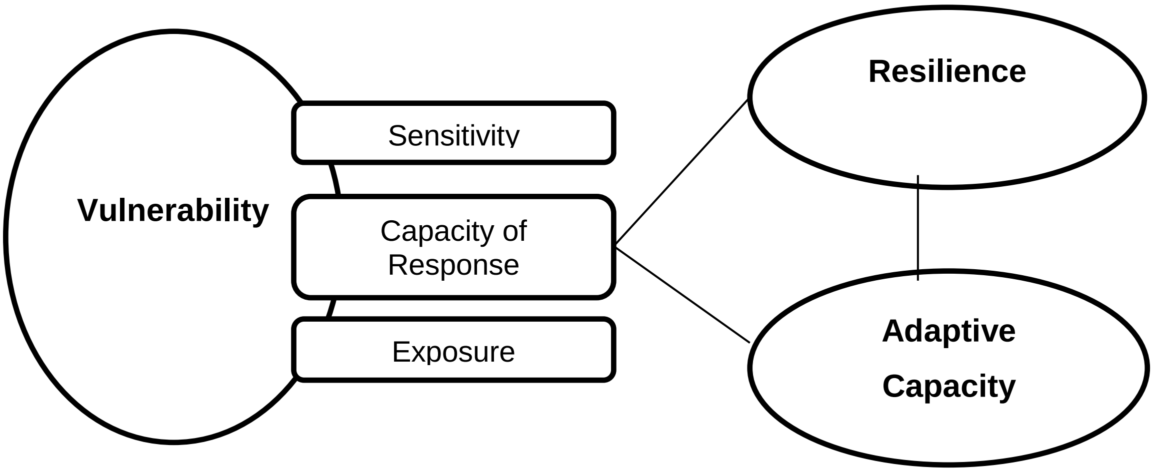

Fig 3.5: The concept of vulnerability and resilience
(Bhamra et al., 2011)

Vulnerability is therefore considered to be negative, yet hypothetically has a greater motivation to action, whereas resilience is considered more positive, though harder to understand and perhaps less motivating (Ellis, 2014). Vulnerability and resilience appear to be on contrasting ends of the balance of community well-being, but nonetheless the expression of each measure is contingent upon the other. According to Villagran (2006), high levels of vulnerability inversely imply low levels of resilience, and vice versa. A different view was presented by a network of ecology scientists through the Resilience Alliance, where they argued that if something was not very resilient it was highly vulnerable and that the opposite was also true. Despite the different approaches at looking at the relationship of resilience and vulnerability, the two concepts are on the same continuum, with capacity and/or resilience as the opposite of vulnerability (Manyena, 2006; Jordaan, 2011). Constas *et al*. (2013) reasoned that the concept of resilience was useful because it provides an overarching organizational scheme within which vulnerability, shocks, and heterogeneity of recovery pathways may be understood, measured, and modelled. This is in contrast to Gallopı´n (2006) who argued that resilience is a subset of vulnerability. This, therefore, means that resilience is a higher order or overarching concept that may help explain how vulnerability states shift over time, across contexts, at multiple scales, and in the face of varied shocks and stresses (Frankenberger *et al.,* 2013). An appreciation of this connection influences the treatment of resilience in vulnerability analysis. It is also important to note that resilience, like vulnerability and risk, is a dynamic concept and multi-dimensional, requiring the simultaneous measurement of several factors, both short and long term (UNDP, 2013).

3.4.4 Resilience Frameworks

Five frameworks were reviewed to find characteristics that contribute to resilience and well as provide linkages between resilience and vulnerability. This was done to focus our efforts on characteristics of resilience in order to appropriately identify and characterise drought resilience.

All over the world, poor people and vulnerable communities are being struck by external shocks such as droughts, thereby exacerbating already existing food insecurity and poverty (FSIN, 2015). There is, therefore, a need to identify clear guidelines on how to measure resilience in order to inform resilience-building policies, programmes or interventions most suitable for a particular area. While it is acknowledged that there are, indeed, many factors that characterise resilience, of importance is selecting a model framework for drought resilience. To enhance this process four frameworks were selected for review based on their multi-dimensional nature and their ability to capture many facets of resilience. The frameworks reviewed are the:

- Sustainable Livelihoods Framework;
- TANGO/DFID Resilience Assessment Framework;
- FAO Resilience Framework; and the
- Community-Based Resilience Analysis (CoBRA) Conceptual Framework and Methodology

3.4.4.1 The Sustainable Livelihoods Framework (SLF)

The concept of a *"livelihood"* seeks to bring together the critical factors that affect the vulnerability or strength of individual or family survival strategies (Allison & Ellis, 2001). According to DFID (1999), the sustainable livelihoods framework therefore recognises that a livelihood comprises of the capabilities, assets and activities needed for a means of living – and is sustainable when it can cope with and recover from shocks and stresses, maintain or enhance its capabilities and assets and provide sustainable opportunities for the next generation. The sustainable livelihoods framework (Figure 3.6) therefore describes the different aspects of peoples' vulnerability while pointing to the social, political and economic structures and processes which influence vulnerability.

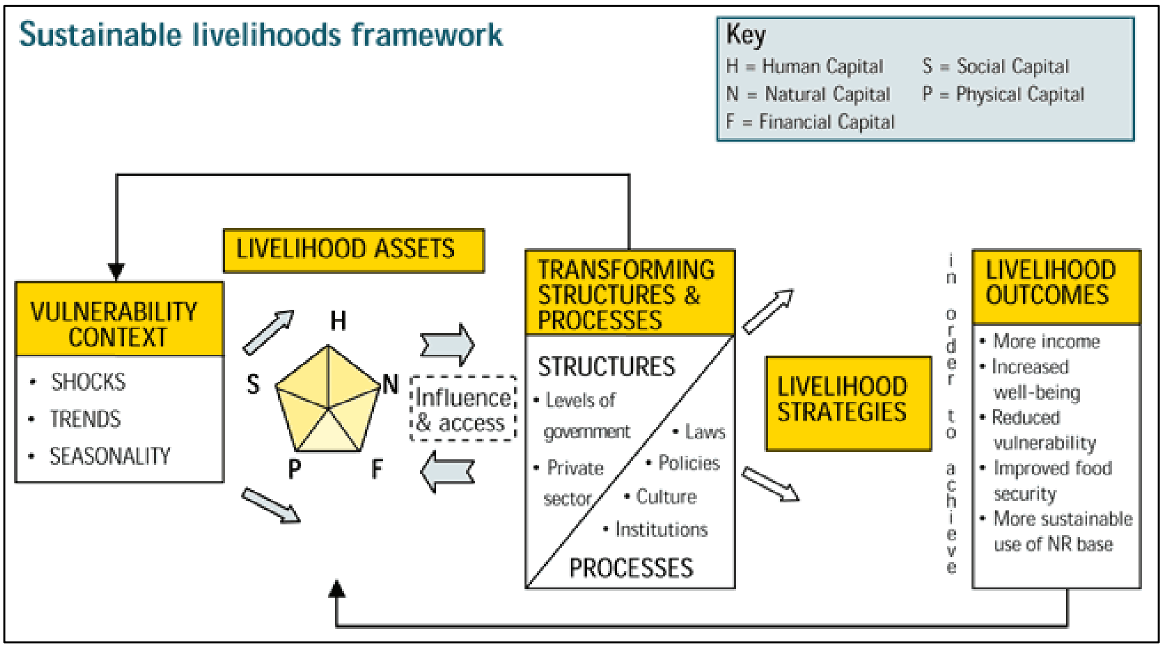

FIG 3.6: Sustainable livelihoods framework
(Source: DFID 1999)

The framework is used as an approach for zoning or mapping the potential characteristics of resilience by defining five fundamental dimensions, or 'capitals' (Table 3.5), namely human, natural, financial, social and physical, that can effectively encompass the indicators of resilience that are reported in the literature (UNDP, 2013).

Table 3.5: Definitions of SLF Components

Physical Capital	The basic infrastructure (water supplies, roads, railways, telecommunications) that people use to function more productively
Human Capital	The sum of skills, knowledge, labour and good health that together enables people to pursue different livelihood strategies and achieve their livelihood outcomes
Financial Capital	The cash that enables people to adopt different livelihood strategies, where this can be in the form of savings, or a regular source of income such as a pension or remittance, including the inputs that support livelihoods, as well as the producer goods (tools, equipment, services) that contribute to the ability to increase financial capital
Natural Capital	The natural resources (land, forests, water) and associated services (e.g. erosion protection, storm protection) upon which resource-based activities (e.g. farming, fishing etc.) depend
Social Capital	Access to and participation in networks, groups, formal and informal institutions, including peace and security, governance and political relationships

(Adapted from DFID, 1999, UNDP, 2013)

People have to cope with hazards and stresses such as drought. The uncertainties and risks created by hazards and stresses influence how people manage and use their available resources, and the choices people make. In the event of disasters, when the impact of a hazard or shock overwhelms the ability to cope, the poorest livelihoods are the hardest hit (Practical Action, 2014).

3.4.4.2 The TANGO/DFID Resilience Assessment Framework

TANGO International presented a composite framework for assessing resilience by focusing on food security shocks in Africa. This model maps the components of resilience and factors affecting resilience (TANGO, 2012). The objective of the TANGO resilience framework (Figure 3.7) is to enable policy makers and practitioners to have a comprehensive understanding of the factors and processes influencing vulnerability and resilience at the household and community levels (UNDP, 2013).

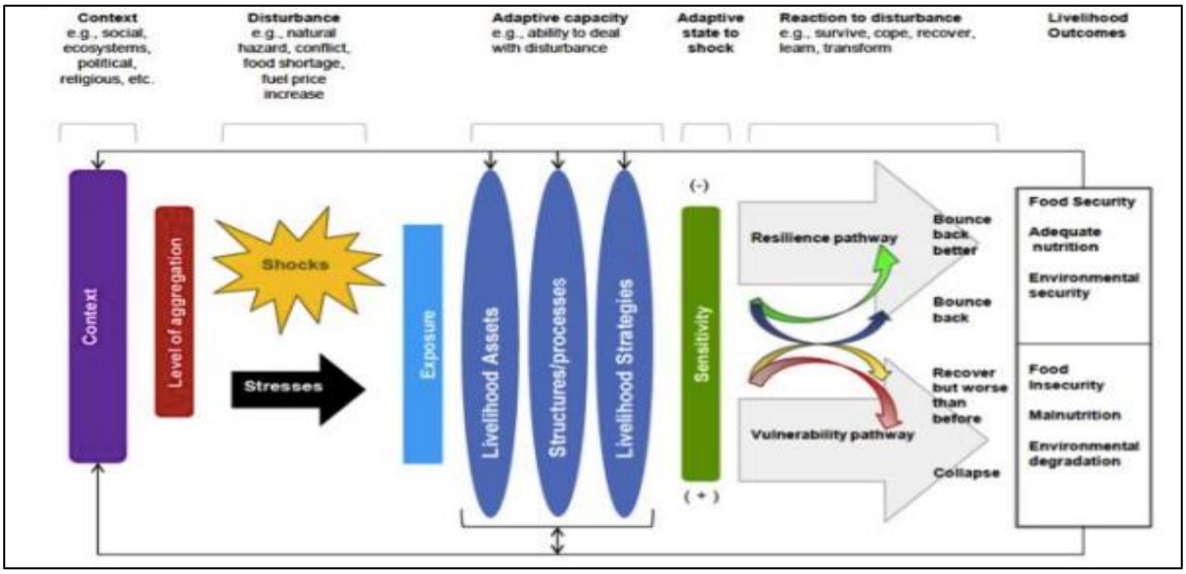

Fig 3.7: The TANGO resilience assessment framework
(Source: TANGO, 2012)

The TANGO/DFID model helps to conceptualize resilience as a dynamic process which ultimately coalesces to put households on positive or negative ‘pathways (Frankenberger *et al.,* 2012). It draws on livelihood models and climate change adaptation thinking in the inclusion of many factors and, as such, it is adapted from the DFID Disaster Resilience Framework (2011), the TANGO Livelihoods Framework (2007) and the DFID Sustainable Livelihoods Framework (1999).

3.4.4.3 The FAO Resilience Framework

The FAO Resilience framework (Figure 3.8) underlines the reasoning for measuring resilience (UNDP, 2013). It assumes that the resilience of a given household at a given point in time, T_0, depends primarily on the options available to that household for making a living (Alinovi *et al.,* 2010a).

The framework looks at the root causes of household vulnerability rather than attempting to predict how well households will cope with future crises or disasters. The key components of the resilient model include income and food access, access to basic services, social safety nets, assets, stability and adaptive capacity. The resilience framework uses a systemic approach and postulates that change is constant. In comparison to other frameworks, which often control change and assume that systems are relatively stable. The framework lays the foundation for policies, which help socio-economic systems cope with, adapt to and even shape change (Alinovi *et al*., 2010a).

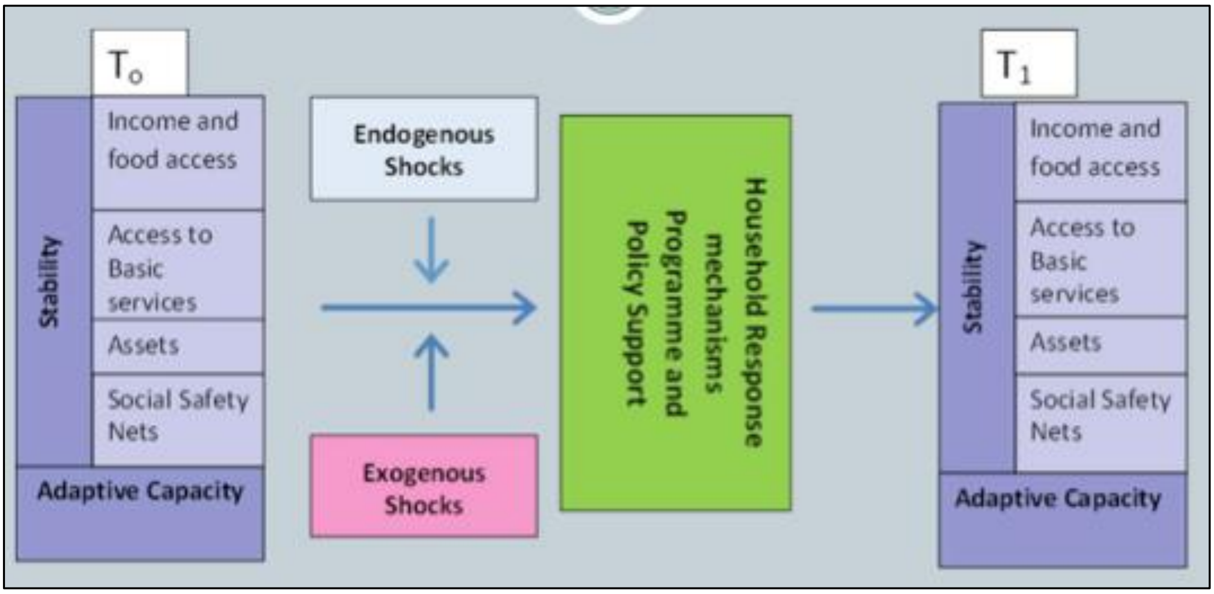

Figure 3.8: The FAO community based resilience framework

3.4.4.4 The Community-Based Resilience Analysis (CoBRA) Conceptual Framework and Methodology

The CoBRA framework (Figure 3.9) is built on various models and components of resilience such as the Sustainable Livelihoods Framework, the DFID Tango and the FAO Livelihood Strategies and the Resilience to Food Insecurity Framework (Alinovi *et al*., 2010). The conceptual framework was developed with an objective for a quantitative impact assessment of interventions to build resilience. The premise for measuring resilience, and the impact of interventions on resilience, is based on the need to first understand the baseline.

The approach aims to learn from positive experiences by identifying resilient households as a starting point and examining how they are able to cope with shocks. Questions to be answered include (i) whether households are resilient at a given point in time, and (ii) how that changes following interventions. The conceptual model is also based on the community perspective, namely (i) how households define and prioritize the characteristics of resilience, (ii) what the characteristics are of existing resilient households, and (iii) how they got to be resilient (UNDP, 2013). There is an understanding that resilience is not static, but rather multi-dimensional, consequently monitoring resilience needs to happen over a longer time frame and that it should be participatory and based on evidence from the community level.

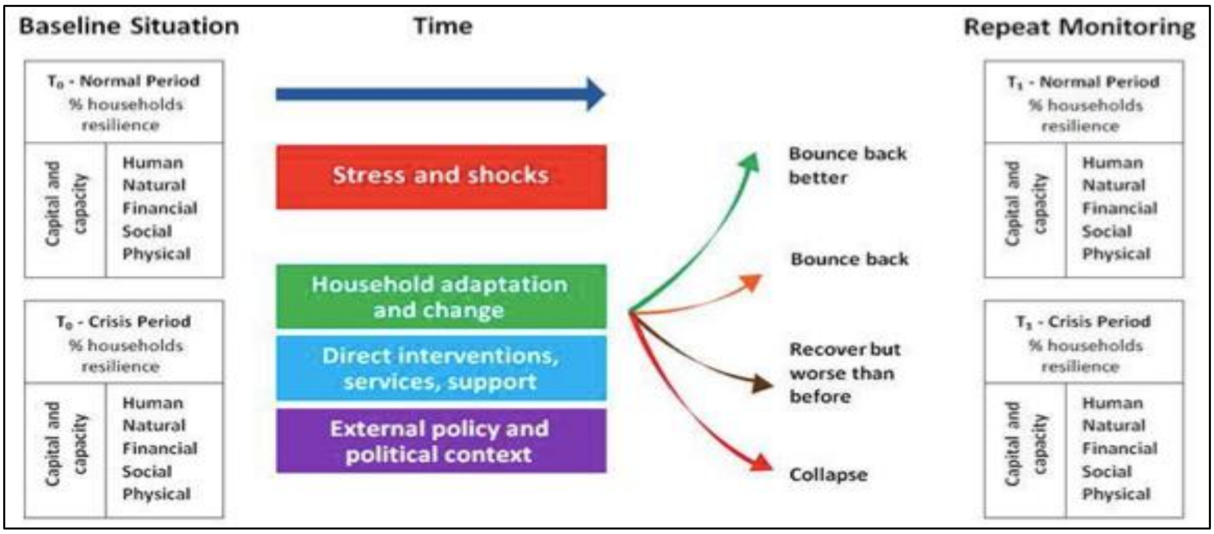

Fig 3.9: The CoBRA community resilience conceptual framework

In order for communities to reduce vulnerability and thereby increase resilience, a multi-faceted approach is required which is linked to temporal and spatial scales. The insight of why and how people become vulnerable to drought informs ways of preventing this from happening, while at the same time it reduces the potential impact. There are a number of characteristics represented across the different models and frameworks that include: income, food security, assets, access to basic services, social safety nets, ecosystem health, livelihood strategies, adaptive capacity, governance, and stability (UNDP, 2013).

3.4.5 Resilience Building Strategies to Drought

Like vulnerability, which is spatio-temporally based, adaptation is considered at the macro-, meso- and micro- levels, with macro-level adaptation in the domain of policy changes and implementation. Adaptive capacity (adaptability) at the micro-level is similar or closely related to other commonly used concepts such as coping capacity, management capacity, stability, robustness, flexibility, and resilience (Smit & Wandel, 2006). The link between government, governance and adaptive policies at national (macro-) level and the adaptive capacity of farmers at the micro-level are of critical importance (Jordaan, 2011). Farm level adaptive capacity is unlikely to be sufficient in poor regions and under-developed economies without sufficient markets and resources (Lotze-Campen & Schellnhuber, 2009). Bene *et al*. (2012) states that three types of capacity (Figure 3.10) are important when living with change and uncertainty, and under the title of the 3-D resilience framework they are

- absorptive capacity – the ability to cope with the effects of shocks and stresses;
- adaptive capacity – the ability of individuals or societies to adjust and adapt to shocks and stresses, but keeping the overall system functioning in broadly the same way; and

- transformative capacity – the ability to change the system fundamentally when the way it works is no longer viable.

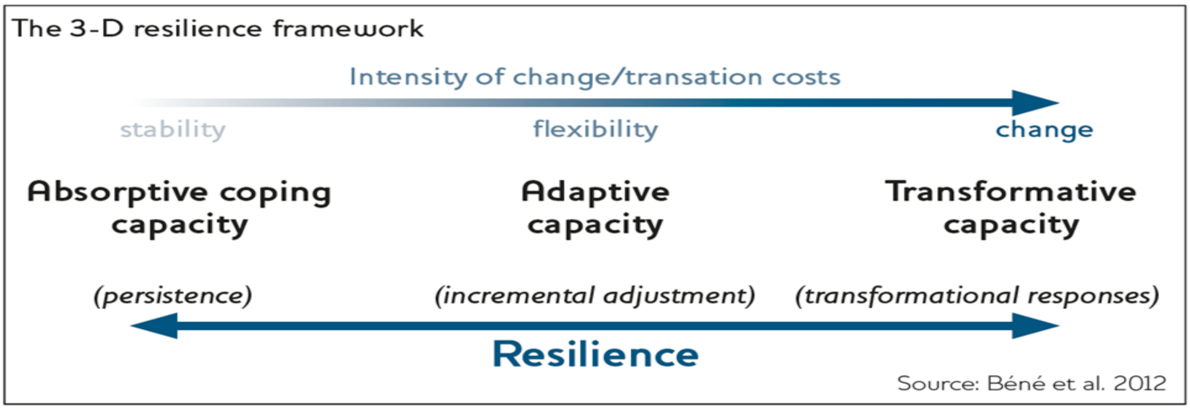

Fig 3.10: 3-D resilience framework

These capacities are interconnected, mutually reinforcing and exist at multiple levels (individual, household, community, state, and ecosystem; Béné *et al*. 2012; Frankenberger *et al*., 2012). The framework signifies the fact that resilience develops not only of one, but all of these three capacities: absorptive, adaptive and transformative capacities. Each of the capacities results in different outcomes, namely persistence, incremental adjustment, or transformational responses. Enhancing community resilience therefore requires an integrated approach to building community capitals that will enhance the capacity of communities for collective action in the areas of disaster risk reduction (Frankenberger *et al.,* 2012), The focus on resilience as a process draws attention to the notion of resilient systems, whereby resilience is not a state, but a dynamic set of conditions, as embodied within a system (Bahadur *et al*., 2010). In order to build a resilient system one needs to understand the relationships between the people, systems, institutions and the hazard itself. Adapted from work by Bahadur *et al*. (2010), the characteristics of a drought resilient community therefore requires:

- a high level of diversity, in terms of access to assets, voices included in decision-making and in the availability of economic opportunities that can be used before, during and after a drought;
- a level of connectivity between institutions and organisations at different scales and the extent to which information, knowledge, evaluation and learning propagates up and down across these scales, with this including early warning information through media, social networking, community, government, non-governmental organisation and private sector; and including
- the extent to which different forms of knowledge are blended to anticipate and manage processes of change;
- a level of redundancy within a system, meaning that some aspects can fail without leading to whole system collapse;
- the extent to which the system is equal to, and inclusive of, its component parts, not distributing risks in an imbalanced way; and
- a degree of social cohesion and capital, allowing individuals to be supported from within.

Folke *et al*. (2002) identified four critical factors that interact across temporal and spatial scales and that seem to be required for dealing with natural resource dynamics during periods of change and reorganization, namely:

- learning to live with change and uncertainty;
- nurturing diversity for re-organization and renewal;
- combining different types of knowledge for learning; and
- creating opportunity for self-organization.

Berkes & Seixas (2005) used these factors towards developing proxies of resilience for lagoon social-ecologic systems. It involved considering clusters of factors for building resilience from the local perspective and their applicability in analysing different systems. The factors can also be applied at different scales for different hazards such as drought. The different clusters for resilience building are summarised in Table 3.6.

Table 3.6: Clusters of factors for building resilience

Resilience Clusters	Resilience Factors
Learning to live with change and uncertainty	Learning from crises Building rapid feedback capacity to respond to environmental change Managing disturbance Building a portfolio of livelihood activities Developing coping strategies
Nurturing diversity for re-organization and renewal	Nurturing ecological memory Nurturing a diversity of institutions to respond to change Creating political space for experimentation Building trust among users Using social memory as source of innovation and novelty
Combining different kinds of knowledge	Building capacity to monitor the environment Building capacity for participatory management Building institutions that frame learning, memory and creativity Creating cross-scale mechanisms to share knowledge Combining local and scientific knowledge
Creating opportunity for self-organization	Building capacity for user self-organization Building conflict management mechanisms Self-organizing for equity in resource access and allocation Self-organizing in response to external drivers Matching scales of ecosystem and governance Creating multi-level governance

Resilience building strategies are broadly categorized as:

- Drought adaptation,
- Drought adjustment,
- Drought avoidance, and
- Coping with drought.

These strategies are discussed in the following sections.

3.4.5.1 Adaptation to drought and extreme weather events

Nelson *et al*. (2007) define adaptation as a process of deliberate change in anticipation of external changes or stresses. They view adaptation as a core feature of socio-ecological systems, built on the resilience of communities within those systems. Burton (2002) views adaptation as the ability of social and environmental systems to adjust to change and shocks in order to cope with the consequences thereof. Stringer *et al*. (2009) agree with the widespread understanding of the role of adaptation as a process of deliberate change to build resilience and overcome the negative impacts of shocks and change. Eriksen *et al*. (2005) describe coping mechanisms as the actions and activities that take place within existing structures and systems, examples being extensive wool production systems with merino sheep or meat production systems with Dorper sheep. When farmers introduce on-farm diversification such as diversification of feed and fodder sources or alternative livestock types, Sewell *et al.* (1968) call it adjustments and consider it a strategy that requires more time than coping. The longer term strategy is adaptation, and this involves significant changes in lifestyles, livelihoods and farming practices (Sewell *et al.,* 1968; Myburg ,1994; Vogel, 1995; O'Farrel *et al.,* 2009).

Adaptation takes place at the macro-, meso- and micro-levels, with macro-level adaptation in the domain of policy changes and implementation. Burten *et al*. (2003), Smit & Wandell (2006), Stringer *et al*. (2009) and Lotze-Campen & Schellnhuber (2009) all agree that the conventional thinking of adaptation at the micro-level is more reactive, while policy driven adaptation is better planned and proactive with the focus on risk reduction. Stringer *et al.* (2009) argue that it is not always the case, and that the complexity of adaptation at different levels should be understood. For example, adaptation may reduce immediate risk, yet it can increase risk in the longer term if not appropriately planned and implemented.

The capacity to avoid, cope, adjust or adapt is a significant factor in characterising vulnerability and is very important in the context of this study. Adaptive capacity (adaptability) at micro-level is similar, or closely related, to other commonly used concepts such as coping capacity, management capacity, stability, robustness, flexibility and resilience (Smit & Wandel, 2006). The IPCC (2001) describes adaptive capacity as "*the potential or ability of a system, region, or community to adjust to the effects or impacts of climate change (including climate variability and extremes). The capacity to adapt is context-specific and varies from country to country, from community to community, among social groups and individuals, and over time*" (IPCC, 2001; Smit & Wandel, 2006). McCarthy *et al.* (2001) consider adaptive capacity as "*a function of wealth, technology, education, information, skills, infrastructure, access to resources, and stability and management capabilities*". Brooks (2003) argues that the adaptive capacity of a system or society reflects its ability to modify its characteristics or behaviour to cope with existing or anticipated external stresses and changes in external conditions.

Adger *et al.* (2009) suggest four meta-domains that limit the adaptation potential of individuals and communities. They challenge the view that exogenous forces outside the control of the individual determine adaptive capacity rather than values, perceptions, processes and power structures within society. Ethics (how and what we value), knowledge (how and what we know), risk (how and what we perceive) and culture (how and why we live) seem to be instrumental in limiting the adaptive capacity of people.

Ethics is a critical factor in the manifestation of adaptive strategies for different groups. What one group may interpret as a successful adaptation strategy, another group might view as a total failure due to different priorities and values held within society. Secondly, knowledge concerning drought impacts is also cited as a reason for delayed adaptation strategies. Adger *et al.* (2009) argue that greater foresight not necessarily facilitates adaptation, but that instead robust decision-making circumvents the need for precise knowledge. Thirdly, society's risk perception is key to their adaptation decisions. If society does not perceive risk as great enough to justify action, risk perception acts as a limiting factor. Fourthly, the undervaluing of places and cultures may limit the options for adaptation (Adger *et al*., 2009).

Adger *et al.* (2009) came to the conclusion that the ability to adapt is, in part, determined by the availability of technology and the capacity for learning, but fundamentally by the ethics guiding the treatment of vulnerable people and places within societal decision-making structures. This is an important observation when designing adaptation strategies with communal subsistence farmers and commercial farmers with different world views.

3.4.5.1.1 Macro-level impact on adaptive capacity

O'Brien *et al*. (2004) and Eakin & Lemos (2006) highlighted that globalisation and the removal of agricultural subsidies and increased import competition reduce the adaptive capacity of farmers to climate shocks, especially in developing countries. There is therefore a need for national and international policies that consider and support adaptation in the agricultural sector at local level (Rosenzweig & Tubiello, 2007; Lotze-Campen & Schnellnhuber, 2009). Belliveau *et al*. (2006) and Easterling *et al*. (2007) recommend the reform of agricultural policies in developed countries to provide for better options for the poor in order to increase their adaptive capacity or resilience. They recommend a shift of financial resources away from direct farming income support towards agricultural education, research and technological development in order to assure increased and more efficient outputs under changing market and climate conditions. Lotze-Campen & Schellnhuber (2009) add improved policies that guide land use changes, regulation of migration patterns, and financial and material support for alternative livelihood options to the set of policies that can increase resilience, while Easterling *et al*. (2007) argue for the establishment of accessible markets and financial services as preconditions for adaptation under climatic shocks.

The link between government, governance and adaptive policies at the national (macro) level and the adaptive capacity of farmers at micro-level are of critical importance. Farm level adaptive capacity is unlikely to be sufficient in poor regions and under-developed economies without sufficient markets and resources (Lotze-Campen & Schellnhuber, 2009).

3.4.5.1.2 Farm level adaptation

Burton & Lim (2005), Rosenzweig & Tubiello (2007) and Jordaan (2011) mention that adaptation in agriculture is the norm rather than the exception, and that farmers in the past demonstrated sufficient adaptive capacity to cope with extreme weather events on short, medium and long term time scales. Important to note, however, is that the adaptive capacity of farmers is determined by (i) education, i.e. human capital, (ii) wealth, (iii) material resources, (iv) societal entitlements, (v) information, (vi) technology, (vii) infrastructure and (viii) resources (Belliveau, 2006; Easterling *et al*. 2007; Adger *et al*, 2009; Jordaan, 2011).

For centuries, drought was one of the main challenges for livestock and rain fed farmers in Africa (Le Houerou, 1996). Livestock farmers responded differently to drought through time. When abundant land is available, farmers use avoidance strategies by adopting a nomadic system – moving from drought-stricken areas to areas with good supply of feed and fodder (Jordaan, 2014). Increased pressure on land forces farmers to respond in different ways. Coping with drought is considered a short term response to feed and fodder shortages (Vogel, 1995; O'Farrel *et al*., 2009).

O'Farrel *et al*. (2009) argued that the way farmers respond to drought is a function of several variables related to the severity, frequency and duration of droughts. In addition, farming practices and the farming system determine the type of response mechanisms; for example, nomadic and trans-human pastoralists can apply evading strategies, while ranchers and crop farmers have to adopt an endurance strategy (Le Houerou, 1996; O'Farrel *et al*., 2009; Jordaan, 2011; Jordaan & Adoko, 2014).

There are five meta-domains that limit the adaptation potential of individuals and communities, which are (Adger *et al*., 2009; Jordaan, 2011):

- Exogenous forces outside the control of the individual, which determine adaptive capacity rather than values, perceptions, processes and power structures within society;
- Ethics (how and what we value), where what one group may interpret as a successful adaptation strategy, another group might view as a total failure;
- Knowledge and experience (how and what we know), where knowledge and experience concerning drought impacts is a reason for timely or delayed adaptation strategies;
- Risk (how and what we perceive), where society's risk perception is key to their adaptation decisions, and if society or individuals do not perceive risk as great enough to justify action, risk perception acts as a limiting factor; and

- Culture (how and why we live), which seems to be instrumental in limiting the adaptive capacity of people, and where the undervaluing of places and cultures may limit the options for adaptation.

3.4.5.2 Drought adjustment strategies

Adjustment is generally regarded as adaptation, but the literature purports adaptation to be a permanent and long term strategy affecting livelihoods and lifestyles, while adjustment in some cases can be linked to coping (Sewell *et al*., 1968; Myburg, 1994; Vogel, 1995; O'Farrel *et al*., 2009; Jordaan, 2011). Adjustment strategies differ from coping mechanisms in the sense that they are more permanent, and adjustments need to be initiated prior to droughts (Sewell *et al*., 1968). Scoones (1992), Myburgh (1994), Vogel (1995), Le Houerou (1996), Hudson (2002) and (Jordaan 2011) defined adjustment to include strategies such as the change of:

- livestock type;
- change in grazing strategies;
- farm level diversification;
- economic diversification;
- building of fodder banks;
- permanent reduction of grazing capacity;
- water reticulation;
- planting of drought resistant crops; and/or
- budgeting and financial planning for droughts

The change of livestock type, for example, is one of the most popular strategies applied by commercial farmers in South Africa, with Merino and Dorper sheep being reared in the Karoo and Mutton Merino in the Eastern Cape and Free State (Jordaan, 2011).

3.4.5.3 Drought avoidance strategies

Pastoral grazing strategies based on nomadic principles first emerged in northern and eastern Africa, and later moved with stockowners and herders in southern Africa. This strategy provides for maximum forage use across a variety of climatic regimes (Danckwerts & Tainton, 1996; Jordaan & Adoko, 2014). This type of climate-driven farming system was applied by the Khoikoi for 2 000 years and where conditions allow, is still in use today (Smith, 1983). The seasonal movement of animals, called transhumance by O'Farrel *et al*. (2009), is characterised by the availability of feed and fodder in different climate or plant regimes at different times. The availability of resources in alternative geographic areas compared with depleted resources at current locations serves as the main driver for animal movements (Danckwerts & Tainton, 1996; Jordaan & Adoko, 2014).

The arrival of European settlers in southern Africa increased the pressure on available land and many of the internal conflicts originated from the conflict over grazing for cattle or sheep. The European settlers recognised the strategic benefit of a transhumance lifestyle as a drought avoiding strategy as well as the effective exploitation of the available natural resources (Penn, 1986). Driven by their need for additional land and resources, settler farmers moved further north inland where an abundance of grazing lands was available. During those early years, drought was a non-issue since farmers could move their animals to fertile land when needed (Beinart, 2003). Land degradation became a problem in certain parts of the Cape Colony, especially during the early 1900s. This was exacerbated by the early 1920s and 1930s droughts. The authorities recognised the need for planning in order to prevent land degradation and to improve efficient utilization of the natural resources. The imposition of regulations for fencing, subsidies for boreholes and water reticulation and predator control transformed the agricultural system – farmers had to change their farming system to settled rangelands (Penn, 1986; Hoffman *et al.,* 1999; Archer, 2000; Beinart, 2003).

Drought avoidance strategies according to climate and vegetation patterns are still strategies practised by livestock farmers today (O'Farrel *et al*., 2007; Jordaan, 2011). Commercial farmers with land in different climate zones plan their farming system according to the availability of feed and fodder in the different climate zones. Examples of such a practice are livestock farmers with land in the highveld of the eastern Free State and Mpumalanga, and with land in the lowveld and KwaZulu-Natal. During the summer months, these farmers farm on the highveld, and move with their animals to the lowveld and KwaZulu-Natal during the winter months when it becomes very cold in the highveld and the normal sourveld becomes unpalatable (Jordaan, 2011). The different climate zones with different vegetation types serve as an ideal risk reduction strategy for droughts. A similar practice is followed in the Northern Cape, where farmers move animals between the summer rainfall area of Boesmanland and the winter rainfall area of Namaqualand. Farmers in the Karoo often own farms at low and high altitude and move animals between farms (Jordaan, 2011). Good road and transport systems make it possible to transport animals over large distances (O’Farrel *et al.,* 2007; Jordaan, 2011). O’Farrel *et al.* (2007) stress the importance of land ownership as a limiting factor to a transhumance farming system. In most cases, a strategy for drought risk reduction is an option only for the larger farmers who can afford more farms and own larger farms. Medium sized and smaller farmers have no option but to adapt to the challenges of recurrent droughts.

Communal and small-scale farmers pursue some drought avoiding strategies on a much lower scale and over shorter distances. Seasonal movement of animals takes place over short distances, but drought periods result in larger scale movement of animals over longer distances (Scoones, 1992). Communal farmers are much more restricted in the sense that they do not own land and depend on strong social structures and networks in order to find alternative grazing for their animals. Family networks and connections more often than not are the key to a drought avoidance strategy (Scoones, 1992; Bruschweiler & Gabathuler, 2006; Smucker & Wisner *et al.,* 2007). Apart from the limitation of land availability, is the cost of transporting animals from one area to another and restrictions imposed by land owners or authorities in control of communal land on the influx of additional animals (Scoones, 1992; Dercon & Porter, 2007).

In order to overcome the constraints of high transport costs and the availability of additional land, communal farmers join their herds in order to survive. They also "*lend*" animals to relatives and friends who have access to grazing and thereby reduce the stocking rate on the drought-stricken areas. The relatives benefit in terms of a percentage of the progeny or milk production during the period when they look after the animals. All these activities have the benefit of cementing social relationships (Scoones, 1992; Smucker & Wisner *et al.,* 2007).

Drought evading strategies based on the principle of "lending" is not new among commercial farmers. In many cases, animals have to be transported over long distances and government support plays an important role in this strategy. Some examples of mass railment of animals from drought-stricken areas to non-affected areas date back to 1933. The mass movement of animals during 1933 from the Northern Cape and the Eastern Cape to the Free State and the central/eastern Karoo is a good example of a drought evading strategy. The *Noordwester* of 20 June 1933, reported on the trucking of the following number of sheep during the second half of May 1933 from the Calvinia region:

- On 25 May 1933; 780 train truckloads form Hutchinson-Calvinia;
- The week ending 1 June 1933; 900 truckloads at Calvinia and 300 between Beaufort West and de Aar;
- From 19-29 May 1933; 1 427 train trucks of animals off-loaded in the Free State, with orders for 500 more;
- The week ending 27 May 1933; 683 train trucks from the northern parts of the Cape Province;
- The Central Karoo, Middelburg, Graaff Reinet received 38 000 animals during the week ending 25 May 1933.

Commercial farmers still apply "*lending*" as a drought evading strategy – in most cases, based on economic principles. The land owner who provides the grazing will negotiate compensation that is affordable to the stock farmer in need of land. The two parties negotiate a cash payment as lease per LSU or SSU per month, or the stockowner offers a percentage of the progeny to the land owner in exchange for grazing rights (Jordaan, 2011).

There are different drought avoidance strategies being practised by famers, both at small scale and large scale. Drought avoidance strategies according to climate and vegetation patterns are still strategies practised by livestock farmers today (O'Farrel *et al*., 2007; Jordaan, 2011; Jordaan & Adoko, 2014). Different strategies being practised include the following:

- Commercial farmers possess land in different climate zones and plan their farming system according to the availability of feed and fodder in the different climate zones. Such is a practice by, for example, livestock farmers with land in the highveld of the eastern Free State and Mpumalanga, or those with land in the lowveld and KwaZulu-Natal. During the summer months, these farmers farm on the highveld, and move with their animals to the lowveld and KwaZulu-Natal during the winter months when it becomes very cold in the highveld and the normal sourveld is unpalatable. The different climate zones with different vegetation types serve as an ideal risk reduction strategy for droughts. In another example, Northern Cape farmers move animals between the summer rainfall area of Boesmanland and the winter rainfall area of Namaqualand.

- Family networks and connections more often than not are the key to a drought avoidance strategy (Scoones, 1992; Bruschweiler & Gabathuler, 2006; Wisner *et al*., 2007).
- Transportation of animals takes place from one area to another (government support plays an important role in this strategy).
- Commercial farmers still apply "lending" as a drought evading strategy – in most cases, based on economic principles. The land owner who provides the grazing will negotiate compensation that is affordable to the stock farmer in need of land. The two parties negotiate a cash payment as lease per LSU or SSU per month, or the stock owner offers a percentage of the progeny to the land owner in exchange for grazing rights.
- Pasturalists move animals over large distances in seach of grazing and water and therefore avoid droughts in specific areas.

3.4.5.4 Coping strategies

Coping capacity also refers to resiliency and/or adaptation. It is an indication of how well individuals, livelihoods, communities or systems cope with the impact of adverse events – drought in the context of this study. It is important to note that coping capacity mirrors the values for vulnerability – it is the "*under the line"* values in the simplified risk equation.

Coping mechanisms for drought refer to the strategy applied by individuals, families, communities, institutions, firms and societies or governments to cope with the negative effects of a drought. Dercon (2007) argues that too much attention in research is given to the risk and coping mechanisms and too little to the impact of these mechanisms. According to him, the long run implications of coping strategies are not fully realised; this then creates a false impression of sustainability without considering the long term implications for economic growth and poverty. Davies (2000), Haile (2005) and Tadesse *et al*. (2008) agree that many coping strategies have resulted in chronic poverty due to unsustainable livelihood strategies. The selling of breeding stock during drought shocks is an example of such a strategy.

Erikson & Silva (2009) conducted research in the Matidze and Massavasse communities in Mozambique and found the following drought coping strategies: (i) local trade; (ii) remittances; (iii) assistance from friends and family; (iv) charcoal production; (v) collecting wild fruits; (vi) fishing; (vii) livestock and poultry sales; (viii) artisan activities; (ix) casual employment; (x) credit; (xi) food for work program (NGO/government intervention); (xii) brewing local alcohol; and (xiii) growing vegetables.

Jordaan & Adoko (2014) reported similar coping strategies in Uganda where livelihoods apply the following coping strategies during drought: (i) limiting meals to 2 per day; (ii) eating wild fruits and roots; (iii) charcoal burning and selling; (iv) sand mining; (v) gold mining; (vi) casual labour; (vii) migration to larger centres with job or income opportunities; (viii) selling of healthy, small animals; and (ix) selling of healthy cattle or camels as a last resort.

Coping strategies differ among communities and households, in most cases depending on what is available from the environment, the market and what other survival options exist (Watts, 1983; Corbett, 1988; Hutschinson, 1992; FEWS, 1999). Previous research on drought coping strategies confirms the diversity of household and community responses to address immediate subsistence needs and to decrease vulnerability (Richards, 1986; Rocheleau, Steinberg & Benjamin, 1995; de Waal, 2004 and Smucker & Wisner, 2007). Erikson & Silva (2009) report an increase in market related activities and a diversification into a multiplicity of strategies. O'Laughlin (2001), Tschakert (2007) and Erikson & Silva (2009) find that due to infrastructural deficiencies, women are often more harshly affected than men and that women are involved in different coping strategies than men. They have concluded that coping strategies have a social, geographic and gender profile.

Watts (1983), Corbett (1988) and Hutchinson (1992) developed a model for household responses (coping mechanisms) during and after shocks. The USAID included the household response framework as a basis for vulnerability assessments in its vulnerability assessment handbook (USAID, 1999). The framework illustrated in Figure 3.11 shows the relation between the vulnerability level and coping strategies and the ways in which households respond to shocks.

Several caveats exist for interpreting and applying the model. Some of the coping activities may be routinely used in non-emergency situations while others may be used as a form of coping during expected seasonal variations, especially when households are poor.

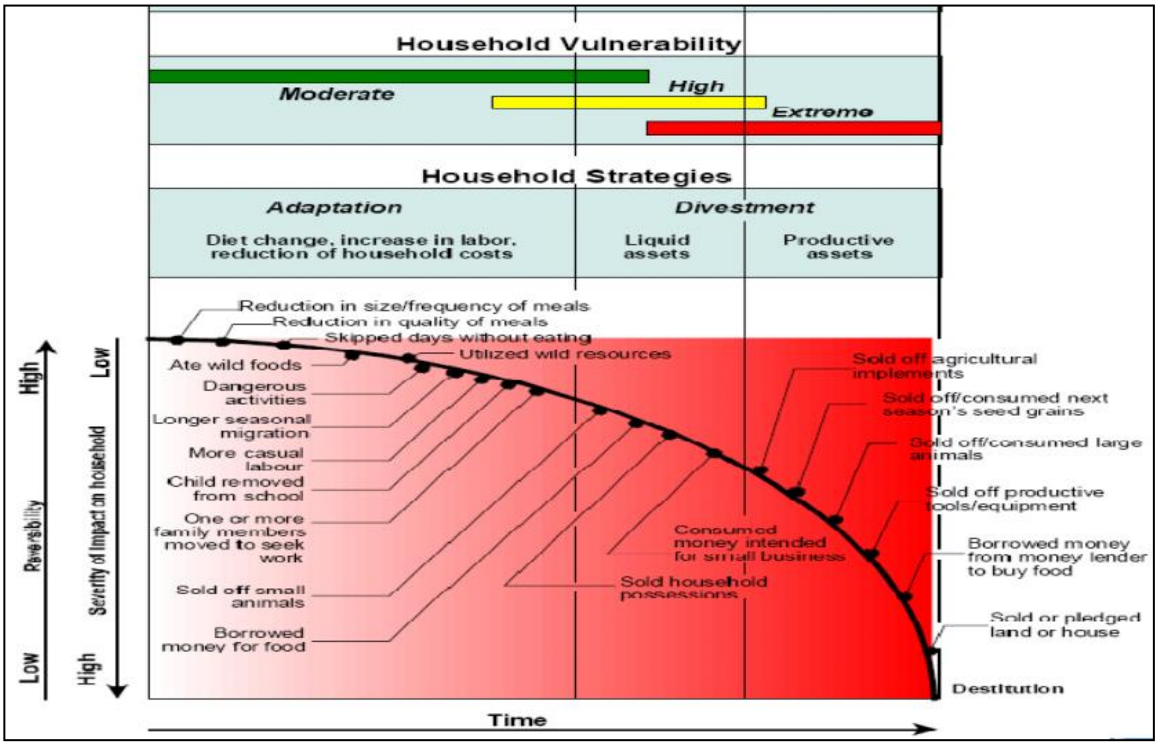

Fig. 3.11: Sequencing of household coping responses
(Source: USAID Food Security & Early Warning Vulnerability Assessment Manual, 1999 [After Watts, 1983])

Hutschinson (1992) argues that coping may not proceed sequentially along a singular trajectory, but that households might pursue several strategies in parallel. Figure 3.11 (also called the Watts framework[6]) illustrates the general progression of types of coping activities that can be applied to most households in most regions as (i) adaptation (making do with what is available); (ii) divestment of liquid assets; (iii) divestment of productive assets; and (iv) out-migration. The World Health Organization (WHO) also uses a classification system that coincides with the Watts framework. WHO classifies the coping strategies as (i) non-erosive; (ii) erosive; and (ii) failed strategies. The activities are basically the same as those illustrated in the USAID framework, and are elaborated upon below:

- Non-erosive coping or adaptation strategies
  - Changing preferred patterns of consumption
  - Borrowing
  - Reduction in food consumption such as skipping meals or shifting to food that is more readily available
  - Substitution of cheaper food
  - Cut in non-essential expenses
  - Sale of non-productive assets

[6] Called the Watts Framework since Watts was the first person to develop the framework, while Corbett and Hutschinson later refined certain aspects of the framework.

    - Alternative livelihood incomes such as own charcoal production and sales

  Note that at this stage the market might reflect an increase in cereal prices and pressure on labour prices.

- Erosive coping or divestment of liquid assets

    - Borrowing, often at exorbitant interest rates
    - Sales of liquid assets such as small animals or accumulated wealth (for example sale of jewellery)
    - Sales of productive assets
    - Tapping into resources of extended family
    - Bonded labour arrangements
    - Child labour

  Note that at this stage markets possibly reflect an increase in the number of small animals for sale at deflated prices, a continued rise in cereal prices and an accelerated decline in terms of trade (e.g. cereal per small stock unit, i.e. SSU).

- Failed coping or divestment of productive assets

    - Heavy reliance on hand-outs
    - Out-migration
    - Prostitution
    - Stealing, begging (Adams, 1998)
    - Consumption of seed
    - Selling of productive items such as breeding cows, draft animals, ploughs, etc.

  Note that markets will show increasing cereal prices and a decline in prices for farm animals, implements and land, and that once crossing this threshold, it is difficult – if not impossible – for a household to return to previous levels of productivity and food security.

- Out-migration

    - When all other resources have been tapped, people start migrating *en masse* out of the region in search for survival. At this stage, international support is needed and people are not in a situation to recover using their own resources. Drought and famine then become a complex emergency issue with people concentrated in refugee camps.

As mentioned previously, the resilience or the ability of a household to cope with shocks is a function of several factors (Watts, 1983; Richards, 1986; Corbett, 1988; Hutschinson, 1992; Rocheleau *et al.,* 1995; FEWS, 1999; de Waal, 2004; Smucker & Wisner, 2007; Erikson & Silva, 2009). The available options such as distance from labour and produce markets (e.g. along roads, in large urban centres), nearby forests, water sources and tourism all have an influence on the vulnerability and coping strategies for communities. The level of own resources on which a household can draw for survival is also critical (Little *et al.,* 2006; De la Fuente, 2007; Dercon & Porter, 2007; de la Fuente, 2008). Figure 3.12 illustrates the comparison of the different thresholds of households with different levels of own resources.

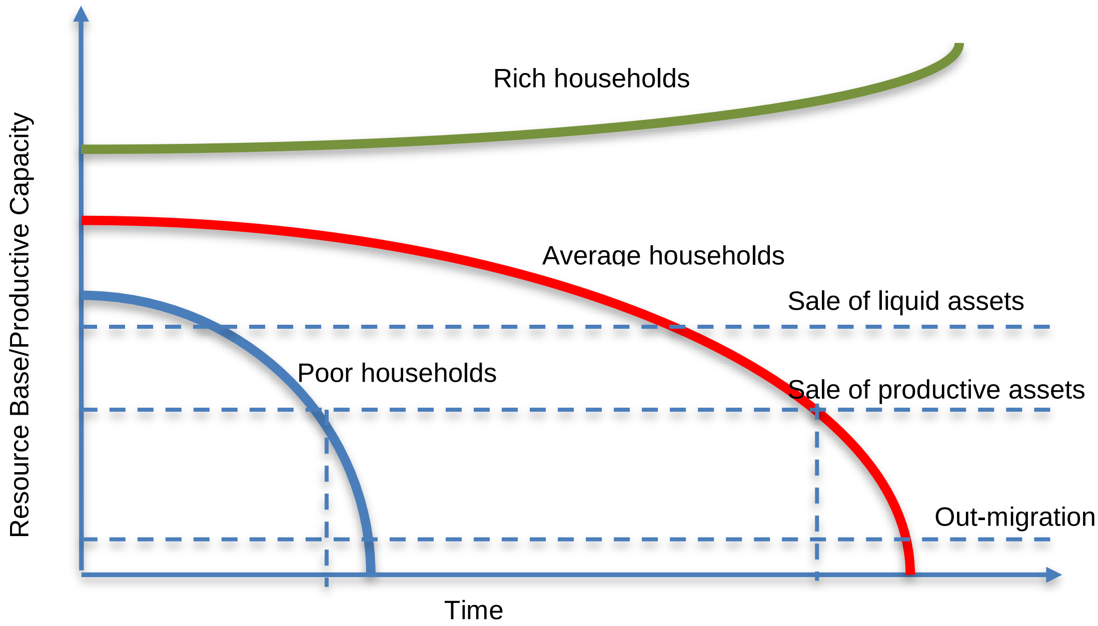

Fig 3.12: Differences between households' responses as a function of resource base
(Source: FEWS 1999; Jordaan, 2011)

Figure 3.12 clearly illustrates that households with different resource levels reach the different thresholds at different times. Evidently households with large resource levels (richer households), in many cases managed to increase their resource base due to favourable prices for animals or other goods (FEWS, 1999; Erikson & Silva, 2009; Jordaan, 2011). They are the only ones with capital and are in a position to exploit members of lower economic classes (FEWS, 1999). Dercon & Porter (2007), De la Fuente & Dercon (2008), and Porter (2010) confirm previous findings from other researchers in Ethiopia where the outcome of shocks vary dramatically among households with little resource base (poor households) compared to richer households. Jordaan (2011) also found that livestock farmers with surplus resources benefit from the negative impacts of drought experienced by resource poor farmers. These farmers manage to buy livestock at low prices when others have to sell, and after the drought they can sell livestock at higher prices. Such farmers are also in a position to buy animals in poor condition, feed them and sell them in better condition to feedlots at a time when the supply of well-conditioned livestock is low.

The vulnerability assessment handbook used by FEWS (1999) highlighted the fact that households form part of different economies and might be impacted differently by the same coping strategies. For example, the sales of small animals might substantially increase the vulnerability of poor household whereas it might not have an impact on richer households at all. Some families might have good linkages with politicians or well-connected people who permit them to tap into resources at a higher level of political or economic organisation. The same accounts for families with membership of extended families or tribes that provide support to members during times of stress.

This section reviewed the different coping mechanisms applied in different countries and in different agricultural systems. Since the focus of this research is on risk assessment in arid and semi-arid regions with extensive livestock farming, attention will be given to livestock farming, which is most common in Africa.

3.4.5.4.1 Alternative livelihood activities (casual labour and informal trade)

Alternative livelihood activities are a non-erosive coping strategy, and is most popular among rural people as a means for survival as a buffer against shocks such as drought (Roncoli *et al*., 2001; Erikson & Silva, 2009). Alternative livelihood activities include (i) casual labour within the community; (ii) casual labour at neighbouring farms and businesses; (iii) formal employment in larger centres and in neighbouring countries; (iv) informal trade; (v) remittances from family members; (vi) loans; and (vi) alternative farming activities. Little *et al*. (2006) completed a study amongst rural households in Ethiopia where they found casual and unskilled labour as one of the major survival strategies among poor people during and after shocks such as drought.

Casual and unskilled labour opportunities in rural areas yield little income, is unreliable and not a sustainable source of income. The limited local employment opportunities force family members to seek jobs elsewhere. Erikson *et al.* (2009) report that people from the Massavasse village in Mozambique seek employment on nearby commercial farms on an almost permanent basis. Many Mozambican families regard income generating opportunities and employment in neighbouring South Africa as an alternative survival strategy for drought in Mozambique. Little *et al.* (2006) report on the value of family members working in large cities such as Djibouti and remitting income from there. The value of family and social networks as a survival strategy is well documented (Jordaan, 2011).

Erikson & Silva (2009) found similar survival patterns in Mozambique where coping strategies varied between villages and families, with diversification in income sources as the main coping strategy. Gebre-Egziabher & Demeke (2004) and Little *et al.* (2006) found that business opportunities in most rural areas were limited to petty trading and other low revenue enterprises, but that they were important for the survival of the poor and contributed significantly to the resilience of rural poor communities. Kinsey *et al*. (1998) found gold panning to be an important source of alternative income in Zimbabwe where as many as 25% of households in their study sample shifted to gold panning as an alternative source of income during the 1992 drought. Erikson & Silva (2009) reported informal and small scale trading at local level as a popular survival strategy in Mozambique. People embarked on selling alcoholic brew, charcoal, livestock, poultry and artisanal products such as reed mats and wild fruits to other villages, traders and intermediaries. Jordaan (2011) also reported informal trading as an important and popular alternative source of livelihood income for poor rural communities in Ethiopia, Sudan, Mozambique, Congo Brazzaville, Zimbabwe and South Africa.

The intensification of a prolonged drought saw a shift in coping strategies from a wide range of market related activities at village level, to a narrowing of market related activities. People had to shift away from village level trade to a focus on outside markets as local stocks and peoples' incomes dwindled. Charcoal burning started as a survival strategy, but later became a viable economic activity for many households who sell charcoal to larger centres (Jordaan & Adoko, 2014)

Rural farmers under stress sought alternative income from ecologically sensitive areas such as forests and therefore contributed to deforestation. Erikson & Silva (2008) and Jordaan & Adoko (2014) reported that people living near forests utilised the forest for burning wood and charcoal or making poles for construction and fencing or other means.

3.4.5.4.2 Food management strategies

Food management strategies are very common during drought and food shortage periods and involve a combination of control, conflict, compliance and cooperation among family members. McMillan (1986), Kevane (2000), Thorson (2000), Roncoli *et al.* (2001) and Little *et al.* (2006) identified the following food management strategies as coping mechanisms during periods of food scarcity:

- Migration by sending young men to larger centres, and children to relatives elsewhere in order to reduce the number of consumers in the household
- Supervising women more strictly in the handling of grain
- Combining cooking responsibilities by reducing the number of women cooking meals
- Using smaller containers to measure grain for cooking
- Reducing the amount of grain used for daily meals
- Reducing the number of meals served per day from three to two
- Relying more on womens' contributions from their fields
- Reducing total consumption of food
- consuming beans, cowpeas or peanuts and famine food[7]

[7] Famine foods are prepared by cooking the young leaves of bushes and trees that become available early in the growing season (Roncoli *et al.,* 2001).

The importance of reduced food consumption is highlighted by the fact that most rural families are subsistent and produce just enough food for own consumption. Evidence suggests that food consumption fell, in all cases, during or after shocks and that it was amongst the first survival (coping) strategies applied by households (Jordaan & Adoko, 2014). Kinsey *et al*. (1998) reported that almost 30% of households from a survey conducted during the 1992 drought in Zimbabwe took only one meal per day, while 50% of households could only take two meals per day. In addition, 70% of families reduced the intake per meal, and about a third of households consumed wild fruits or famine food.

3.4.5.4.3 Sale of non-productive items and productive items

Assets or wealth are captured as stocks, or in most cases in rural Africa as livestock – as opposed to income and consumption flows – that are used as a source of livelihoods against climatic or other shocks. However, the loss of assets as a result of shocks is difficult to recover as a resource for livelihood. The loss of assets (wealth) could compromise health and socio-economic development in the medium to the long term (De la Fuente, 2007; Porter, 2010).

Few rural families manage to accumulate wealth in the way of liquid assets such a cash or jewellery. Kinsey *et al*. (1998) found that few families make use of liquid assets to survive simply because they are too poor to accumulate such assets. On the other hand, some families do indeed manage to save some cash, in which regard women seem play an important role. Roncoli *et al.* (2001) found in a study conducted in Burkina Faso that some men entrusted their spouses with money to save for times of distress. Makoka (2008) mentioned the importance of cash savings as an important *ex-post* coping strategy in Malawi, but found that although asset sales were regarded as a major strategy, safety nets remained the major coping mechanism for smallholder farmers in Malawi. The Watts framework indicates that families will utilise cash and liquid non-productive assets to smooth consumption first, this implying that the threshold for productive livestock sales is postponed. Such families might have a better chance to recover if they are not forced to eventually sell productive livestock under distress.

The difference between productive and non-productive items is founded in the future value of an asset and not necessarily in the current value. Small stock amongst smallholder stock farmers is generally regarded as a non-productive asset since farmers sell it routinely when cash is needed. Cattle sales, on the other hand, confer a much higher degree of stress since cattle are regarded as wealth (Roncoli, 2001). In most cases farmers sell cattle under distress due to lack of feed and fodder when drought is in an already advanced stage, and cattle sales remain the major coping strategy during drought (Kinsey *et al.,* 1998; Jordaan, 2011; Jordaan & Adoko, 2014). When this happens the supply of poorly conditioned and unhealthy cattle surpasses the demand; prices are highly deflated and farmers are unable to reconstitute their stock after the drought (Fafchamps, 1998; Little *et al*., 2006; de la Fuente & Dercon, 2008; Jordaan, 2011; Jordaan & Adoko, 2014). In a study in Ethiopia, Little *et al.* (2006) found that cattle were sold at 30% of the original value during serious drought shocks, and that farmers had no choice but to sell productive animals at giveaway prices for survival. Amare *et al*.

(2000) and Little *et al*. (2006) reported livestock sales as the main drought coping mechanism for 90% of male and 70% of female herd owners during the 1997-2000 drought in Ethiopia, which resulted in a decline of 40% in oxen and total herd numbers (De la Fuente & Dercon, 2008).

Many developers and scientists consider livestock in rural Africa as a key asset to compensate for the failure of access to credit and insurance markets, but the covariance between local shocks and local asset prices (markets) undermines the capacity of livestock ownership to serve as a sufficient buffer during shocks and crises. The deterioration of the terms of trade during drought (shocks) with most consumption goods, complicates the value of livestock for consumption smoothing (De la Fuente, 2007; De La Fuente & Dercon, 2008). Fafchamps *et al*. (1998), for example found that livestock only compensated for between 20%-30% of crop income shortfalls during the 1984-1985 drought in Burkina Faso. Reardon & Taylor (1996), on the other hand, argued that livestock ownership and recurrent sales buffered the poor because the un-equalizing effect of the 1984-1985 Burkina Faso drought was partially counterbalanced with animal sales by the poor. Hoddinot and Kinsey (2001) reported a positive correlation between growth of children and animal ownership and livestock sales during the 1994-1995 drought in Zimbabwe. They argued that animal sales indeed smoothed consumption and that childrens' growth from families with livestock were not negatively affected, as was the case with poor families without livestock sales as a coping strategy.

One cannot neglect the importance of livestock as an asset to smooth consumption during shocks, but the long term negative effects are not always calculated when considering the short term advantage of livestock sales as a consumption smoothing strategy. Researchers are in agreement that households not only reduce consumption and deplete their assets in the wake of natural shocks, but they also lose the ability to rebuild productive assets and to recover to the same state as before (Carter *et al*., 2004; Little *et al.,* 2006; Baez, 2007; de la Fuente, 2007). Dercon (2002) found that cattle holdings in Ethiopian households could only replace two thirds of original cattle numbers ten years after the drought. Little *et al.* (2006) reported that households that lost animals during drought remained vulnerable and poor for six years after the drought in Ethiopia, and poor families had to borrow animals (often on a share-herd basis) to re-stock their herds after the 1998-2000 drought.

3.4.5.4.4 Social networks

Social networks among rural poor communities are an important strategy to cope with any type of shock (Bruschweiler & Gabathuler, 2006). Social networks and relations are normally based on kinship and other principles, and allow poor people to sustain themselves even at low levels of welfare. In their study amongst rural people in Ethiopia after the 1998-2000 drought, Little *et al.* (2006) found that almost 50% of informal money borrowing and more than 40% of sharecropping took place amongst relatives. They also found that 63% of all assistance was between kin or marriage relations. Contrary to what one might expect, material assistance declined during periods of drought, simply because people were already so poor and had little to share, and this partly explains why poor households suffer during shocks, but are able to recover as soon as assistance from relatives re-emerged (Little *et al*., 2006; Smucker & Wisner, 2007).

Smucker & Wisner (2007) argue that coping mechanisms based on social or kinship networks present the smallest threat to long term sustainable livelihoods because of the low requirement to commit productive resources for coping with drought. An interesting observation made by Smucker & Wisner (2007) in the Thakara region in Kenya was that assistance from family and social networks declined over time from 1971 to 2000, with the wealthier sector of the population less reliant on social networks than the poor. While the importance of social and kinship networks dwindled from 1971 to 2000, the dependence on assistance from government increased for all rural people. Respondents in this research related this observable fact to a broader cultural shift that eroded family support structures and mutual relationships.

3.4.5.4.5 Animal feeding strategies

Farming communities mainly apply *dry season feeding* strategies upon realising that sufficient feed and fodder are not available from the veld as usual. Farmers seek additional feed and fodder first in the hope that the drought is a short term one and that they will be able to keep original animal numbers. Leng (1986), Hoon (1999), Johnson (1999) and Rothauge (2008) propose the use of supplementary feeding through concentrates to provide the nutritional needs of animals. Maphane & Mutshewa (1999), however, report that energy concentrates and mineral supplements remain a luxury to the small-scale communal farmers in Botswana, who cannot purchase these essential nutrients. This is also confirmed by Maphane & Mutshewa (1999) in Botswana, Matita (1999) in Malawi, Mukumbuta & Yamba (1999) in Zambia and Uaila (1999) in Mozambique, Chenimbiri (1999) in Zimbabwe, Els *et al*. (1999) in Namibia and Hudson (2002) and Jordaan (2011) in South Africa. They found the opposite amongst commercial farmers and some of the larger, more progressive communal farmers, as these farmers had successfully utilised supplementary feeding through concentrates as a drought coping strategy. The main reasons cited by these scientists for the lack of supplementary feeding amongst communal farmers were the following (Jordaan, 2011):

- Lack of capital to purchase supplementary feeding;
- Lack of input suppliers and long distances from input suppliers;
- High transport costs from input suppliers or lack of transport; and
- Ignorance regarding the benefits of supplementary feeding.

One of the best known strategists for drought planning at farm level, Emeritus Professor Ron Leng from the University of New England (Australia) proposed the following major rules when considering a strategy for drought feeding (Leng, 1986):

- When a drought is present, if you have to think about what you are doing, you will be in no position to obtain the necessary resources to apply modern concepts. You have to be knowledgeable in order to plan your actions thoughtfully should the situation get worse.
- The aim of a drought feeding strategy should always be to optimise the utilisation efficiency of the available least-cost resource. Early in the drought, this is nearly always dry veld, but it becomes some form of supplementary feeding as available veld is reduced.
- When a drought is prolonged and pasture is virtually absent, or the animals have grazed as much as possible without excessive soil erosion occurring, it is important to use combinations of supplements to optimise utilisation of the least expensive (money and labour wise) feed resource.

3.4.5.4.6 Drought insurance

The lack of access to credit, land and institutions to rural poor people is a well-documented restriction to economic growth and poverty alleviation (Porter, 1990; Norton & Alwang, 1993; Wisner *et al.,* 2004; Dercon & Porter, 2007; Dercon, 2009; Jordaan, 2011). Barnett *et al*. (2008) highlight the incomplete, and in most cases non-existent, formal insurance markets in most developing countries. In addition to the above-mentioned restrictions to the poor, short term economic, social and natural shocks have long term consequences on resources of poor families in that, more often than not, production assets are depleted (Fafchamps *et al.*, 1998; Hoogeveen, 2000; Kreimer, 2000; Little *et al*., 2006; Alderman & Haque, 2007; Dercon, 2009; Erikson & Silva, 2009; Porter, 2010). Poor people in developing countries are disproportionately vulnerable to agricultural risks and shocks, making the need for insurance more important (Dercon, 2004). Barnett *et al*. (2008) report on the strong potential role for risk transfer mechanisms such as insurance and credit markets in the wake of financial market failures and poverty traps in developing countries. They assert that much of this potential is now being directed towards the development and application of index-based risk transfer products (IBRTPs).

Farmers prefer to stabilise consumption through different strategies such as insurance and capital formation, and in the cases of resource poor farmers for which insurance is not available, through trading off potential income by adopting low-risk low-return strategies and capital depletion by selling productive assets. Resource poor farmers would, for instance, rather not buy fertiliser to increase productivity since they regard it as high risk because they must still bear the cost of fertiliser even if the harvest fails. It is common for resource poor farmers to be risk averse with resultant low returns (Kinsey *et al.,* 1998; Kreimer *et al*., 2000; Dercon, 2004; Alderman & Haque, 2007; Dercon & Porter, 2007, Dercon, 2009; Karlan & Morduch, 2010).

In the*“2020 Vision for Food, Agriculture and the Environment”* prepared by Stephan Dercon, the International Food Policy Research Institute (IFPRI) warns that insurance is not necessarily the best policy intervention to deal with risks and shocks amongst resource poor people such as farmers (Dercon, 2009). They warn that risk reduction planning and management outweigh the advantages of insurance, and that insurance might allow more risk taking amongst the poor, but that it is not a substitute for income growth policies. Alderman & Haque (2007) and Karlan & Morduch (2010) also mention the lack of data and research on the impact of insurance on the poor, where the covariate nature of many shocks tend to deteriorate informal insurance and traditional mutual assistance. Safety nets in developing countries have an *income transfer* function as well as an *insurance* function, but little is known about its insurance function following shocks such as drought.

Insurance companies regard drought insurance as too risky and because of that, the high risk is set off against unaffordable high premiums for farmers. In addition to the challenges of drought risk for commercial farmers, smallholder farmers and resource poor families who depend on agriculture for a livelihood are largely excluded from any insurance products. The classic problem connected to agricultural and drought insurance are (i) moral hazards; (ii) adverse selection; (iii) correlated risk and potentially large financial losses; (iv) high transaction costs (marketing, monitoring, loss assessing and delivery costs); (v) high loss adjustment costs; and (vi) smallholder farmers that exacerbate the high per-unit cost for farm-level products (Skees & Collier, 2004). Goldstein *et al*. (2003) and Alderman & Haque (2007) ascribe the undersupply of insurance to (i) asymmetries of information which lead to fraudulent claims; (ii) adverse selection of individuals, where individuals with higher risk profiles seek insurance and those with lower risk profiles find it uneconomical to insure; and (iii) the lack of reliable information leading to inaccurate cost estimates for risk. According to Barret *et al*. (2008) the failure for insurance market failures in developing countries are (i) the lack of effective legal systems to enforce insurance contracts; (ii) the strong covariate risk exposure of poor people; (iii) the asymmetric information problems; and (iv) the high transaction costs.

Most of the obstacles for traditional insurance packages can be addressed by implementing weather-based index insurance. Common features of effective indices are that they are (i) objective; (ii) transparent; (iii) independently verifiable; (iv) easily measured; (v) readily available on time; (vi) have the exceedance probability accurately calculated; and (v) contain available of time series data (Alderman & Haque, 2007). Index insurances, or IBRTPs, differ from traditional insurance products in that they are linked to a specific index such as rainfall, temperature, evapotranspiration etc., instead of to actual losses. IBRTPs make payments based on the realization of an underlying index relative to a specified threshold, which is transparent and an objectively quantifiable random variable (Alderman & Haque, 2007; Barret *et al.,* 2008; Deng *et al.,* 2008). An example of such a variable for drought insurance could be the standard precipitation index (SPI) for rainfall, where payments will be facilitated once the 24-month SPI reaches the threshold of minus 1.5[8].

The advantages of IBRTPs over traditional insurance products should pave the way for a revolution in the insurance industry in providing a risk transfer mechanism to smooth consumption during

[8] Detail discussion of SPI follows in Chapter 4 of this document

shocks[9]. IBTRPs can open insurance markets to the poor in the same way as the Grameen Bank opens credit markets to the poor. Barnett *et al.* (2008) state the main advantages of IBRTPs as (i) the realisation of the index being exogenous to policy-holders; (ii) it not being subject to asymmetric information problems; and (iii) transaction costs being low since the insurer does not have to verify and assess farm level losses.

Ethiopia successfully introduced index insurance against drought at the national level during 2006 through a partnership with the World Food Programme (WFP) and the Ethiopian government in an attempt to transfer national drought risk to the global insurance market. There was no payout due to good rains, but the feasibility of the concept was demonstrated (Hess & Verlangier, 2009). A pilot project for farm level insurance was also launched during 2006 at specified locations with reliable rainfall data, but the uptake from farmers was very low.

Malawi introduced an index insurance scheme during the 2005/2006 season that was based on precipitation data. The payout was based on (i) the deficit in cumulative rainfall at specific dates at three stages in the growth cycle; and (ii) the establishment of vegetative growth, flowering, pod formation and maturity (Alderman & Haque, 2007). In a sense, this was a combination of index and traditional insurance. Karlan & Morduch (2010) reported the tendency amongst farmers in Malawi, where initial uptake for index insurance was very low, of only a few well-educated farmers showing interest in insurance. According to Karlan & Morduch (2009), one of the reasons for the low uptake could be the implicit insurance through loan contracts where farmers did not pay back in case of droughts.

Hellmuth *et al*. (2009), made the following recommendations after investigating the implementation of index insurance in different countries around the globe:

- The lack and quality of sufficient time series data limits the scale-up of index insurance. Implementation of index insurance needs the improvement of data systems and new technologies to fill data gaps.
- Subsidy schemes for premiums should be investigated since risk transfer to the international insurance market can have a net benefit for the national economy. Further research is needed on this aspect.
- Index insurance should be integrated into broader development and disaster risk reduction programmes.
- Investment in marketing and capacity building is needed to support the introduction of index insurance.
- Evaluation and monitoring is needed to assess the real impact on poverty and livelihood sustainability

[9] Droughts in the context of this research

- Insurance should be demand driven and based on risk and needs assessment.
- Index insurance could be a useful strategy for climate change adaptation.
- Governments should provide a strong legal and regulatory environment for index insurance.

Sharing of experiences in the implementation of index insurance is necessary through linking insurers.

3.4.5.5 Drought coping strategies specific to South Africa

Coping with drought is a strategy followed by most commercial as well as small-scale communal farmers today. Le Houerou *et al.* (1996) suggest that coping – which he also refers to as endurance[10] – is a strategy mostly adopted by farmers who are more closely tied to the land and for whom evasion or movement is not an option. Coping with drought entails different management strategies with the aim to minimize losses during drought. These strategies include options to maintain production output, limit inputs and ultimately to maintain reasonable profit levels without depleting the natural resource base to such an extent that it cannot recover sufficiently after the drought.

Myburg (1994), Archer (2004) and Jordaan (2011) found that farmers in the Karoo and the arid Northern Cape are flexible concerning the reduction of stock numbers as a coping mechanism during dry periods, as well as preserving the natural resource base. Coping strategies that involve grazing patterns and reduced stocking rates, are closely related to well-planned camping and water articulated systems (Jordaan, 2011). Le Houerou (1996) describes the timely destocking strategy as the best means of preserving the ecosystem during and after drought. Myburgh (1994) argues that destocking has the same result as an increase in land size, but it is unpopular in most instances since the replacement of the genetic material might be difficult after the drought. The market plays an important role due to the over-supply of animals at the onset of a drought, which has a negative effect on prices. Jordaan (2011) reported that livestock farmers in the Northern Cape apply reduction in animal numbers as the first coping strategy to drought.

The purchase of feed and fodder is probably the most popular coping mechanism used by farmers. Farmers will rather buy feed and fodder (if they do not have own reserves) in anticipation that the drought will be over soon (Myburgh, 1994; Hudson, 2002; Jordaan, 2011). With prolonged droughts, the cost benefit of this strategy eventually forces farmers to sell off some of their livestock. The Department of Agriculture proposes that farmers sell 30% of their livestock at the onset of a drought in order to prevent unnecessary feeding costs and overgrazing on drought stressed grazed lands (Hudson, 2002; Jordaan, 2011).

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[10] Endurance meaning *"sitting it out"*

Pen feeding becomes an option once the grazing land conditions are depleted to the extent that it cannot sustain the nucleus breeding stock. Farmers utilise this intensive system to conserve animals' energy by restricting their movement over large areas in search for forage. It is sometimes required to withdraw all stock from the grazing lands to ensure ecosystem recovery after the drought (Rothauge, 2008).

Coping with increased financial expenditure and lower incomes is the most challenging aspect of coping with drought. Examples of financial coping mechanisms are, firstly, a firm control over expenditure and rigorous budget cuts where possible. Farmers cut down on luxuries such as holidays, visits to neighbours and friends, and household expenditures; capital expenditures are put on hold; budgets are scrutinised and unnecessary expenditures prevented (Jordaan, 2011). The second financial coping strategy is to seek additional funding if own cash reserves become depleted. External assistance is sought through the acquisition of loans for monetary support or communal efforts by pooling resources, labour sharing or applying for subsidised support (Myburgh, 1994; Jordaan, 2011).

Efficient water use and the management of water sources are critical during droughts. Water availability is the single most important factor for livestock health and survival during droughts and is experienced as the primary limiting factor of herd size (Hudson, 2002). Animals need up to 12 times more than normal intake of water during warm and dry periods (Hudson, 2002; Scoones, 1992). This increases the importance of sufficient and clean water supply. In most cases farmers drill additional boreholes or transport water to watering points as a mechanism to cope. This can be costly, especially if farmers have to transport water over long distances. Pen feeding sometimes becomes necessary because of the lack of sufficient water supply in the grazing camps (Jordaan, 2011).

Coping for communal farmers is somewhat different from that of commercial farmers since they do not have access to additional resources, and what they have in terms of land is limited and in most cases already degraded (Jordaan, 2011). Communal farmers are significantly more dependent on social structures and networks for their survival during drought (Scoones, 1992; Beinart, 2003). They are much more vulnerable to drought than commercial farmers and do not have the resources and means to cope with drought without the support of others – be it family members, friends or government. According to Scoones (1992) and Jordaan (2011) additional feed and fodder are the most popular coping strategy among communal farmers, yet Olaleye (2010), in a master's study amongst communal farmers in the Free State, found that only 43% of communal farmers provided supplementary feeding to their animals during droughts[11]. The lack of capital was cited as the main reason why 57% of farmers did not provide supplementary feeding. The findings regarding supplementary feeding among communal farmers confirmed the findings of scientists from other African countries as discussed in the previous section, e.g. Maphane & Mutshewa (1999) in

[11] This should be compared to 33% farmers who supply supplementary feeding during normal times.

Botswana, Matita (1999) in Malawi, Mukumbuta & Yamba (1999) in Zambia, Uaila (1999) in Mozambique, Chenimbiri (1999) in Zimbabwe and Els *et al*. (1999) in Namibia.

Hudson (2002), in a master's study in North West Province, confirms the differences in coping strategies for communal and commercial farmers. He reports that 44% of commercial farmers reduce stock numbers as a drought strategy compared to only 3% of communal farmers. Twenty-three per cent of communal farmers, on the other hand, indicate that they first buy fodder compared to only 16% of commercial farmers. The study concluded that communal farmers only started selling animals under severe conditions when they needed money to buy feed and fodder to keep remaining animals alive. By then, animals were already in such a poor condition that they received way below market prices for them.

Jordaan (2011) reported that commercial livestock farmers in the Northern Cape cope with drought by applying the following strategies:

- Purchasing of additional licks and concentrates;
- Selling animals, starting with poor quality and older animals before the onset of a dry period;
- Use of own fodder banks
- Additional sales of breeding animals during the drought;
- Purchasing of additional feed and fodder; and
- Leasing of additional land if it is available.

Drought can have a devastating impact on the farming community and farmers can be financially ruined as a result of droughts. In order to cope with the additional expenditures, farmers also apply the following survival and coping strategies (Jordaan, 2011):

- Lowering of living standards by cutting down on personal expenditure such as holidays and luxuries;
- Suspension of infrastructure maintenance programmes;
- Utilising savings for additional purchases;
- Rescheduling of current loan instalments;
- Taking out additional loans from banks, including the Landbank and Agricultural Cooperatives and Companies;
- Selling of non-farm assets;
- Selling of surplus farm assets; and/or
- Selling of livestock breeding material (as a last resort after initial livestock sales).

The perception of drought risk also seems to be an important factor. Some farmers in the Northern Cape reported that they never needed drought support as a result of conservative farming methods, and it was clear that these farmers took account of the climatic extremes of the arid Northern Cape and structure their farming activities and decision-making accordingly. It was clear that those farmers' perceptions of drought risk differed significantly from the majority of farmers, and therefore the risk reduction effort was embedded in their normal planning (Jordaan, 2011). All the "*conservation farmers*" had experienced previous droughts, which confirmed the findings noted in the literature that if people perceived risks to be real, they would act accordingly (Slovik, 2002; Dwyer, 2004).

Each day, people make their own risk management decisions, which include consciously and subconsciously reviewing the possible consequences and benefits of risk. Dwyer (2004), on the other hand, notes that in situations where actual risk is often unknown or untested, such as the risk from natural hazards, perceived risk may be considered a substitute for actual risk. In the case of extreme droughts, most farmers have a perceived risk of drought, and the potential impact is known (whether through own experience or through the experience of previous generations, whereby older farmers tell the new generation about the previous drought impacts). It therefore seems that perceived risk still has to be taken into account when calculating risk – especially since perceived risk contributes to risk reduction planning and could be useful in extension work.

3.4.6 Measuring Drought Resilience

Resilience is not fixed, it can be adjusted and and developed within a system; it is dynamic and communities can do something about it. It is not possible for communities to achieve absolute resilience against drought or any other hazards because of the dynamic nature of hazards – no hazard is the same. In spite of its being dynamic, it is still essential to understand the dimensions and factors that contribute to resilience. There are many tools available to measure resilience. The majority of approaches, tools and methods currently available, reflect the diversity of disciplines and sectors (Mitchell & Harris, 2012).

Resilience analysis is not an alternative to vulnerability analysis, but rather complements it. Vulnerability analysis tends to measure only the susceptibility of people to damage when exposed to particular hazards or shocks (Alinovi *et al.,* 2010a). Resilience assessment, on the other hand, focuses on the reasons why some systems or farmers perform better under stress than others (Jordaan, 2011). Measuring drought resilience requires an interdisciplinary approach that focuses on assessing factors such as (i) technological capacity, (ii) skills, expertise and education levels, (iii) economic status and capacity, (iv) growth prospects, (v) the quality of environment, (vi) natural resource management, (vii) institutions, (viii) livelihood assets, (ix) political structures and processes, (x) infrastructure, (xi) flows of knowledge and information, and (xii) the speed and breadth of innovation (Mitchell & Harris, 2012). The task of measuring resilience is also highly variable, depending on the understanding and weight given to concepts such as vulnerability, coping and adaptive capacity (Dalziell & McManus, 2004).

Risk is a product of exposure, vulnerability and resiliency either to hazard(s) or effect(s) of climate change, or both. The greater the vulnerability, exposure, magnitude and likelihood of the hazard/climate shock, the greater the risk. Thus, to reduce drought risk, exposure needs to be minimized, vulnerability reduced, and capacities for resilience strengthened. This is a dynamic process requiring continual effort across economic, social, cultural, environmental, institutional and political spheres (Turnbull *et al*., 2013). Different approaches are known for measureing and the most relevant in terms of drought resilience are the following, namely the:

- Vulnerability approach,
- Adaptive capacity approach,
- Indicator approach,
- Community capitals approach, and the
- Financial approach.

3.4.6.1 Vulnerability approach

According to Ibarrarán *et al*. (2008), resilience includes components of sensitivity and coping, or adaptive capacity, which ultimately constitutes vulnerability. There is disagreement on this view, since in practice, some components of vulnerability are usually dropped when developing resilience indicators (Ellis, 2014). Ibarrarán *et al*. (2008) suggest that resilience is not simply the inverse of vulnerability, while McAslan (2011) also suggests that vulnerability and resilience are not necessarily the inverse of each other. Fischer *et al*. (2013) and Ellis (2014) highlighted vulnerability as being a function of three core factors and suggested the following questions to be associated with each component of vulnerability:

- The character, magnitude and rate of climate change impacts to which the system is exposed *(Exposure: What environmental events related with climate change may adversely affect resources that human communities rely on or derive value from? Which communities derive value from resources that are likely to be affected?)*;
- The sensitivity of the system, i.e. the degree to which a system could be affected adversely or beneficially by climate change *(Sensitivity: How many drought related changes in local resources affect human communities' use of those resources and vice versa? Which communities will be affected and why?)*;
- The adaptive capacity of a system. i.e. the ability of a system to adjust to drought, to moderate potential damages, to take advantage of opportunities or to cope with the consequences *(Adaptive Capacity: What capabilities do human communities have for adapting and mitigating drought-related impacts? What opportunities exist for human communities to learn to become more capable of adapting?).*

Despite the disagreements in the literature, the relationship between vulnerability and resilience is very clear. It means, therefore, that if one takes resilience to be the inverse of vulnerability, then the discussion above on vulnerability indicators are relevant to the development of resilience indicators.

3.4.6.2 Adaptive capacity approach

A second approach to operationalizing resilience is presented by Malone (2009). He suggests for analytical and practical purposes that resilience be equated with adaptive capacity. Adaptive capacity is defined as: *" to design and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards. The adaptation process requires the capacity to learn from previous experiences to cope with current climate, and to apply these lessons to cope with future climate, including surprises"* (Ellis, 2014).

The capacity to avoid, cope, adjust or adapt is a significant factor in characterizing resilience. Coping capacity is considered in the short term, however, adaptation is the longer-term strategy which involves significant changes in lifestyles, livelihoods and farming practices (Sewell *et al*., 1968; Myburg, 1994; Vogel, 1995; O'Farrell *et al*., 2009, Jordaan, 2011). The IPCC (2001) and Smit & Wandel (2006) describe adaptive capacity as *"the potential or ability of a system, region, or community to adjust to the effects or impacts of climate change (including climate variability and extremes). The capacity to adapt is context-specific and varies from country to country, from community to community, among social groups and individuals, and over time".* Burton (2002) defines adaptation as the ability of social and environmental systems to adjust to change and shocks in order to cope with the consequences.

McCarthy *et al.* (2001) consider adaptive capacity as "*a function of wealth, technology, education, information, skills, infrastructure, access to resources, and stability and management capabilities"*. Bhamra *et al*. (2011) concluded that the adaptive capacity of a system is related to the mechanisms for the creation of novelty and learning, whereas Gunderson (2000) described adaptive capacity in regard to ecological resilience as a "*system's robustness to alterations and changes in resilience"*. Brooks (2003), argues that the adaptive capacity of a system or society reflects its ability to modify its characteristics or behaviour to cope with existing or anticipated external stresses and changes in external conditions. Eriksen, Brown & Kelly (2005) describe coping mechanisms as the actions and activities that take place within existing structures and systems. According to the concept of vulnerability, Bhamra *et al*. (2011) adapted the Gallopı´ns (2006) model, and concluded that adaptive capacity was linked to the capacity to respond. He had defined resilience as the ability of a system to evolve in order to accommodate environmental threats or changes and the ability to expand the range of variability. Nelson *et al*. 2007) defined adaptation as a process of deliberate change in anticipation of external changes or stresses. They viewed adaptation as a fundamental feature of socio-ecological systems, built on the resilience of communities within those systems.

Studies in search of indicators of adaptive capacity have attempted to provide a conceptual framework and operational methods to measure adaptive capacity (Swanson *et al*., 2007). Smit *et al*. (2001) identified six determinants of adaptive capacity (Table 3.7), which provide guidance for the development of indicators in the context of climate change. The six determinants are (i) economic resources, (ii) technology, (iii) information and skils, (iv) infrastructure, (v) institutions, and (vi) equity.

Table 3.7: Determinants of adaptive capacity

Determinant	Rationale
Economic resources	Greater economic resources increase adaptive capacity
	Lack of financial resources limits adaptation options
Technology	Lack of technology limits range of potential adaptation options
	Less technologically advanced regions are less likely to develop and/or implement technological adaptations
Information and skills	Lack of informed, skilled and trained personnel reduces adaptive capacity
	Greater access to information increases likelihood of timely and appropriate adaptation
Infrastructure	Greater variety of infrastructure can enhance adaptive capacity, since it provides more options
	Characteristics and location of infrastructure also affect adaptive capacity
Institutions	Well-developed social institutions help to reduce impacts of climate- related risks and therefore increase adaptive capacity
	Policies and regulations may constrain or enhance adaptive capacity
Equity	Equitable distribution of resources increases adaptive capacity
	Both availability of and entitlement to resources are important

Smit et al. (2001)

Swanson *et al*. (2007) further elaborated on the determinants of adaptive capacity as indicated by Smit *et al*. (2001). They identified 24 aspects of adaptive capacity from the adaptive capacity determinants in Table 3.8. These indicator aspects are specific, measurable and time-bound and explain the resilience determinants proposed by Smit *et al.* (2001).

Table 3.8: Indicators identified for the aspects of adaptive capacity:

Determinant	Aspect	Indicator
Economic resources	Income generation relative to capital investment	Ratio of gross farm receipts to total capital investment. Higher is better
	Income generation relative to sundry expenses	Ratio of income to expenses. Higher is better
	Off-farm earnings	Off-farm earnings as a per cent of total family income where families have at least one farm operator. Higher is better.
	Diversity of employment opportunities	Ratio of off-farm contribution of time to on-farm contribution of time Ratio of employment in agriculture to employment in other industries - Lower is better
Technology	Water-access technology	Ratio of value of irrigation equipment to value of all other farm equipment. Higher is better
	Computer technology	Ratio of farms reporting use of computer to all other farms. Higher is better

	Technological flexibility	Ratio of value in tractors under 100-horse power to total value of all other tractors. Lower is better
	Technological exposure	Ratio of technologically demanding to less demanding farm types. Higher is better
Information, skills and management	Enterprise information management	Ratio of farms reporting computer livestock and crop record keeping to all other farms. Higher is better.
	Sustainable soil resource management practices	Ratio of area of no-till or zero-till seeding to tilled area. Higher is better
	Sustainable environmental management practices	Ratio of farms reporting windbreaks and shelterbelts to all other farms. Higher is better
	Human resources management	Ratio of total farms reporting paid agricultural labour to all other farms. Higher is better
Infrastructure	Soil resources	Proportion of area in dependable agricultural land. Higher is better.
	Surface water resources	Ratio of surface water area to total land area. Higher is better.
	Groundwater resources	No. and/or yield of wells. Higher is better.
	Transportation network	Ratio of high capacity to low capacity roads. Higher is better.
Institutions and networks	Informal operating arrangements	Ratio of total farms reporting formal agreements to total no. of farms reporting sole proprietorships and partnerships without written agreement minus miscellaneous category. Lower is better
	E-mail use	Ratio of total farms reporting e-mail use to all other farms. Higher is better
	Internet access	Ratio of farms reporting Internet use to all other farms. Higher is better.
	Opportunity to access agricultural education institutions	Distance between constituency/township and the nearest regionally significant agricultural education institution. Lower is better
Equity	Employment opportunities	Unemployment rate from farm compared to data for Population. Lower is better.
	Opportunity to access health and social services	Ratio of labour force in health and social service occupations to all other occupations. Higher is better
	Distribution of income – agricultural producers	Ratio of farms reporting sales in excess of X Rands to all other farms. Lower is better.

Source: Adapted from Swanson et al. 2007

3.4.6.3 Indicator approach

Indicators are used to measure progress towards a desired goal. Indicators related to climate change help to assess climate change trends and progression, and are used to communicate climate change, climate impacts and the need for and effectiveness of adaptation measures to the general public (Ellis, 2014). They provide support for science-based decision making in the development of mitigation and adaptation strategies (EPA, 2012). They are preferably quantitative and serve four basic purposes: simplification, quantification, standardization and communication (Natural England, 2010). Indicators can be both capital (static) and capacity (dynamic) that measure both the current status of attainment and its potential or actual capacity for change (UNDP, 2013).

The use of indicators in assessing resilience of farmers and communities allows for comparisons of regional, country, provinces, or smaller localities in terms of their vulnerability and resilience to a current and potential hazard such as drought (Brenkert & Malone, 2005). Comparison can provide the basis for developing resilience-building policies and programs. Ibarrarán *et al.* (2010) proposed a comparative quantitative framework, the Vulnerability-Resilience Indicators Model (VRIM), that was developed specifically to integrate socio-economic and environmental information and provide this quantitative comparative basis for assessing resilience. Using the VRIM (Figure 3.13) model the relationships between sensitivity, vulnerability, resilience, adaptation and coping capacity can be compared.

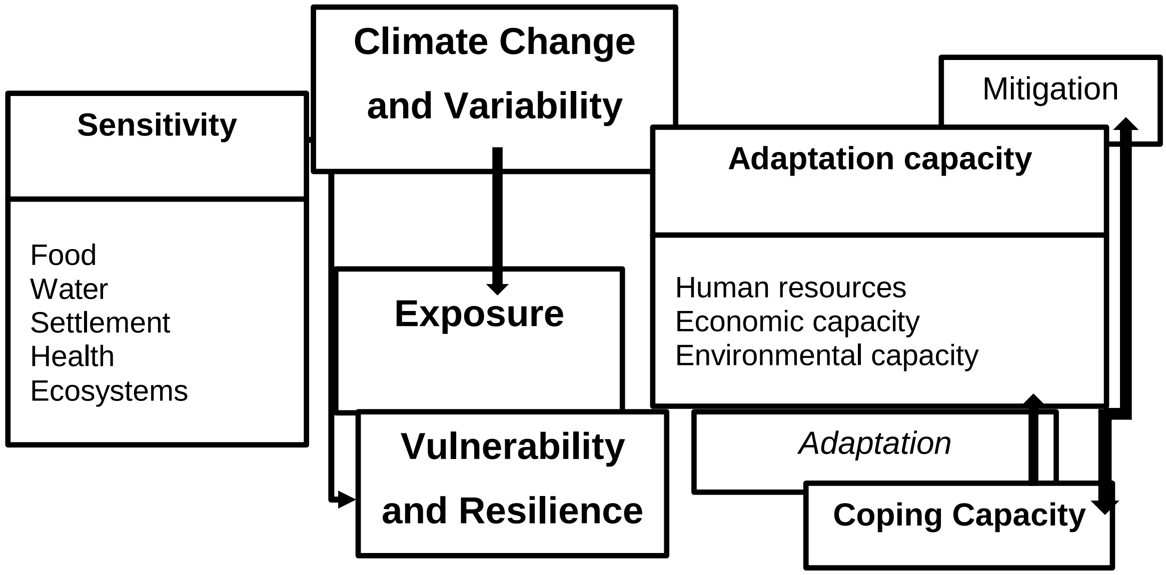

Fig 3.13: Simplified diagram of the Vulnerability-Resilience Indicators Model

The VRIM has been used to compare and evaluate adaptive capacity in 160 countries and examine resilience (Malone & Brenkert, 2009; Ibarraran *et al*., 2010). Table 3.9 lists vulnerability/resilience factors that have been adapted for drought hazard. Through analyzing the sectoral indicators and conducting field assessments and stakeholder reviews, comprehensive drought resilience indicators can be identified and developed. Many of the frameworks identified (i) physical capital, (ii) human capital, (iii) financial capital, (iv) natural capital and (v) social capital as dimensions that contribute to resilience, whilst at the same time realising that these dimensions lead to stability and adaptive capacity which are critical for resilience. The hazard literature suggests that the sustainability and/or resilience of a community depends on its ability to access and utilise the major forms of capital (Beeton, 2006; Walter, 2004). These dimensions can therefore be used to group and map the multi-dimensional components of resilience and to allow cross-comparison between different communities or regions.

Table 3.9: Factors to assess vulnerability/resilience of a society

SECTORAL INDICATORS	PROXY VARIABLES	PROXY FOR
Food security	Cereals production/crop land area	Degree of modernization in the agriculture sector; access of farmers to inputs to buffer against climate variability and change
	Protein consumption/capita	Access of a population to agricultural markets and other mechanisms (e.g., consumption shift) for compensating for shortfalls in production
Water resource sensitivity	Renewable supply and inflow of water	Supply of water from internal renewable resources and inflow from rivers divided by withdrawals to meet current or projected needs
	Population in drought-prone areas	Potential extent of disruptions from low water availability

Settlement/ infrastructure sensitivity	Population without access to clean water	Access of population to basic services to buffer against climate variability and change
	Population without access to sanitation	
Human health sensitivity	Completed fertility	Composite of conditions that affect human health including nutrition, exposure to disease risks, and access to health services
	Life expectancy	
Ecosystem sensitivity	% land managed	Degree of human intrusion into the natural landscape and land fragmentation
	Fertilizer use/ cropland area	Nitrogen/phosphorus loading of ecosystems and stresses from pollution
Human and civic resources	Dependency ratio	Social and economic resources available for adaptation after meeting other present needs
	Literacy	Human capital and adaptability of labour force
Economic capacity	GDP (market)/capital)	Distribution of access to markets, technology, and other resources useful for adaptation
	An income equity measure	Realization of the potential contribution of all people
Environmental capacity	% Land unmanaged	Landscape fragmentation and ease of ecosystem migration
	SO_2 /area	Air quality and other stresses on ecosystems
	Population density	Population pressure and stresses on ecosystems

Adapted from Moss et al. (2001); Brenkert & Malone (2005)

Through the different capitals identified by the frameworks, indices to categorise resilience can be identified or developed. Measuring resilience therefore requires identifying the indicators of drought resilience and data for measuring. UNDP (2013), in their conceptual framework for a study on measuring resilience, proposed that resilience can be measured in two ways. Firstly, universal indicator(s) of resilience help in the understanding whether resilience is increasing, decreasing or remaining the same (*In order to quantitatively measure resilience, there needs to be a consensual definition as to which households are resilient and which ones are not, and importantly the differences between these two groups. At what point do you cross over to being a resilient household?).* Typical examples here are characteristics of commercial farmers (resilient) vs characteristics of communal farmers (vulnerable). Secondly, composite and context-specific indicators of resilience enable us to understand how local drivers of resilience are expanding or contracting, and the impact of interventions on those drivers. Table 3.10 shows the components and potential indicators of resilience that are based on the Community Capital Assets Approach and Adaptive Capacity Approach as proposed by UNDP (2013).

Table 3.10: Components and potential indicators of resilience

Category	Definition	Examples	Potential Indicators - Capitals	Capacity
Physical	The basic infrastructure (roads, railways, telecommunications) that people use to function more productively.	• Infrastructure – roads, water, electricity, telecoms • Access to new technologies / equipment • Land security / ownership	• Access to all weather roads • % Households with electricity supply	• % Households with year round access to clean water • Water storage / reserve capabilities • Crop storage / reserve capacity
Human	The sum of skills, knowledge, labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood outcomes.	• Educational and skill levels of household members • Food security of household • Health and nutritional status of household members	• % Households requiring formal food / cash assistance • % Global and severe acute malnutrition rates • Gross / net enrolment rates	• No. of households members with secondary education or higher • No. of household members economically active
Financial	The cash that enables people to adopt different livelihood strategies. This can be in the form of savings, or a regular source of income such as a pension or remittance. The inputs that support livelihoods, as well as the producer goods (tools, equipment, services) that contribute to the ability to increase financial capital.	• Income reliability and growth • Opportunities for employment and trade • Productivity of livelihood • Price and income variations • Functioning markets • Risk financing / insurance • Assets owned and goods produced – livestock / crop / stock • Access to financial services	• Income level • % Households with secure access to land for livelihood purposes • Livestock numbers and value • Crop production / value	• No. of household sources of earned income • Access to functioning markets • Access to saving and credit facilities • Access to agric / livestock extension services
Natural	The natural resources (land, forests, water) and associated services (e.g. erosion protection, storm protection) upon which resource-based activities (e.g. farming, fishing etc.) depend	• Access to and quality of natural resources – land / rangeland / forests, water, soil • Sustainable management and regulation of natural resources • Carrying capacity – human and animal populations	• Extent of natural tree cover • Households undertaking reforestation activities • No. of functional NRM / rangeland	• % Time quality pasture available • Quality of rangeland management • Rate of deforestation
Social	Access to and participation in networks, groups, formal and informal institutions. Peace and security.	• Local kinship support networks • Number, scale and functionality of community organisations / governance structures and self-help groups • Participation in the above groups • Community ability to plan, mobilise resources and implement; o Conflict reduction o Improved services o Natural resource management • Fair and transparent access to resources • Leadership role of women	• No. of functioning local structures / committees • % Of households with woman and marginalized groups involved in local planning processes	• Quality of leaders /institutions (fair, responsive, non-corrupt) • % Population living in peace and security • % Year there are no incidences of conflict / insecurity • Community resources raised to build resilience

Source UNDP, 2013

3.4.6.4 Community capitals asset approach

Malone (2009) outlined another approach to measure resilience. The approach emanates from the sustainable development research, where instead of placing emphasis on sensitivity, exposure and adaptive capacity, it recognizes vulnerability as a lack of capabilities or physical, financial, social, human and natural *"capitals"* (Ellis, 2014). Although it is not absolute, in this model resilience is the opposite of vulnerability and is considered to be the possession of these capabilities or capitals. Malone (2009) described these capitals also as "*livelihood capitals*". Understanding the (i) community assets, (ii) its transactional linkages and relationships, (iii) social capital, and (iv) collective capacity of customary institutions, and (v) community social dimensions, helps in the understanding of the process and potential of community resilience. The relationships and linkages of the assets complement and work in conjunction with one another to achieve a resilient community (Norris *et al.,* 2008). These assets are the tangible and intangible resources that enable communities to meet the basic needs of their members (Frankenberger *et al.,* 2013). Frankenberger *et al*. (2007) also noted that the more dissimilar the assets are, the higher is the contribution in the reduction of vulnerability to shocks. Higher levels of absorptive and adaptive capacity result from the ability of communities to access and utilise these assets in a way that allows them to respond to changing and unforeseen circumstances.

Monitoring of the community assets is significant for assessing resilience because it helps identify transformations and tendencies regarding risks affecting the community. Frankenberger *et al.* (2013) highlighted that when measuring livelihood assets at the community level, it is essential to address four critical questions:

- What is the extent and quality of each form of capitals?
- Which populations have access to the capitals?
- Which institutions control access to the capitals?
- How does the current status of the capitals contribute to or constrain livelihood security and resilience?

Communities are vulnerable because they have shortfalls in one or more capitals, consequently have limited capacity to absorb the negative consequences of shocks and/or stresses and to engage in adaptive livelihood strategies (Frankenberger *et al.,* 2013). It is therefore important to understand in detail the community, or livelihood, assets (capitals) as they are contributing factors in achieving or failure to achieve resilience.

Flora & Flora (2004) developed a more detailed community capitals framework (CCF7) based on analysis of entrepreneural communities. In the context of this research the CCF7 framework can be applied since farming is an entrepreneural activity. They identified the same important capitals as most other frameworks, but they also add cultural capital as an important capital. The CCF7 framework goes beyond the identification of seven capitals; it also explore the interaction amongst the seven capitals and how they build upon each other. The CCF7 framework can be used as a tool for analysis and also as a way to assist project managers to identify key boundary partners. The CCF7 framework can be used as a tool to assist extension officers with extension programs; for example they can use the framework to determine what investment is required in terms of education and leadership training in order to unlock financial capital sources. Leadership training might also have an impact on social capital in that formal social structures might be exploited more efficiently.

The CCF7 framework includes the following capitals (Flora & Flora, 2004):

- **Natural Capital**; the environment, soil, land, water, natural beauty, lakes, rivers and streams, forests, wildlife, soil, the local landscape;
- **Financial Capital**; money, charitable giving, grants, access to funding, insurance and wealth;
- **Built Capital** (Infrastructure); buildings and infrastructure in a community, schools, roads, water and sewer systems, water reticulation systems, camps, access roads;
- **Human Capital**; all the skills and abilities of people, leadership, knowledge, and the ability to access resources, experience, education;
- **Social Capital**; groups, organizations, networks in the community, the sense of belonging, bonds between people, national and international linkages;
- **Political Capital**; connections to people in power, access to political resources, leverage, and influence to achieve goals; and
- **Cultural Capital**; ethnicity, generations, stories and traditions, spirituality, habits, and heritage, cultural beliefs.

Following below is a discussion of the seven CCF7 capitals

3.4.6.4.1 Social capital

Social capital can be termed as the quantity and quality of social resources (e.g., networks, membership in groups, social relations, and access to wider institutions in society) upon which people draw in pursuit of livelihoods (Frankenberger & Garrett, 1998). Putnam (2000) defined social capital as the features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit. What is common among the many definitions of social capital is the aspect of social structure, trust, norms, and social networks that facilitate collective actions (Green & Haines, 2002). Social capital has often been described as the "*glue*" that binds people in society together (Frankenberger *et al*., 2013). In the context of drought resilience, social capital reflects social cooperation or community connectedness, which provides an informal safety net during drought disasters and often helps people to access resources (Walter, 2004; Jordaan, 2011). Social capital can therefore contribute to community resilience by providing an informal buffer to those affected by disaster, overcoming challenges to adaptation through coordinated local processes, and enabling transformative change by strengthening the community's collective voice (Jordaan, 2011; Aldrich, 2012, Jordaan & Adoko, 2014).

Dynes (2002) and Walter (2004) indicated that community ties and networks are highly beneficial in building disaster resilience as they allow individuals to draw on the social resources in their communities and increase the likelihood that such communities will be able to adequately support each other during and after disasters. Friends, relatives and co-workers are usually the first in assisting during disaster response and recovery.

The framework draws on both qualitative and quantitative evidence to demonstrate that social resources, at least as much as material ones, prove to be the foundation for resilience and recovery. It is argued that social capital influences increased "*participation among networked members; providing information and knowledge to individuals in the group; and creating trustworthiness"*. Béné *et al*. (2012) and Smith & Sterling (2010) noted the usefulness of Aldrich's framework for studying the influence of social capital on community resilience, this being because resilience at this level requires (i) institutional reforms, (ii) behavior shifts, (iii) cultural changes, (iv) the questioning of values, (v) challenging of assumptions and (vi) close examination of identities, stereotypes, and fixed beliefs.

- **Bonding social capital** describes the connections among individuals who are emotionally close, such as friends or family, and result in tight bonds to a particular group (Adler & Kwon, 2002). The strong connection makes this type of social capital good for providing social support and personal assistance, especially in times of need such as disaster (Hurlbert *et al*., 2000).
- **Bridging social capital** describes acquaintances or individuals loosely connected that span social groups, such as class or race (Aldrich & Meyer, 2014). It connects members of one community or group to other communities/groups (Aldrich, 2012a). Bridging social capital makes a direct contribution to community resilience in that those with social ties outside their immediate community can draw on these links when local resources are insufficient or unavailable (Wetterberg, 2004).
- **Linking social capital** links regular citizens with those in power. It epitomises customs of respect and networks of trusting relationships between people who are interacting across explicit, formal, or institutionalized power or authority gradients in society (Szreter & Woolcock, 2004). Linked networks are critical for resilience because they provide resources and information that are otherwise unavailable through bonding or bridging capital (Aldrich, 2012a). Flora & Flora (2004) classified this type of linkage as political capital (See Figure 3.14).

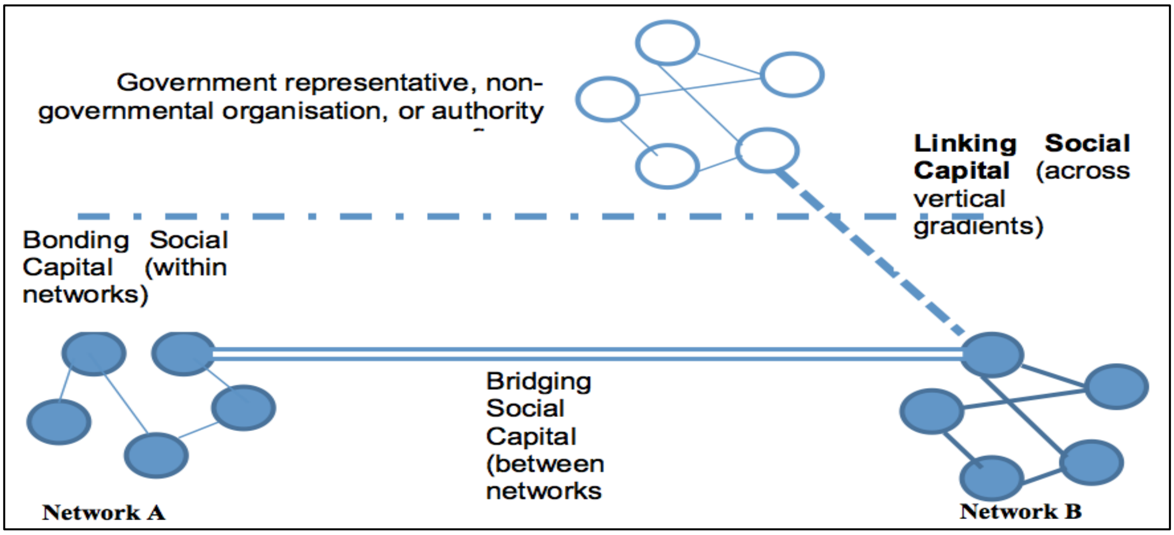

Fig 3.14: Bonding bridging and linking social capital

3.4.6.4.2 Economic/ Financial capital

This represents financial resources (savings, income, investments or businesses, and credit) that people use to support their livelihoods (DFID, 1999; Smith, Simard, & Sharpe, 2001; TANGO, 2006). Through access and availability of economic resources, there is an increase in the ability and capacity of individuals, groups and communities to absorb disaster impacts and speed up the recovery process (Aldrich & Meyer, 2014). The accessibility, reliability, and inclusiveness of formal and community-based savings and credit institutions are one indication of a community's resilience capacity because these represent social protection mechanisms that can be tapped into to cope with a shock or stress (Frankenberger *et al*., 2013). Walter (2004) also indicated that individuals with access to financial resources recover more quickly from disasters. Having access to credit and hazard insurance are associated with the level of household preparedness and ability to take protective measures (Lindell & Prater, 2003). Likewise, post-disaster investment of financial capital has potential of having direct and positive outcomes for community infrastructure (through construction of roads, bridges, dams, etc.) and human capital development (through funding of health care and education; Gill & Ritchie, 2011).

The resilience, or the ability of a household to cope with shocks, is a function of several factors (Watts, 1983; Richards, 1986; Corbett, 1988; Hutchinson, 1992; Rocheleau *et al.*, 1995; FEWS, 1999; de Waal, 2004; Smucker & Wisner, 2007; Erikson & Silva, 2009). The available options such as distance from labour and produce markets (roads, large urban centres), nearby forests, water sources and tourism all have an influence on the resiliency and coping strategies for communities. The level of own resources on which a household can draw for survival is also critical (Little *et al,* 2006; de la Fuente, 2007; Dercon & Porter, 2007; de la Fuente, 2008, Jordaan, 2011).

Households with different resource levels reach the different thresholds at different times. Households with large resource levels (richer households) in many cases managed to increase their resource base due to favourable prices for animals or other goods (FEWS, 1999; Erikson & Silva, 2009). They are the only ones with capital and are in a position to exploit members of lower economic classes or smaller farmers (FEWS, 1999, Jordaan, 2011). Dercon & Porter (2007), de la Fuente & Dercon (2008) and Porter (2010) confirm previous findings from other researchers in Ethiopia where the outcome of shocks vary dramatically among households with a low resource base (poor households) compared to *"richer"* households.

Farmers with high debt ratios show the same characteristics as farmers with a low resource base since they are forced to service debts even in times of shortages and do not have the capacity to withstand severe or extreme droughts.

Physical capital is one of the most important resources in building a disaster-resilient community (Mayunga, 2007). Lack of physical infrastructure or critical facilities may have a direct negative impact on a community's capacity to prepare, respond, and recover from disasters (Aldrich & Meyer, 2014). Physical capital therefore denotes the built environment or infrastructure such as transportation, shelter, energy, communications, water systems, health facilities and markets (DFID, 1999; Walter, 2004; Frankenberger *et al*., 2013). It also includes production equipment and other material means that enable people to maintain safety and enhance their relative level of well-being (Mayunga, 2007). Features of a community's physical infrastructure such as roads, bridges, dams and levees as well as communication systems are essential elements for proper functioning of a community (Walter, 2004). Important in the context of drought are on-farm infrastructure such as fences, water reticulation systems, livestock handling facilities and irrigation infrastructure (Jordaan, 2011).

3.4.6.4.3 Human capital

Human capital includes the managerial capacity and the labour force and their ability to withstand shocks or to adapt in time. Production output as an essential element of resiliency building is directly corrolated to human capital (Smith *et al*., 2001; TANGO, 2006). Critical components of human capital are education and health of management and the workers (DFID, 1999; Smith *et al*., 2001; Walter, 2004). Education, embraces the knowledge and skills that are accumulated through different forms of education, training, and experience. Health, including psychological health embraces the sound decision making capacity of management (farmer) and the productivity of the working-age population. Smith *et al*. (2001) concluded that an unhealthy population is not able to efficiently exploit other forms of capital. At household level, the educational level and health status shape the ability of individuals to absorb the negative impacts of a shock and to successfully adapt to changing social, economic, and environmental conditions, whereas at community level, human capital exhibits the collective level of access to skills, labour, knowledge, and physical and mental health. Education is also key to innovation and adaptation (Frankenberger *et al*., 2013). Godschalk *et al*. (1999) and Walter (2004) acknowledged their in their research that knowledge, skills, health and physical ability determine an individual's level of disaster resilience more than any of the other capitals.

3.4.6.4.4 Natural capital

The natural capital is denoted by the availability of natural resources to the community. These include land, water, forest, rangeland, fisheries, wildlife, biodiversity and environmental services (TANGO, 2006). The majority of the natural hazards posing risks for vulnerable populations have an instant, detrimental and long-lasting impact on the natural resource base (Frankenberger *et al*., 2013). The effective control of natural resources and ecosystem services, while maintaining a sustainable livelihood base, is a key element of community resilience (Twigg, 2009; Pasteur, 2011). Community level resilience to drought is affected by a variety of factors relating to the quality of natural assets such as soil, forest cover, pasture, fishery stocks, habitats, surface water and groundwater supplies (Frankenberger *et al*., 2013).

3.4.6.4.5 Political capital

TANGO (2003) define political capital as the access to power relationships, and the capacity to influence the political system and governmental processes at local and higher levels. Political capital can also give rise to inequity and differences in power dynamics within and between individual communities (Pasteur, 2011; Gill & Ritchie, 2011). There are different levels of political capital, namely: (i) the effectiveness of local government in addressing the needs and priorities of the community, (ii) voter participation, (iii) involvement of women and minorities in political leadership and decision-making, (iv) interaction between formal government and traditional authorities, and (v) transparency and accountability among government officials (TANGO, 2003).

3.4.6.4.6 Cultural capital

Cultural capital was ignored by many scholars for many years. Flora & Flora (2004) highlighted the importance of cultural capital as an important indicator for entrepreneurship. Cultural capital considers ethnicity, generation differences, traditional beliefs and norms, stories and folklore, spirituality, habits and heritage. Jordaan (2011) highlighted perseverance and the protestant work ethic of farmers in the Northern Cape as amongst the main reasons why farmers are resilient against drought shocks. These are typical cultural capitals required for resilience building.

3.4.6.5 Financial approach

Rose & Krauseman (2013) proposed an economic framework for the development of a resilience index for businesses. They examined existing resilience indices in relation to economic principles and evaluated the potential of different indices to measure potential for businesses to recover post disasters. They concluded that entrepreneurial and business behaviour was key to short term recovery and their framework provides appropriate short term indicators to develop an index measuring economic resilience.

Rose (2004; 2007) and Rose & Krauseman (2013) defined two types of economic resiliency, namely (i) static economic resiliency as *"the ability of a system to maintain function when shocked"* and (ii) dynamic economic resiliency as "*hastening the speed of recovery from shock*". Static economic resiliency is the core of the economic problem where already ordinary scarce resources are applied more efficiently in order to recover from the shock. This refers to the efficient utilization of existing capitals or stock. Dynamic economic resilience refers to the dynamic application of alternative resources or investment decisions that involve diverting resources from current consumption in order to reap future gains from enhanced production. Economic resilience, especially in the case of drought resilience, focuses on the flows of goods and services (measure as GDP, employment, production, etc.) in contrast to the concept of resilience in engineering where the focus is on stocks of assets (measured in terms of property and asset damage). Property damage is easy to calculate and takes place at a specific point in time while measurement of flow of goods might have a long lasting effect. The impact of drought on livestock farmers is a typical example where farmers require up to five years before full recovery after drought (Jordaan, 2011).

Inherent and *adaptive resilient capacity* are two concepts important to the measurement or resiliency amongst smallholder and commercial farmers. Inherent resilience refers to resiliency measures already built into the system (Rose & Krausman, 2013). Examples in the context of this this research are (i) access to resources, (ii) market relations and agreements, (iii) supportive and traditional institutional arrangements, (iv) access capacity, (v) secure property right systems, (vi) experience and knowledge, and (vi) social networks. Adaptive resilient capacity refers to "*ingenuity under stress"* (Rose & Krausman, 2013). Examples of adaptive resiliency could be (i) reduction in animals numbers while maintaining production output with remaining numbers, (ii) utilization of new technology for improved production, (iii) avoidance strategies by leasing land in other regions, (iv) kraal feeding of animals, (v) drought feed and fodder schemes to animals, (vi) selling of non-productive assets, (vii) alternative and temporary employment, and (viii) creation of alternative income sources such as farm tourism.

Considering the above, Rose & Krausman (2013) propose an operational metric of resilience based on the economic concept of "*partial equilibrium"* and "*general equilibrium"* and they name it *"Direct Static Economic Resilience*" (DSER) and "*Total Static Economic Resilience"* (TSER) respectively. DSER refer to the household, individual, farm or business level analysis while TSER refers to the macro level, namely the economy as a whole. Measurement of DSER is the extent to which the entity can still produce in spite of an external shock. DSER is measured by estimating the continuous output as a percentage of the maximum potential loss due to an external shock.

Challenges occur in determining what is potential maximum loss. In the case of drought one can assume that maximum loss is the potential loss in the absence of both static economic resiliency and dynamic economic resiliency. By way of example, take of a livestock farmer with 1000 ewes and an annual turnover of gross income of R1 000 000. As the result of a D3 drought his income is reduced to only R500 000 in year 1, to R700 000 in year 2 and he is back to normal production in year 3. TSER for this farmer is therefore 60%[12] to D3 droughts if he recovers fully after 2 years. DSER will consider the resiliency of the sector on a meso- and macro-scale.

Jordaan, (2011) calculated mean annual losses as a result of drought in his research amongst Northern Cape farmers and that could form the base from where to calculate TSER and DSER.

3.4.7 Coping Capacity Indicators for the Eastern Cape

Coping with drought is specifically linked to different agricultural systems and the following coping capacity indicators were selected for the Eatern Cape:

- Livelihoods income,
- Alternative income sources,
- Alternative land,
- Reserves,
- Early warning,
- External support and Government safety nets, and
- Management skills.

3.4.7.1 Livelihood income

Livelihood income ultimately determines the food security situation in a household. Generally, livelihood income of communal farmers is extremely low with most communal farmers living in poverty. Agriculture is their primary source of income and considering the extremely low yields in crop production and high mortalities amongst livestock, one can understand the reasons for low net income after own consumption. Commercial farmers on the other hand, are classified as “wealthy” with reasonable livelihood incomes (Jordaan, 2011).

Living in poverty also means that families do not have resources to send children to good schools and often cannot afford secondary education. This transfers the cycle of poverty to the next generation and increases the livelihood’s vulnerability to exogenous shocks. On the other hand, livelihoods with a good income result in additional resources to sell during dry periods. Hence the ability to afford

[12] ((R500,000+R700,00)/(R1,000,000x2))

schooling for children, purchasing radios and cell phones and therefore being in a better position to receive early warnings for dry periods and make timely decisions is crucial among poorer farmers.

3.4.7.2 Alternative income sources and financial safety nets

Alternative income sources for communal farmers are limited and may include (i) casual labour, which is limited; (ii) informal trading; (iii) keeping small animals such as chickens and pigs; and (iii) small-scale vegetable production. Some families only exploit alternative income sources during periods of external shock when the traditional income sources from crops and livestock are threatened, while others utilise the alternative sources as a permanent way of supplementing traditional income from crop and or livestock production. Alternative income sources for commercial farmers vary and might include (i) non-agriculturally related income from other businesses; (ii) property lease income; (iii) interest on investments; (iv) stock market investments; and (v) salaries from another job.

3.4.7.3 Alternative land and options for production

Alternative land and grazing is a key coping strategy for many farmers and is mostly available only to some of the larger commercial farmers. Communal farmers normally do not have alternative options for grazing and they are limited in terms of available land.

3.4.7.4 Reserves

Reserves are one of the main indicators for drought risk and include additional feed and fodder (crop residues), reserve capital (money) reserve capital goods to sell without limiting production (surplus livestock) and even insurance against exogenous shocks.

3.4.7.5 Early warnings

Drought is a slow onset disaster and early warnings are in most cases useful to assist farmers in making timely decisions. Livestock farmers can identify and sell animals before the onset of a drought while crop farmers can plant alternative and/or drought resistant crops, or they can shift planting dates if they receive accurate and timely early warnings.

Mutua (2011) described early warning (EW) as the delivery of effective information on time to help people prepare their response to forthcoming hazards to reduce risk. Drought EW is a key element of drought risk management whose goal is to increase the communities' coping capacity to enhance greater resilience. It is an important indicator because a community with effective early warning systems is empowered to prepare in time to reduce negative impacts of the hazard. EW can be either traditional or based on modern technology. The Report for the Long Term Adaptation Scenarios (LTAS, 2014) states that the South African Weather Service (SAWS) is tasked with producing early warning information on various weather related hazards, including drought. This information is disseminated to different metropolitan municipalities and government sectors. Drought early warning information can be forecasted as early as two years plus before it occurs, although the certainty of those forecasts is low (LTAS, 2014). Umlindi is an example of a South African drought EWS which was developed by the Agricultural Research Council (ARC). The National Crop Estimates Committee (NCEC) estimates crop output using Umlindi (LTAS, 2014).

Traditional early warning systems include, for example, the one used by the Swazis, whereby the cry of particular birds is used to predict rain, and yields of certain wild fruit plants to predict famine. They also use the behaviour of certain animals to predict either a dry or a wet season (Mwaura, 2008). Traditional seers have also been key actors in foretelling agricultural seasons through the interpretation of dreams (Mutua, 2011). Effective dissemination of information from either of these EWSs is crucial for drought mitigation and preparedness.

3.4.7.6 Management skills

In most cases, management skills are a combination of level of education, experience, leadership, commitment and attitude. Measuring management skills for effective drought risk reduction is difficult in a project with such a wide scope as this. The importance of management, however, cannot be ignored as a drought risk reduction indicator and should be included as a coping capacity indicator. Management involves the efficient utilization of resources such as capital, land, water and labour, which are supported by financial management principles and an understanding of, and participating in, regional and global markets.

3.4.7.7 Indigenous knowledge

Indigenous knowledge is the information or wisdom that is passed down from one generation to the next. The local people, or communities, learn from experience or by observing the elders (Magoro, 2004; United Nations Environment Programme UNEP, 2008). This indicator is important especially in a rural context such as the study area with high poverty levels, high unemployment and limited formal education (Notsi, 2012). Indigenous knowledge in such settings is invaluable for its accessibility without the need to invest money to obtain it. In a village in KwaZulu-Natal, South Africa, a local farmer for example created his own sorghum seed by covering the tender seed-heads of selected stalks with grass until harvest time to protect them from birds (Boylan, 2007).

A study carried out by Notsi (2012) in Tsitas Nek (Lesotho) and Mabeskraal village (South Africa) and Jordaan and Adoko (2014) In Uganda revealed some of the African indigenous farming methods used. For example, harvested crops are protected from pests by applying wood ash and they can be kept safe from pests for up to three years. These communities also use creeper crops to control weeds and keep moisture in the soil. UNEP (2008) claimed that indigenous knowledge is still integral among most African local or indigenous communities. The older people use indigenous knowledge to reduce impact of disasters. This knowledge, however, known mostly by community elders, could be easily lost because of poor documentation.

3.4.7.8 Social capital/Social networks

Resilient communities are characterized by the presence of strong social networks, which rally collective action, as well as organizing for the provision and restoration of services in times of disaster (Sutton, 2010). Social capital consists of linkages and relationships that exist between individuals and social groups, which enable the general well-being of the community (Adger *et al*., 2004).

A society with social support networks and community organisations (ADPC, 2000; Hassen, 2008) where people feel safe, volunteer and trust their neighbours, is resilient enough to cope with and recover from the impacts of hazards (Stone, 2000). These networks can either be formal such as the farmers' associations and drought mitigation clubs, or informal such as church groups, womens' groups, extended families and neighbourhood groups (ADPC, 2000; Wongbusarakum & Loper, 2011). Local people belonging to social networks share mutual assistance and support when the need arises. They are able to call on each other for help, and have rights and access to some resources because of their group membership status (Hassen, 2008).

3.4.7.9 Classification of selected coping capacity indicators

Coping capacity for each of the quaternary catchments will be measured based on the Likert scale from 1 to 5, as follows:

Vulnerability		**Coping Capacity**	
1:	Not vulnerable at all	1:	Not coping at all
2:	Slightly vulnerable	2:	Slightly coping
3:	Moderately vulnerable	3:	Moderately coping
4:	Very vulnerable	4:	Cope well
5:	Extremely vulnerable	5:	Cope extremely well

Table 3.11: Classification and indexing of resilience indicators

Indicator	Index	Description of indicator classification	Statement of measurement	Relationship with Vulnerability	Data Source
Social networks	5	Social networks are very involved in drought support	Extent of social network involvement in drought issues	The more involved the social networks the greater resilience to drought	Survey
	4	Social networks involved in drought issues, not effective			
	3	Social networks moderately involved in drought issues			
	2	Social networks not involved in drought issues			
	1	No social networks at all			
Civic organisations	5	Government very supportive of farmers as well as NGOs	Level of civic organizational support in drought mitigation and response	The greater the civic support the greater the resilience to drought	Survey
	4	Government's support is good, NGOs' support is good			
	3	Little government support, more NGO support			
	2	No government support for farmers, little NGO presence			
	1	No government support for farmers at all, no NGOs			
Preparedness strategies	5	All farmers prepare for drought, have stocks	Proportion of farmers that prepare for drought	The more prepared farmers are to drought the greater the resilience	Survey
	4	>60% farmers prepare for drought, have stocks			
	3	40%-60% farmers prepare for drought, have stocks			
	2	10%-40% farmers prepare for drought, have socks			
	1	>90% have do not prepare for drought, no stocks			
Early Warning Systems (EWS)	5	All farmers have access to trustworthy EWS	Level of access to EWS	The more farmers receive EW, the greater the resilience to drought	Survey
	4	>60% farmers have access to EWS			
	3	40%-60% farmers have access to EWS			
	2	10%-40% farmers have access to EWS			
	1	>90% farmers have no access to EWS			
Indigenous knowledge	5	All farmers well-informed on effective farming practices	Level of indigenous farming knowledge	The greater the proportion of farmers informed the greater the resilience	Survey
	4	>60 farmers are informed			
	3	40%-60% farmers are informed			
	2	10%-40% farmers are informed			
	1	>90% are not informed on effective farming practices			
Financial safety nets/ Alternative source of income	5	Have plenty of alternative sources. Relief schemes, insurance, capital reserves (loans, extra feed), EPWP, informal trade	Indication of other source of income	The more sources of income they have the greater the resilience	Survey
	4	At least two sources of income with at least 1 source not affected by drought			
	3	At least 2 sources of income, but affected by extreme droughts only			
	2	Income source affected by severe droughts			
	1	Limited income and highly vulnerable to drought			
Off farm/ regional economic diversification	5	Many alternative economic activities, e.g. irrigation farming, tourism, mining, forestry, services etc.	Indication of other economic activities	The more economic activities the greater the resilience	Survey StatsSA
	4	Rain fed farming with different systems plus sufficient irrigation			
	3	Rain fed farming and some irrigation			

	2	Rain fed farming, but with two alternatives			
	1	One system rain fed farming the only economic activity			
Alternative land	5	Total mobility, no restrictions on movement and have access to alternative climate zones for additional grazing during dry periods.	Availability of another land	Availability of alternative land the greater the resilience	Survey
	4	Some restricted movement but have alternative land available during severe droughts			
	3	Restricted movement, but can go to other neighbouring villages or farms			
	2	Have no alternative land but current land have reserve capacity			
	1	Have no alternative land available and current land already overgrazed			
Management	5	Good management (production & reproduction, financial, nutritional, health, veld and pasture management)	Indication of farm management	The use of good management in the farm the greater the resilience	Survey
	4	Good production management, but lack financial and marketing management			
	3	Average management, but lack financial, marketing and veld and pasture management			
	2	Limited management skills and apply only one of the management principles from nutritional, health and reproduction			
	1	Poor management skills and evidence of farm level management			

3.5 Conclusion

The literature is clear on the integration of vulnerability and coping capacity as important elements of the risk equation. The selection of indicators to measure vulnerability and coping capacity was based on guidelines from the literature and a preliminary *"transect drive"* through the study area. Similar research completed by Jordaan (2011) in the Northern Cape and Jordaan and Adoko (2014) in Uganda was useful in the selection of indicators. Fieldwork through interviews and workshops during the phase within this project which followed, however, was likely to provide information on additional indicators or a change in the number of indicators as discussed in this report.

The information from this chapter, however, provided a sound base for the planning of questionnaires and discussion during workshops.

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4 Drought Hazard Assessment

Jordaan, A.J. & Sakulski, D.M.

Executive Summary

Drought risk assessment originates from the hazard which, according to the most well known definition, is drought caused by too little precipitation and too much evapotranspiration. This chapter focuses on the drought hazard (H), i.e.the meteorological variables, in the drought risk assessment equation. Historical meteorological data are analysed for all 260 quaternary catchments in the selected three districts, namely Joe Gcabi, OR Tambo and Cacadu.

A website http//dimtecrisk.ufs.ac.za/wrc_ec was developed as an interactive tool for analysing data "on the fly". The large volumes of data available made it impossible to present all data in hard copy in a single report. Reliable time series of meteorological data remains one of the challenges of drought hazard assessment. For the analysis, a base period stretching from 1950 to 1999 (50 years) was utilised for all quaternary catchments and a base period from 1900 to 1998 for point data at selected stations, with reliable data obtained for a few point stations stretching from 1900 to 2010. These data were used to estimate alpha and beta parameters of the gamma distribution, which are used to calculate the cumulative probabilities of precipitation events.

The analysis of precipitation shows a slight decrease in the higher rainfall zones and a slight increase in the lower rainfall zones. The number of rainy days in the high rainfall zones, on the other hand, shows a declining trend while it remain constant in the lower rainfall zones; possibly an indication of potentially higher rainfall intensities in the higher rainfall zones. Changes in both annual precipitation and in the number of rainy changes, though, are statistically not significant with p values too high. The average temperature and evapotranspiration show a positive trend, but also statistically not significant with the exception of a number of catchments where a significant positive trend in temperature was detected.

4.1 Introduction

The results of the SPEI calculations provide for drought frequency, duration, intensity and severity. These are calculated for each quaternary catchment and are now useful for the calculation of drought risk once it is combined with exposure, vulnerability and coping capacity, which will be dealt with in chapters to follow.

The drought risk equation is simplified as follows:

$$R = \left(\frac{\boldsymbol{H}}{\boldsymbol{C_H}}\right) x \left[\frac{\sum(V_{econ}V_{env}V_{Soc})}{\sum(C_{econ}C_{env}C_{soc})}\right]$$

where: $H = f(H_P H_s)$

with: H_p = Probability for drought with certain magnitude (severity) to occur

H_s = Severity of Drought H

and: $H_s = f(H_i\ H_d)$

where: H_i = Intensity of Drought H

H_d = Duration of Drought H

Also: C_H = 1, since one cannot manage or control the rainfall and evaporation in the context of this research, which focuses on dry land, i.e. rain fed, farming systems. In the case of irrigation agriculture, C_H could potentially have a number >1 since efficient water supply and water management can reduce the hazard risk, which is not the case with rain fed agriculture.

Hazard assessment is one of the variables in the drought risk assessment shown in the above equation, and it acts as the initiating factor for droughts. Drought is the result of water shortage for a given system and in the context of this assessment, the shortage of water in support of normal biological production, and/or the lack of drinking water (Wilhite, 2000). One therefore expects that most indicators for the hazard are weather related, although scientists have also developed drought indicators based on biological factors (Fouche *et al.*, 1985, 1992; Du Pisani, 1998).

An important development in the use of indices and drought risk assessment took place during the 2009 UNCCD *"Inter-Regional Workshop on Indices and Early Warning Systems for Drought"* at Lincoln, Nebraska in the USA at which leading international institutions such as the WMO, UNCCD, NOAA, USDA, different regional drought monitor centres and research institutions were represented by 54 experts from 22 countries. They agreed on the following messages, conclusions and recommendations as the main outcomes of the workshop proceedings (Castillo, 2009; UNCCD, 2009):

- Drought is recognized as part of the normal climate cycle; however, equal levels of drought have different impacts on people, depending on the vulnerability level of the affected group.
- Drought lacks a precise and universally accepted definition and therefore there are different definitions for different types of drought. The workshop, however, distinguished drought from aridity and water shortage as a social construct.
- The lack of consistent methodologies and databases for the assessment of vulnerability to drought was highlighted. Participants acknowledged the lack of sufficient examples that systematically attempt to gather information on drought impacts for different sectors and vulnerabilities and they concluded that drought impacts were more than often underestimated

because of the absence of convincing quantitative analyses of estimated losses (this concern will be addressed in this research).

- The workshop emphasized the need to move from reactive to a more proactive approach and highlighted the need for coordination between regional agencies, especially in the field of early warning.
- The workshop participants agreed that no one drought index fits all needs, but they also agreed that the SPI should be used to characterized meteorological drought around the world[13].
- Emphasis was placed on the need for statistically coherent information that is validated by users and oriented towards providing timely and appropriate responses

The *"Lincoln Declaration on Drought Indices"* was regarded as the single main outcome of the workshop. The following were highlighted in the *Lincoln Declaration*:

- A multi-disciplinary approach incorporating user involvements is necessary for the implementation of drought indices and early warning systems, with end-users in mind.
- All meteorological services around the world are encouraged to use the SPI for the characterization of meteorological droughts and the WMO was requested to implement the recommendation. The SPEI was later recognized as a more accurate index than the SPI.
- The development of a comprehensive manual for the SPI was proposed. Such a manual was to include computation methods, examples where it is applied, the strengths and limitations, mapping capabilities and how it can be used. This information, including programs to do the calculations, are available at no cost on several web sites, for example:

http://sac.csic.es/spei/download.html;
http://dimtecrisk.ufs.ac.za/nc;
http://www.drought.unl.edu/monitor/spi.htm.

- Finalization was needed on recommended indices for agricultural and hydrological droughts.
- The need to develop a framework that integrates drought monitoring to address all sectorial needs was expressed, as was the development of a consensus drought indicator with potential global use.
- The implementation of a simple, systematic analysis of drought impacts in different sectors in all affected countries was proposed, in order to provide useful decision-making information for policymakers.

Most of the precipitation (input) data used for the analysis in this research was available from the WR90 study titled "*Surface Water Resources of South Africa 1990*". The aim of WR90 study was "…

[13] The SPEI was later developed as a more accurate indicator due to the inclusion of evapotranspiration and with this in mind was chosen as the hazard indicator for this study. Detailed discussion and equation of SPI and SPEI follows later in this report.

to update and improve the 1981 survey of the Surface Water Resources of South Africa by the Hydrological Research Unit of the University of Witwatersrand, Johannesburg."

In addition to the WR90 data, point data from various sources such as the World Meteorological Organization (WMO), the Agricultural Research Council (ARC) and South African Weather Service (SAWS) are also included. Many of the data from SAWS for the past 20 years were not "*cleaned",* with obvious discrepancies in the time series data, and they were therefore "*un-usable".*

Ground radar precipitation data were used to calculate the Standardized Precipitation Evaporation Index (SPEI) on a continual basis, both for the purpose of this research as well as for the database-driven, web-enabled SPI and SPEI calculation (http:///dimtecrisk.ufs.ac.za/wrc_ec). For this analysis, a base period stretching from 1950 to 1999 (50 years) was utilised for quaternary catchments and a base period from 1900 to 1998 for point data. Reliable data could be obtained for a few point stations, stretching from 1900 to 2010. These data were used to estimate alpha and beta parameters of the gamma distribution, which are used to calculate the cumulative probabilities of precipitation events.

The next section is a discussion of the different indices for drought hazard assessment and in what way they can be used for drought risk assessment.

4.2 Drought Hazard Indices

Drought monitoring and drought assessment require the integration of all information such as indices and impact indicators in a comprehensive framework. Drought monitoring through indices alone, however, does not constitute drought risk since the impact (vulnerability) of different sectors (economic, social, environment) needs to be linked to the *"hazard"*, i.e. the lack of sufficient amounts of water, which are indicated through the different indices (Du Pisani *et al.,* 1998; Wilhite, 2000; Wisner *et al.,* 2004). The data used for the risk assessment should be statistically coherent and quantifiable, validated by feedback from users and functional for use as timely early warning and drought disaster declaration information.

It became clear from the literature that not one drought index fitted all needs to determine the different types of droughts. Meteorologists and other specialists have developed numerous indicators for drought, yet none of these satisfied the need under all conditions. Examples of these, in alphabetical order, are (i) the crop moisture index (CMI) (ii) mean monthly rainfall deficit, (iii) per cent of normal precipitation, (iv) Palmer Drought Severity Index (PDI; Palmer, 1968; Alley, 1984; Karl & Knight, 1985), (v) the PUTU suite of crop models (Fouche *et al.,* 1985; Fouche, 1992), (vi) the Rainfall Anomaly Index (Van Rooy, 1966), (vii) the relative drought resistance method (Roux, 1993), (viii) the rainfall deciles method (Erasmus, 1991), (ix) the Roux expert system (Roux, 1991) (x) the surface water supply index (SWSI; Shafer & Dezman, 1982) (xi) the reclamation drought index (xii) deciles (Gibbs & Mather, 1967) (xiii) the Standard Precipitation Index (SPI; McKee *et al.,* 1993) (xiv) the Standard Precipitation Evapotranspiration Index (SPEI; Vicente-Serrano *et al.,* 2010) (xv) the ZA schrubland model (Venter, 1992), (xvi) the Zucchini-Adamson models (Zucchini *et al*., 1991), and others which are not relevant in the context of this study (e.g. Wilhite, 2000; WMO, 2006; Vasilaides & Loukas, 2009).

Several indices measure the deviation of precipitation for a given period from historical norms. None of the major indices is inherently superior to the rest in all circumstances, yet some indices are better suited than others for certain uses (UNCCD, 2009). The Palmer Drought Severity Index (PDSI), for example, has been widely used by the US Department of Agriculture to determine when to grant emergency drought assistance, and can be used when working with large areas of uniform topography such as the Karoo. In areas with mountainous terrain and the resulting complex regional microclimates, it is found useful to supplement Palmer values with other indices such as the Surface Water Supply Index (SWSI), which takes snowpack and other unique conditions into account. The most commonly used index worldwide, however, is the Standardized Precipitation Index (SPI) and where possible the Standardized Precipitation Evaporation Index (SPEI; UNCCD, 2009).

The SPI and SPEI are both amongst the most important indicators to characterize meteorological droughts around the world. Temperature, and ultimately evaporation, plays an important role in moisture deficits, and the more recently developed SPEI used in this research provides an even better indicator for drought than the SPI (Vicente-Serrano, Begueria & Lopez, 2010; Beguria *et al.,* 2010). Kim *et al*. (2009), on the other hand, are of the opinion that the Effective Drought Index (EDI) is a better index than the SPI and SPEI since runoff during heavy storms is considered, which is not the case with SPI and SPEI.

The above-mentioned indicators are briefly discussed below, with a detailed discussion of the SPI and SPEI as the recommended indicators for drought hazard measurement.

4.2.1 Crop Moisture Index (CMI)

The Crop Moisture Index (CMI) was developed by Palmer in 1986 with the objective of identifying potential agricultural droughts, but it only represented the short term moisture supply across major crop producing regions and was not intended for the assessment of long term droughts. The CMI was developed from procedures within the calculation of the PDSI, yet it differed in the sense that the PDSI monitors long term meteorological dry and wet spells whereas the CMI was designed to evaluate short term moisture conditions.

The CMI utilises the meteorological approach to monitor week-to-week crop conditions. It is based on total precipitation and mean temperature for each week within a climate zone as well as considering the CMI value for the previous week. The value of the CMI is that it responds rapidly to changing conditions and crops, and potential crop yield can be monitored at a weekly basis based on moisture conditions in different locations.

As mentioned above, the short term application of the CMI and its rapid response to short term meteorological conditions may provide misleading information about longer term conditions. The CMI is designed to monitor short term moisture conditions for a specific crop and typically begins and ends each growing season at zero. One of the negatives of the CMI is that beneficial rainfall during a dry period may allow the CMI to show adequate moisture conditions while the long term drought persists. The CMI's application is therefore limited to the growing season of a specific crop and cannot be used to monitor droughts outside a specific growing season (i.e. longer term droughts).

4.2.2 Crop Specific Drought Index (CSDI)

The Crop Specific Drought Index (CSDI) developed by Meyer *et al*.(1989) combines specific crops, specific soils, the ratio of water consumed by the specific crop to the potential consumption and the growth stage during which the moisture stress occurs. Meyer *et al.* (1989) developed the CSDI initially for corn (maize). That was followed by a CSDI for soybeans by Meyer & Hubbard (1995), then for wheat (Xu, 1996) and later for sorghum by Camargo & Hubbard (1999).

The definition of CSDI is based on the ratio of actual evapotranspiration to potential evapotranspiration as follows (Meyer *et al.,* 1989):

$$CSDI_{pred} = \Pi_{i=1}^{n} \left(\frac{\Sigma ET_{calc}}{\Sigma ET_{pc}} \right)_i^{\lambda i} = \frac{Y_{pred}}{Y_{pot}}$$

where: ET_{calc} and ET_{pc} are the calculated and the potential evapotranspiration in mm for the crop at each growth period;

n the number of periods chosen to represent the crop's growth cycle;

λi the relative sensitivity of the crop to moisture stress during the ith period of growth; and

Υ_{pred} and Υ_{pot} are predicted and potential yields.

The CSDI performed well and had certain advantages over the PDSI and the CMI (Meyer*, et al.,* 1989; Camargo & Hubbard, 1999), but it remained crop specific and did not have much application in the context of this research, except for drought analysis for rain fed crops.

4.2.3 Deciles

Gibbs and Mather developed the decile index system during 1967 and it has been widely used in Australia since then. The decile index provides an accurate statistical measurement of precipitation provided that long climatic data are available. Monthly precipitation occurrences are grouped into deciles so that, by definition, *"much lower than normal"* weather cannot occur more often than 20% of the time. The technique to calculate deciles is based on the distribution of long term precipitation records into tenths of the distribution of occurrences and each category is then called a decile. The first decile then is the precipitation amount not exceeding by the lowest 10% of the precipitation occurrences while the second decile represents the precipitation amount not exceeding by the lowest 20% of occurrences. The largest precipitation decile is the tenth decile, which is then represented by the decile with the largest long term precipitation. The fifth decile is then by definition the median with the precipitation amount not exceeded by 50% of occurrences over the recording period (White & O'Meagher, 1999; Hayes, 2011).

The Australian Drought Watch System uses the decile method with success owing to the simplicity of the technique. The technique requires less data, has fewer assumptions and is relatively simple to calculate compared to the PDSI used in most of the USA (Smith et al., 1993). Interesting about the application of the decile system in Australia is that farmers and ranchers can request government assistance during droughts only if the drought is an event that occurs only once in 20-25 years; that implies deciles one and two over a 100-year period, and that the drought has lasted for longer than 12 months (White & O'Meagher, 1999; Hayes, 2011).

One of the challenges in the South African drought support policy is that no uniformity and clear guidelines exist for when a dry period is a drought. South Africa relies on the per cent of normal indicator, which does not provide the uniformity of the decile method. The uniformity in drought classification in the Australian system has assisted Australian authorities to determine appropriate drought responses. Important, however, is that the decile technique requires long term precipitation data for a specific region, and it is not accurate in the absence thereof (Hayes, 2011).

4.2.4 Effective Drought Index (EDI)

The EDI is a function of precipitation needed for a return to normal climatic conditions (PRN), which is the precipitation necessary for the recovery from the accumulated deficit in precipitation since the beginning of the dry period (Byun & Wilhite, 1996). PRN is derived from the monthly effective precipitation (EP) and its deviation from the mean for each month. EP is defined as a function of the current month's rainfall and weighted rainfall over a defined preceding period. If P_m is the precipitation for *m*-1 months before the current month and *n* is the duration of preceding months then the *EP* for the current month is (Smakhtin & Hughes, 2007; Kim *et al*., 2009):

$$EP = \Sigma_{w=1}^{n}\left[\frac{\Sigma_{i=1}^{m} P_m}{n}\right]$$

For example if *n*=3 then $EP = P_1 + \frac{P_1+P_2}{2} + \frac{P_1+P_2+P_3}{3}$

where P_1, P_2 and P_3 are the respective precipitation values during the current month, previous month and two months before. The mean and standard deviations of the *EP* values for each month are then calculated and the time series of *EP* values is converted to deviations from the mean (DEP). PRN values are then calculated as:

$$PRN = \frac{DEP}{\Sigma\left(\frac{1}{N}\right)}$$

The summation represents the sum of the reciprocals of all the months in the duration *N* (i.e. for *N*=3 months, this term will be equal to: 1/1+1/2+1/3). The EDI is then calculated as:

$$EDI = \frac{PRN}{Std(PRN)}$$

where Std (PRN) is the standard deviation of the relevant month's PRN values.

Smakhtin & Hughes (2007) and Kim *et al.* (2009) report that no normalization of the index or rainfall data is performed in this algorithm and therefore the skewness of the original time series is preserved. As a result of this skewness, rainfall data can result in a larger range of positive EDI values than the range of negative EDI values. The negative values are the important ones depicting dry periods in that they represent the "*rainfall"* that is required for a return to normal from a dry period. The EDI values are standardized in the same way as the SPI and SPEI values (discussed later), which allows one to compare drought severity at different locations regardless of climatic differences between these locations.

Like the PSDI, the SPEI and the SPI, the EDI also has thresholds indicating the range of dryness from extremely dry to extremely wet conditions. The dry period range of the EDI is as follows (Kim *et al.,* 2009):

- < – 2.00 extreme drought
- -1.5 to -1.99 severe drought
- -1.0 to -1.49 moderate drought
- -0.99 to 0.99 normal conditions

4.2.5 Erasmus Rainfall Deciles Method

Developed by Erasmus (1991), and based on the same principles as deciles developed by Gibbs & Mather (1967), Erasmus used drought intensity profiles for 400 individual rainfall stations and ranked the cumulative frequency distribution of moving three-monthly rainfall totals into decile ranges. The current dry period intensity was then calculated, ranked and compared with specific decile ranges.

4.2.6 Palmer Drought Severity Index (PDSI)

The PDSI, developed by W.C. Palmer in 1965, is a soil moisture algorithm calibrated for relatively homogeneous regions and it was the first comprehensive drought index developed in the United States. The PDSI values might lag emerging droughts by several months and they are less suited for mountainous land or areas of frequent climatic extremes, being complex to calculate. Palmer (1965) developed an index to measure the departure of the moisture supply from the expected. Palmer based his index on the supply-and-demand concept of the water balance equation, taking into account more than just the precipitation deficit at specific locations. The objective of the PDSI was to provide measurements of moisture conditions that were standardized, so that comparisons using the index could be made between locations and between months (Palmer, 1965).

The PDSI is a meteorological drought index, and it responds to weather conditions that have been abnormally dry or abnormally wet. When conditions change from dry to normal or wet, for example the drought measured by the PDSI ends without taking into account streamflow, lake and reservoir levels, and other longer term hydrological impacts (Karl & Knight, 1985). The PDSI is calculated based on precipitation and temperature data, as well as the local Available Water Content (AWC) of the soil. From the inputs, all the basic terms of the water balance equation can be determined, including evapotranspiration, soil recharge, runoff and moisture loss from the surface layer. Human impacts on the water balance, such as irrigation, are not considered.

The PDSI considers the duration, or wet spell, of droughts since an abnormally wet month during a long term drought could have a major impact on the index and Palmer (1965) wanted to include the impact of such a wet spell on the index in a balanced way. For example a series of months with near-normal precipitation following a serious drought does not mean that the drought is over. Palmer (1965) therefore developed criteria in order to determine the beginning and end of a drought and a wet spell, which adjust the PDSI accordingly (Alley, 1984). Karl & Knight (1985) report that Palmer's index becomes a hydrological index during near-real time, and it is then referred to as the Palmer Hydrological Drought Index (PHDI) because it is based on precipitation and soil recharge, runoff, evapotranspiration and storage, and does not take into account the long term trend.

Willeke *et al.* (1994) mention the PDI as the most effective index for measuring impacts sensitive to soil moisture conditions such as crop production, and it is also useful as a drought monitoring tool that can initiate drought contingency plans. The PDI is widely used in the USA for different applications. The PDI has three distinctive characteristics (Alley, 1984): (i) it provides spatial and temporal representations of previous droughts, (ii) it shows the measurement of deviations of recent weather patterns, and (iii) it places current weather conditions in historical perspective.

The PDSI is calculated on a monthly basis with values that vary between six and minus six. Palmer initially designed the index so that a value of minus four in South Carolina (USA) has the same meaning as a minus four in Idaho in terms of the moisture departure from a climatological norm (Alley, 1984). The detailed equations on how to calculate the PDSI are discussed in Palmer (1965) and Alley (1984). Heddinghaus & Sabol (1991) report on a modified method to compute the PDSI that differs slightly from the original PI during the transition between dry and wet spells. Several States including Utah, Idaho, New York and Colorado today use the PDSI as part of their drought monitoring system.

According to Alley (1984) and Karl & Knight (1985) the main limitations in the use of the Palmer Index are the following:

- Applying the index for a climate division may be too general because the PI is sensitive to the AWC of a soil type.
- The two soil layers within the water balance computations are simplified and may not be accurately representative of the soils of a location.
- All precipitation is treated as rain and snow, with snow cover and frozen ground not included in the index. Timing of PDSI or PDHI values may therefore be inaccurate during months when snowfall occurs.
- The Thornthwaite method is used for the estimation of precipitation, but this method is only an estimation.
- The lag between precipitation and runoff is not considered. Runoff is normally under-estimated due to the model's only considering runoff once water capacity of the surface and sub-surface soil is full.
- The values signaling the beginning and end of dry and wet spells and quantifying the drought intensity were arbitrary selected based on Palmer's research in central Iowa (USA) and western Kansas (USA), and have little scientific meaning.

The classification for the PDSI is as follows (Palmer, 1965):

• 4 and more	extremely wet
• 3.0 to 3.99	very wet
• 2.0 to 2.99	moderately wet
• 1.0 to 1.99	slightly wet
• 0.5 to 0.99	incipient wet spell
• 0.49 to -0.49	near normal
• -0.5 to -0.99	mild drought
• -1.0 to -1.99	mild drought
• -2.0 to -2.99	moderate drought
• -3.0 to -3.99	severe drought
• -4.0 and less	extreme drought

Kogan (1995) mentions that although the PDSI is widely accepted in the USA, it has little acceptance in the rest of the world, and Smith *et al.* (1993) suggest that the PDSI is not suitable for regions with extreme variability in runoff and precipitation. Willeke *et al.* (1994) are concerned about the fact that the extreme and severe drought classification occur with greater frequency in certain parts of the USA than in others, and that that limits the accuracy of comparing drought intensity between two regions. McKee *et al.* (1995) are of the opinion that the PDSI is designed for agriculture, and cannot accurately represent the hydrological impacts of longer droughts.

4.2.7 Per Cent of Normal Rainfall

Per cent of Normal is one of the simplest measurements of precipitation for specific locations and its application is well suited to the needs of weathercasters and general audiences. It can be used to compare precipitation in a single region or season, but it is also easy to mis-interpret the results (Hayes, 2011).

The calculation of the per cent of normal is undertaken by dividing actual precipitation by average precipitation, multiplied by 100. The normal precipitation is typically determined from at least the 30-year mean. This is then calculated for various time periods, which can be a single month or a series of months representing a specific season or annual or water-year time periods. Normal precipitation for a specific location is considered to be 100% (Hayes, 2011).

Willeke *et al.* (1994) highlight the disadvantage of the per cent of normal technique by arguing that the technique assumes a normal distribution where the mean and median are the same, yet that is not the case with seasonal and monthly precipitation. For example, the median is normally lower than the mean in most arid and semi-arid regions (Wilhite, 2000).

4.2.8 PUTU Suite of Crop Models

Developed by Booysen (1983) and further refined by Fouche *et al.* (1985) and Fouche (1992), this suite of models depends on daily rainfall data, temperatures and irradiance as well as clay content of the soil. These models are dynamic, process-driven rangeland production models that consist of various sub-routines such as the water balance, carbohydrate metabolism, plant phenology, etcetera. The model includes the establishment of long term yield profiles at 350 rainfall stations in South Africa by ranking the cumulative distribution functions of their grassland yields in descending order. Current dry period intensity is then assessed by comparing the rangeland production at any given time against the long term cumulative distribution function.

4.2.9 Reclamation Drought Index (RDI)

The RDI values and severity designations are similar to the SPI, PDSI and SWSI and are calculated at river basin level. The RDI calculation differs from SWSI calculations in that it includes temperature and precipitation together with streamflow and reservoir levels as input variables. The temperature values provide for evaporation estimates, but again, as is the case with the SWSI, inter-basin comparisons are not possible since the index is unique to a specific river basin.

The RDI was developed by the US Bureau of Reclamation and promulgated in the Reclamation States Drought Assistance Act of 1988, as a trigger to release drought emergency relief funds. The main strength of the RDI was its ability to include both climate and water supply factors into the equation (Hayes, 2003).

4.2.10 Rainfall Anomaly Index

This technique was developed by Herbst *et al.* (1966) and uses rainfall as input data. The technique indexes the current rainfall as a variance from the mean precipitation of historical periods of extremes of low precipitation by calculating the effective precipitation for each month and allowing for the carry-over effects of a surplus or deficit in precipitation from previous months by using a series of weighting factors. The mean monthly deficit is then calculated from the difference between actual and mean precipitation (Du Pisani *et al.,* 1998).

4.2.11 Relative Drought Resistance Model

The Relative Drought Resistance Model (RDR) developed by Roux (1993) uses total rainfall over a predetermined period as input data. The meteorological status is calculated by expressing total precipitation for a predetermined period prior to the drought as a percentage of the long term average precipitation during a corresponding length of time. The period to be considered is calculated from the RDR of the area. The principle of this methodology is that the higher the mean precipitation and the lower the annual variance, the less drought tolerant the vegetation and *vice versa*, and the sooner one can then expect a drought.

4.2.12 Roux Expert System

The Roux expert system proposed by Roux (1993) uses subjective values for various agricultural variables as input data. The data gathering is done through a questionnaire, whereby farmers and experts have to classify certain variables such as (i) rangeland physical condition and health, (ii) availability of planted pastures or crops for feeding and (iii) livestock condition and status of drinking water for livestock. Respondents choose alternatives that describe the current circumstances best and the scores are processed to a drought index (Du Pisani *et al.,* 1998).

4.2.13 Surface Water Supply Index (SWSI)

Shafer and Dezman (1982) designed the Surface Water Supply Index (SWSI) as a complement to the PDSI in order to also include snowpack as a key element of water supply. The SWSI is calculated by river basin, based using snowpack, streamflow, precipitation and reservoir storage as key variables for the equation. The SWSI is unique to a specific river basin and thus limits inter-basin comparisons

The SWSI incorporates both climatological and hydrological features into a single index that resembles the PDSI for each river basin (Shafer & Dezman, 1982).

The objective of the SWSI is to incorporate both hydrological and climatological features into a single index value resembling the Palmer Index for each major river basin in the state of Colorado (Shafer & Dezman, 1982). The application of the SWSI is especially important in areas with heavy snowfalls and snowpacks become more important during winter months, with streamflow replacing the importance of the snowpack during warm summer months.

The calculation for SWSI is as follows:

- Monthly data are collected and summed for all the precipitation stations, reservoirs, and snowpack/streamflow measuring stations over the basin.
- Each summed component is normalized using a frequency analysis gathered from a long term data set.
- The probability of non-exceedence (i.e. the probability that subsequent sums of that component will not be greater than the current sum) is determined for each component, based on the frequency analysis.
- This allows comparisons of the probabilities to be made between the components.
- Each component has a weight assigned to it depending on its typical contribution to the surface water within that basin, and these weighted components are summed to determine a SWSI value representing the entire basin.
- Like the Palmer Index, the SWSI is centered on zero and has a range between -4.2 and +4.2.

One of the main limitations of the SWSI is that one cannot compare SWSI values between basins and regions (McKee *et al*., 1993). Secondly, Heddinghaus & Sabol (1991) argue that any changes or development such as new reservoirs in a basis mean that the whole SWSI algorithm for that basin needs to be redeveloped in order to account for changes in streamflow and the weighting of other components. That therefore inhibits the maintenance of a homogeneous time series index. Extreme events with a disastrous impact also cause problems when the events exceed those within the historical time series.

4.2.14 ZA Shrubland Model

The ZA shrubland model was adapted from the meteorological model of Zucchini & Adams (1991) for arid and semi-arid shrublands. The model is based on the concept of a carry-over effect of rainfall as influenced by the amount of rainfall and temperature. The model weights the cumulative effective precipitation over consecutive six-month periods with that of the cumulative mean effective precipitation. Current drought intensity is assessed by weighting the current rainfall with historical values (Du Pisani *et al.,* 1998).

4.2.15 Zucchini-Adams Model

The Zucchini-Adams model developed by Zucchini & Adams (1991) uses daily, weekly, monthly or annual rainfall as an input. The model is characterised by the half-life of an exponentially decaying factor such as rainfall. The exponential function is used to describe the decay in the benefit associated with precipitation as the time from the precipitation event increases.

4.2.16 Standardized Precipitation Index (SPI)

The SPI and SPEI is globally the preferred index to be used for drought risk assessment (WMO, 2009), henceforth the use of the SPEI in this research. The SPI and SPEI is therefore discussed in detail in the following two sections. In order to understand the meaning of the SPI and SPEI, one should also review some other definitions and concepts related to these indices. These are discussed below (Mckee *et al.,* 1993; Western Regional Climate Center, 2011):

- ***Accumulated Precipitation*** *is the total precipitation that has fallen during the indicated number of months, through to the end of the month displayed.*
- ***Accumulated Precipitation Departure*** *is the amount by which the indicated accumulated precipitation is above or below the long term average for exactly the same set of months. The local seasonal cycle of long term average precipitation is automatically accounted for. A departure of 0 indicates totals are exactly equal to climatological values.*
- ***Accumulated Precipitation Percent of Average*** *is the observed accumulated precipitation, over the time scale of interest and extending through the end of the last month indicated, divided by the long term average precipitation which would be expected to accumulate over the same set of months, and then multiplied by 100. A value of 0 indicates no precipitation at all, and a value of 100 per cent indicates that the amount is equal to the climatological average.*
- ***Percentile, or "Probability of Non-Exceedance"*** *is the quantity that indicates how often a value of the magnitude observed is experiencd, i.e. its degree of "unusualness". A value of 0 means that zero per cent of the other values in the record have not exceeded that value, or in other words, that all other values exceed that value, so that the value in question is so low that it seldom if ever occurs. A value of 50 indicates that half of the historical values are higher and 50 per cent are lower. A value of 75 indicates that 75 per cent of the values are as low as this value, or conversely, that only 25 per cent of the values are higher than the given value. A value of 99 means that 99 per cent of the observed values are lower, and that this value is in the top one per cent of all values. Values near 50 are not unusual; values near 0 or 100* are very unusual.

The SPI was formulated by McKee, Doesken & Kleist of the Colorado Climate Centre in 1993 to provide a better representation of wetness and dryness than the Palmer index (McKee *et al.,* 1993). In contrast to the Palmer index, which is based on a monthly water balance accounting scheme that involves precipitation, evapotranspiration, runoff and soil moisture, the SPI was developed to quantify a precipitation deficit for different time scales and for different locations. It was designed to be an indicator of dry and wet periods that recognizes the importance of time scales in the analysis of water availability and water use (McKee *et al.,* 1993; 1995; Keyantash & Dracup, 2002; Moreira *et al.,* 2008).

The advantage of the SPI and SPEI is that one can relatively easily analyse dry periods or anomalously wet periods for a particular time scale for any location in the world with daily precipitation records (McKee, 1995; Moreira *et al.,* 2008). The appropriateness and robustness of these indices to characterize dry periods has already been shown in several studies (Keyantash & Dracup, 2002; Paulo, Perreira & Matias, 2003; Paulo & Perreira, 2005; 2007; 2008, Moreira *et al.,* 2008). Drought early warning and measurement of the onset of drought using drought indices have received considerable research attention from scientists. Candelliere & Salas (2007), for example, developed a stochastic approach to forecast monthly SPI values for different time scales. Neural networks and stochastic models applied to precipitation time series data were also developed by Mishra & Desai (2006) and Thyer *et al*. (2006). The stochastic properties of the SPI time series data for predicting index class transitions were analysed using Markov chain modelling and log-linear models were used for the same purpose (Paulo *et al.,* 2005; Moreira *et al.,* 2008). Moreira *et al.* (2006) applied log-linear models to analyse drought class transitions, and to search for the impact of climate change on drought severity and frequency.

The SPI has the following desirable traits (McKee *et al.,* 1993):

- The SPI is uniqeuly related to probability.
- The SPI is normally distributed and is thereful useful to monitor dry and wet periods.
- Because of the normal distribution of the SPI, both drier and wetter climate regimes are represented in a similar way.
- The precipitation data used in SPI can be used to calculate per cent of mean precipitation for a specific time period.
- The precipiatation data used in SPI can be used to calculate the precipitation deficit for a specific period.

The technique to calculate the SPI is discussed below. Conceptually, the SPI is equivalent to the Z-score often used in statistics, as follows (Lloyd-Hughes & Sanders, 2002; Giddings *et al*. 2005):

$$\text{Z-score} = (\text{X-Mean})/\text{Standard Deviation}$$

A typical frequency distribution of precipitation for a given time scale is skewed, with the mean precipitation larger than the median. It is, in other words not Gaussian, but rather skewed towards larger values of precipitation (skewed to the right). The lower median than the mean is typical in arid and semi-arid regions such as the Karoo and the western parts of the Eastern Cape. That means that precipitation values are below the mean for more than half of the time. Katz & Glantz (1986) found that precipitation frequency distribution for longer time scales such as 24 months and 48 months became more Gaussian with a skewness coefficient of near zero. Thom (1966) and Sakulski & Jordaan (2014) found the Gamma distribution to fit climatological precipitation time series well.

The Gamma distribution is defined by its frequency or probability density function:

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \qquad \text{for } x>0$$

Where $\alpha > 0$ α is a shape parameter

$\beta > 0$ β is a scale parameter

x > 0 x is the precipitation amount

$$\Gamma(\alpha) = \int_0^\infty y^{\alpha-1} e^{-y} \, dy$$

$\Gamma(\alpha)$ is the gamma function

Calculation of the SPI is done by fitting a two-parameter gamma probability density function to a calculated frequency distribution of precipitation totals for a data set. Two parameters, alpha and beta, of the gamma probability density function, are estimated for each data set, for each month of the year, and for each time scale, e.g. three months, six months, 12 months, 24 months and 48 months (McKee *et al.,* 1993, Sakulski, 2002).

Thom (1966), as cited by Sakulski (2002), suggested that the maximum likelihood solutions are used to optimally estimate the parameters alpha and beta:

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$\beta = \frac{x}{\alpha}$$

where
$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$$

n = number of precipitation observations

The resulting parameters are used to calculate the cumulative probability of an observed precipitation event for a specific month and time scale for a specific area. The cumulative probability is given as:

$$G(x) = \int_0^x g(x)dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx$$

If $t = x/\beta$ the equation becomes the incomplete Gamma function:

$$G(x) = \frac{1}{\Gamma(\alpha)} \int_0^x t^{\alpha-1} e^{-t} dt$$

As an Excel function, Gamma transform = GAMMADIST($x, \beta, \alpha, true$)

The gamma function is not defined for the value of $x = 0$, and when a precipitation distribution contains zero values, the cumulative probability therefore becomes:

$$H(x) = q + (1-q)G(x)$$

where q is the probability of a zero value. Thom (1966) estimated q by m/n if m is the number of zero values in a precipitation time series. In this research, the mathematical program *"Mathematica"* was used to calculate the SPI with built in algorithms.

The Standardized Precipitation Index (SPI) is then calculated by transforming the cumulative probability, *H(x),* to the standard normal random variable *Z* with a mean of 0 and a variance of 1. Abramovic & Stegun (1965), as cited by Sakulski (2002), proposed an easy way to calculate the SPI using approximations. It converts cumulative probability to the standard normal random variable *Z*:

$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t_3} \right), \qquad 0 < H(x) \leq 0.5$$

$$Z = SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t_3} \right), \qquad 0.5 < H(x) < 1$$

where $$t = \sqrt{\ln\left(\frac{1}{(H(x))^2} \right)}, \qquad 0 < H(x) \leq 0.5$$

$$t = \sqrt{\ln\left(\frac{1}{(1-H(x))^2}\right)}, \qquad 0.5 < H(x) < 1$$

$c_0 = 2.515517$
$c_1 = 0.802853$
$c_2 = 0.010328$
$d_1 = 1.432788$
$d_2 = 0.189269$
$d_3 = 0.001308$

The SPI and SPEI represent the number of standard deviations above or below the mean (*Z*-score). Owing to the fact that the precipitation distribution is originally skewed, the above-mentioned is not exactly true for the short time scales. The SPI and SPEI will have a standard normal distribution with an expected value of 0 and a variance of 1 during the base period for which the gamma parameters are estimated. Drought risk assessment requires an index with a fixed expected value in order to make comparisons of the index values between different regions with different climate regimes (Katz & Glantz, 1985). The spatial and temporal dimensions of drought could be a challenge when developing a drought index because, not only must an anomaly be normalized with respect to location, but an anomaly must also be normalized in time if it is to produce a meaningful estimate of drought. The SPI and SPEI accomplished both (McKee *et al.,* 1993; Giddings *et al.,* 2005; Kim *et al.,* 2009). The SPI is firstly normalized to a region or station because it accounts for the frequency distribution of precipitation as well as the accompanying variation in the region or at the station, and secondly, the SPI is normalized in time because it can be calculated at any number of time scales. In addition to that, no matter the location or time scale, the SPI represents a cumulative probability in relation to the base period for which the gamma parameters were estimated (Sakulski, 2002; Giddings, *et al.,* 2005; Kim *et al.,* 2009)

Figure 4.1 shows the standard normal distribution for the SPI and it illustrates that about 16% of the time the SPI will be below -1.0, which indicates *dry* conditions, with 6.7% of the time below -1.5, which indicates *severe droughts*, while *extreme droughts* have values below -2. Also, 16% of the time the SPI will be above +1.0, which indicates anomalously *wet* conditions. About 68% of the time SPI is between -1.0 and +1.0, which indicates *normal* conditions.

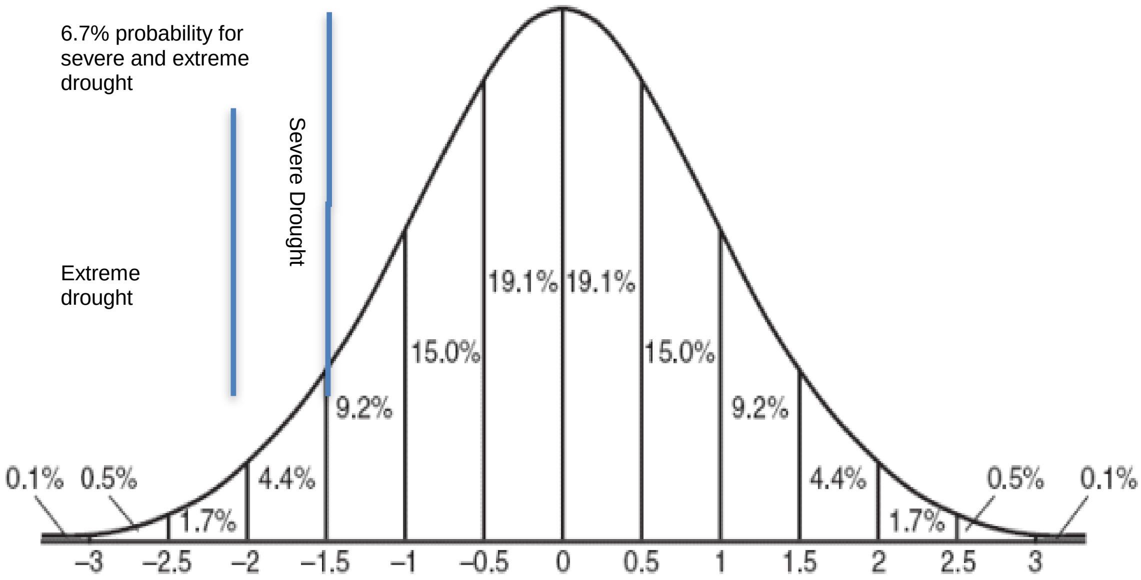


Fig 4.1: Standard normal distributions with the SPI and SPEI

As explained earlier, the algorithm for the SPI calculation was developed by Sakulski (2002) using *Webmathematica®* as an open source support tool to calculate SPI values *"on the fly"* for any time series for for the Northern Cape (See http://dimtecrisk.ufs.ac.za/nc) and the SPEI for the Eastern Cape (http://dimtecrisk.ufs.ac.za/wrc_ec).

Since 1993, when McKee *et al.* (1993) introduced the SPI, several authors have proposed slightly different categories (classifications) of dry and wet periods. According to McKee *et al.* (1993), a drought event for time scale x is defined as a period in which the SPI is continuously negative and the SPI reaches a value of -1.0 or less. The dry period begins when the SPI first falls below zero and ends with the positive value of the SPI following a value of -1.0 or less. The problem with McKee's classification is that it does not provide for a normal year classification with a small deviation from the SPI of zero. One should expect slightly above zero or slightly below zero as normal. Agnew (2000) argues in strong language against this; in his words, he wrote: *"In McKee's classification, all negative indexes (SPI) are taken to indicate the occurrence of drought; this means for 50% of the time, drought is occurring. This is clearly nonsense!" McKee* arbitrarily defined drought intensity for values of the SPI with the following categories (McKee *et al.,* 1993; 1995):

• 0 to -0.99	mild drought
• -1.0 to -1.49	moderate drought
• -1.5 to -1.99	severe drought
• less than -2.0	extreme drought

Agnew (2000) questions the values assigned by McKee *et al.* (1993) and raises the notion of *"persistent drought",* which confuses drought from desiccation[14]. Warren and Khogali (1992) distinguish drought from desiccation by arguing that (i) drought occurs when moisture supply is abnormally below the average for up to two years, while (ii) desiccation is a period of aridization brought about by decades of climate change. Therefore coping mechanisms for desiccation require long term measures such as resettlement and land use change, while drought requires short term measures.

Agnew (2000) suggested alternative thresholds because of the use of different drought classes with the analysis of annual rainfall from the Sahelian region in West Africa, which is well known for its extreme droughts, and the problem of changing the base averaging periods. Categories proposed by Agnew (2000) are:

• more than -0.5	no drought
• -0.5 to -0.84	moderate drought
• -0.84 to -1.28	severe drought
• -1.28 to –1.65	extreme drought

Hayes (1999) proposes modifications to Agnew's categories by using 5%, 10% and 20% probability occurrences as guideline for his classification. He proposes the use of the term *dry* instead of *drought* because that is more appropriate for short time scales. Hayes (1999) links the term *extreme* to the 5% probability and *severe* a 10% probability.

These categories are also the basis for the US monthly national SPI maps:

• 2.0 +	extremely wet
• 1.5 to 1.99	very wet
• 1.0 to 1.49	moderately wet
• -0.99 to 0.99	near normal
• -1.49 to –1.0	moderately dry
• -1.99 to –1.5	severely dry
• -2.0 and less	extremely dry

The classification proposed by Hayes (1999) is suggested for use in South Africa, but with slight aptations to make provision for the different agricultural sectors within the country.

[14] Aridness or aridity

4.2.17 Standard Precipitation Evapotranspiration Index (SPEI)

The most recently developed indicator for drought is the Standard Precipitation Evapotranspiration Index (SPEI) developed by Vicente-Serrano *et al*., 2010). The SPEI is based on both precipitation and temperature data and has the advantage of combining a multi-scalar character with the capacity to include the effects of temperature variability on drought risk assessments.

The SPEI combines the sensitivity of the PDSI to changes in evaporation demand that are caused by fluctuations and trends in temperature with the simplicity of the calculation and multi-temporal nature of the SPI. Because of the inclusion of temperature and temperature trends, the main advantage of the SPEI above other indices is in its ability to identify the role of temperature variability and evapotranspiration in drought risk assessments in the context of global warming (Vicente-Serrano *et al.,* 2010; Beguiria *et al*., 2010; Potop, 2011).

In order to understand the principles for the SPEI calculation one should understand evapotranspiration. Evapotranspiration is the most significant component of the hydrological budget after precipitation, and it varies according to weather, temperature and wind conditions. The impact of evapotranspiration becomes more significant during dry periods since it continues to deplete the limited remaining surface water supplies as well as soil moisture (Thornthwaite, 1948; Alley, 1984; Allen, 1998; Wilhite, 2000; Vicente-Serrano *et al.,* 2010).

Evapotranspiration is the water lost to the atmosphere through evaporation and transpiration. Transpiration is the loss of water through the leaves of plants and evaporation is the loss of water from open water bodies and the soil. The determinants of evapotranspiration include net solar radiation, surface water area, wind speed, density and type of vegetation cover, soil moisture, root depth, reflective land surface characteristics and season of the year (Hanson, 1991).

Potential evapotranspiration (PET) is defined as the amount of evaporation that would occur if a sufficient water source were available to a plant. If the actual evapotranspiration is considered to be the net result of atmospheric demand for moisture from a surface and the ability of the surface to supply moisture, then PET is a measure of the demand side. Surface and air temperatures, insolation, and wind all affect this. Wilhite (2000) defines a dry land as a place where annual potential evaporation exceeds annual precipitation.

The SPEI is based on the same calculation methodology for SPI, but the calculation of potential evapotranspiration (PET) is also included since SPEI uses the monthly or weekly difference between precipitation and PET as basis for calculation. Calculation of PET is the most difficult component because of numerous parameters such as surface temperature, air humidity, soil incoming radiation, water vapour pressure and ground-atmosphere latent and sensible heat fluxes (Allen*,* 1998; Vicente-Serrano *et al.,* 2010). The lack of reliable data for all the parameters has forced scientists to use alternative methods for calculating PET and Vicente-Serrano *et al. (*2010) therefore propose the

Thornthwaite method of calculating PET. Thornthwaite (1948) proposes the use of monthly mean temperature. Following Thornthwaite's method, PET is then calculated as follows (Beguiria *et al,* 2010; Vicente-Serrano *et al.,* 2010):

$$PET = 16K\left(\frac{10T}{I}\right)^{m}$$

where T is the monthly mean temperature in °C; I is a heat index, which is calculated as the sum of 12 monthly index values i, being derived from mean monthly temperature using the formula:

$$i = \left(\frac{T}{5}\right)^{1.514}$$

where m is a coefficient depending on I, and K is a correction coefficient computed as a function of the latitude and month by:

$$K = \left(\frac{N}{2}\right)\left(\frac{NDM}{30}\right)$$

where NDM is the number of days of the month and N is the maximum number of sun hours, which is calculated according to:

$$N = \left(\frac{24}{\pi}\right)\varpi_s$$

where ω_S is the hourly angle of sun rising, obtained as:

$$\varpi_s = \arccos(-tan\phi tan\vartheta)$$

where Φ is the latitude and ϑ is the solar declination (both in radians):

$$\vartheta = 0.4093sen\left(\frac{2\pi J}{365} - 1.405\right)$$

where J is the average Julian day of the month. With a value for PET, the difference between the precipitation (P) and PET for the month i is calculated as:

$$D_i = P_i - PET_i$$

which provides a simple measure of the water surplus or deficit for the month being analysed. The calculated D_i values are aggregated for different time scales, following the same procedure as for the SPI. Vicente-Serrano *et al.* (2010) found the selection of the most suitable statistical distribution to model the D series difficult, given the similarity among the four distributions (Pearson III, log-normal, Log-logistic and General Extreme Value). They based the selection of the most suitable statistical distribution model on the behaviour at the most extreme values. They realized the Log-logistic distribution showed a gradual decrease in the curve for low values, and coherent probabilities were obtained for very low values of *D*, corresponding to 1 in 200 to 1 in 500 year occurrence. In addition they found no values below the origin parameter of the distribution.

The probability density function of a three parameter Log-logistic distributed variable is expressed as

$$f(x) = \frac{\beta}{\alpha}\left(x - \frac{y}{\alpha}\right)^{\beta-1}\left(1 + \left(x - \frac{y}{\alpha}\right)^{\beta}\right)^{-2}$$

where *α*, *β* and *γ* are scale, shape and origin parameters, respectively, for *D* values in the range (*γ* > *D* < ∞). Parameters of the Log-logistic distribution can be obtained following different procedures. Among them, Vicente-Serrano *et al.* (2010) who found the L-moment procedure to be the most robust and easy approach. Vicente-Serrano *et al.* (2010) further follow Singh *et al.* (1993) who reported that when L-moments are calculated, the parameters of the Pearson III distribution can be obtained as follows:

$$\beta = \frac{2w_1 - w_0}{6w_1 - w_0 - 6w_2}$$

$$\alpha = \frac{(w_0 - 2w_1)\beta}{\Gamma(1 + 1\beta)\Gamma(1 - 1\beta)}$$

$$y = w_0 - \alpha\Gamma(1 + 1\beta)\Gamma(1 - 1\beta)$$

where Γ(*β*) is the gamma function of *β*. The probability distribution function of *D* according to the Log-logistic distribution is then given by:

$$F(x) = \left[1 + \left(\frac{\alpha}{x} - y\right)^{\beta}\right]^{-1}$$

where Γ(*β*) is the gamma function of *β*. The probability distribution function of *D*, according to the Log-logistic distribution, is then given by:

$$SPEI = W - \frac{C_0 + C_1W + C_2W^2}{1 + d_1W + d_2W^2 + d_3W^3}$$

where $W = \sqrt{-21n(P)}$

for *P* ≤ 0.5, *P* being the probability of exceeding a determined *D* value, *P* = 1-F(*x*). If *P* > 0.5, *P* is replaced by 1−*P* and the sign of the resultant SPEI is reversed. The constants are: C_0 = 2.515517, C_1 = 0.802853, C_2 = 0.010328, d_1 = 1.432788, d_2 = 0.189269, d_3 = 0.001308.

The average value of the SPEI is 0, and the standard deviation is 1. Like the SPI, the SPEI is a standardized variable and it can be compared with other SPEI values over time and space. An SPEI of 0 indicates a value corresponding to 50% of the cumulative probability of *D*, according to a Log-logistic distribution.

Scientists, in general, agree that precipitation is the most important variable to explain drought and that it should always be included in the calculation of drought indices (Alley, 1984; McKee *et al.,* 1993; Breguiria *et al*, 2010; Vicente-Serrano *et al.,* 2010; Hayes *et al,* 2011). The inclusion of a variable that accounts for climatic water demand, on the other hand, is not always considered, since its role in drought conditions is not always well accepted and understood. Hu and Wilson (2000) and Vicente-Serrano *et al.* (2010) argue that temperature, and for that matter evapotranspiration, plays a major role in explaining drought variability in drought indices. They argue that evapotranspiration determines soil moisture variability and consequently water available to vegetation, and that this has a direct effect on agricultural droughts commonly recorded by short time-scale indices. Narasimhan and Srinivasan (2005) and Vicente-Serrano *et al.* (2010) conclude that evapotranspiration-based indices show better results than purely precipitation-based indices for short term agricultural droughts.

Vicente-Serrano *et al.* (2010) find little difference between precipitation-based indices such as SPI and evapotranspiration indices such as the PDSI and SPEI in which temporal trends in temperature are not taken account of. They find that the inclusion of PET only affects the index when PET differs from average conditions, for example in global warming scenarios.

As an example of the results, let us analyse the SPEI results for tertiary catchment D14F step by step. The catchment covers the southern part of Barkley East local municipality in the Joe Gcabi district municipality. The maximum annual precipitation for catchment D14F is 1050,7 mm (1988), the minimum 240 mm (1954), the median 653,7 mm and the mean 644,3 mm. Basic input data for SPEI in this example is monthly rainfall in mm and evapotranspiration per tertiary catchment.

Step 1: Extract sub-matrix data from existing data for the period February-March-April (F-M-A for the 3 month SPEI); then, define a new set of data as 3-months-sum, for each year[15]. The histogram and PDF plot is shown in Figure 4.2.

[15] Depending on the SPI period to be calculated it could be 6-month-sum or 12-months-sum

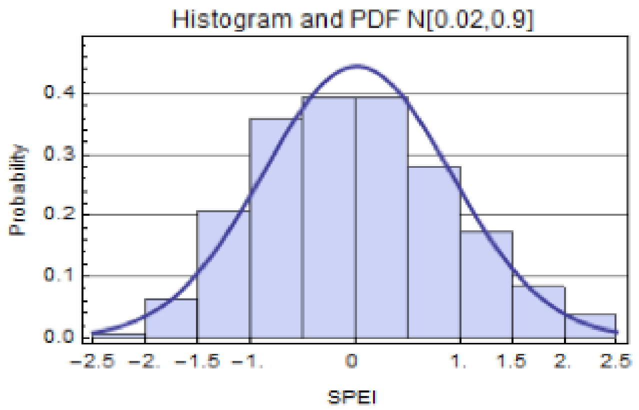


Fig 4.2: Histogram and PDF plot of 3-month precipitation data for April

Step 2: Calculate the empirical cumulative probability by applying a frequency analysis. Sakulski (2002) found the empirical probability to be optimal where precipitation data were sorted in ascending (increasing) order of magnitude so that the kth value was K-1 values from the lowest and where n was the sample size (See Figure 4.3)

Empirical cumulative probability = $\frac{k}{n+1}$

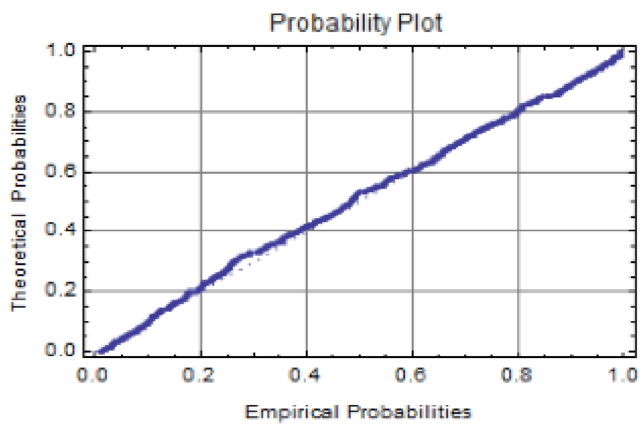


Fig 4.3: Empirical cumulative probability

Step 3: The smooth curve as shown in the left graph of Figure 4.4 (a) denotes the cumulative probability distribution of the fitted 2-parameter Gamma distribution of the 3-months-sum precipitation data.

Step 4: The smooth curve in the right graph in Figure 4.4 (b) denotes the cumulative probability distribution of the Standard Normal random variable Z, using the same cumulative probability scale of the empirical distribution and fitted Gamma distribution on the left hand side of the graph (Figure 4.4 (a))

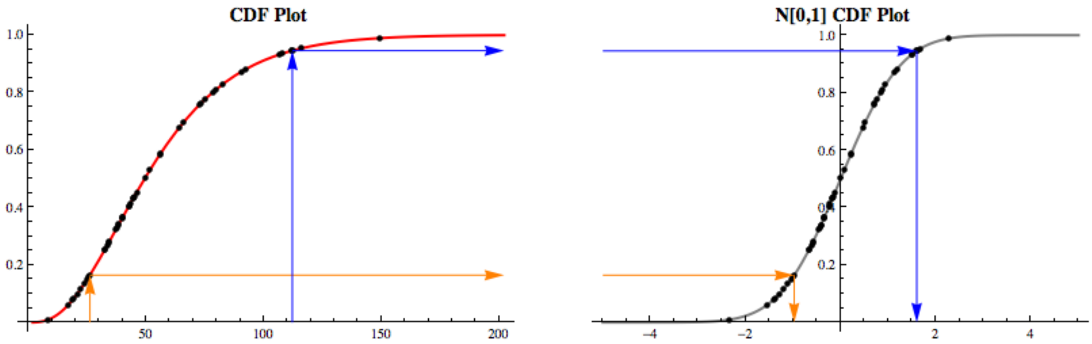


Fig 4.4 (a) & (b): Gamma to Standardised Normal distribution.

For example, to find the SPEI for the 27 mm (F+M+A) rainfall, go vertically upwards from the 27 mm mark on the x-axis in Figure 4.4 (a) until the fitted Gamma cumulative probability curve is intersected. Then go horizontally (maintaining an equal cumulative probability) to the right to Figure 4.4 (b) until the curve of the Standard Normal cumulative distribution is intersected. Then proceed vertically down to the x-axis of Figure 4.4 (b) in order to determine the SPEI value. In this case, the SPEI is approximately -1. The histograms, probabilities and Gamma Standardised normal distribution for different SPEI values are illustrated in Figures 4.5 to 4.7.

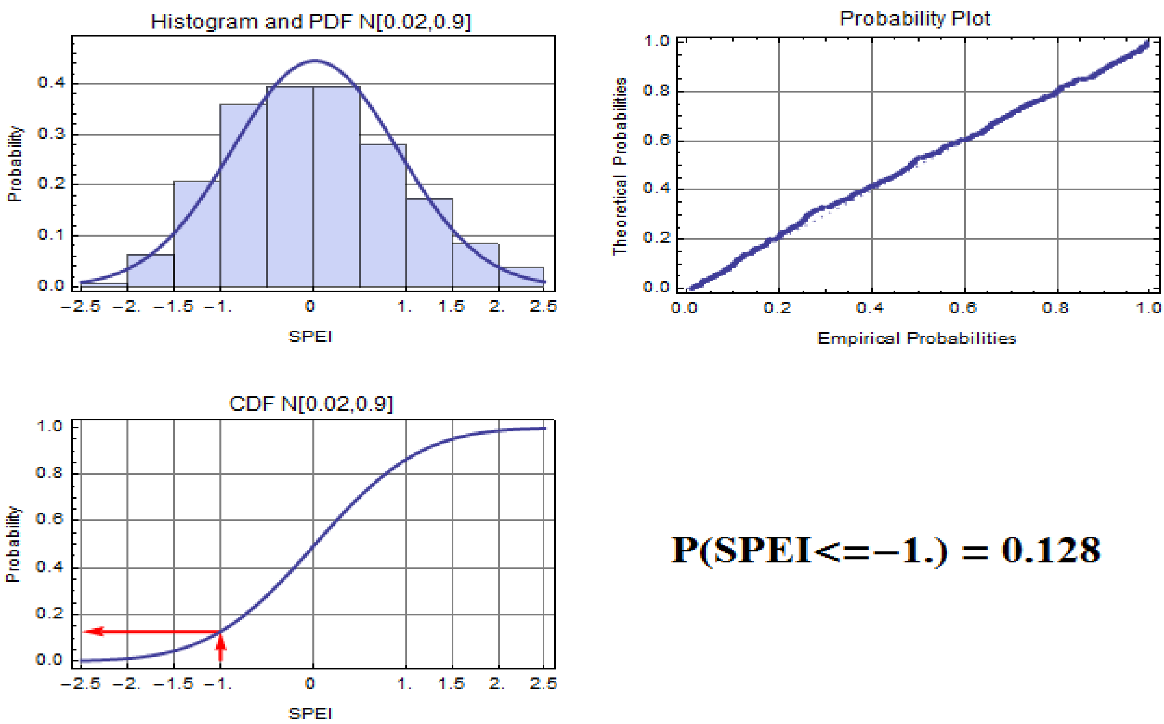


Fig 4.5: Histogram, probability and normal distribution for SPEI <=-1 in quaternary catchment N14B.

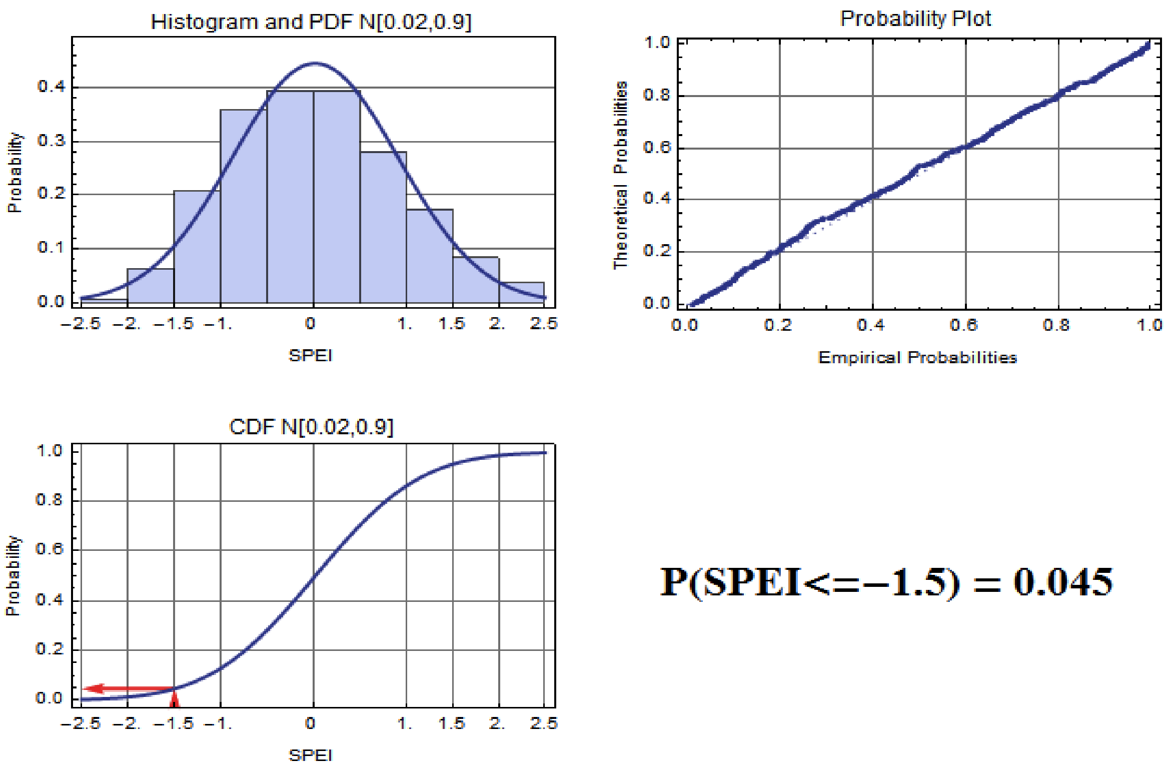


Fig 4.6: Histogram, probability and normal distribution for SPEI <=-1,5 in quaternary catchment N14B.

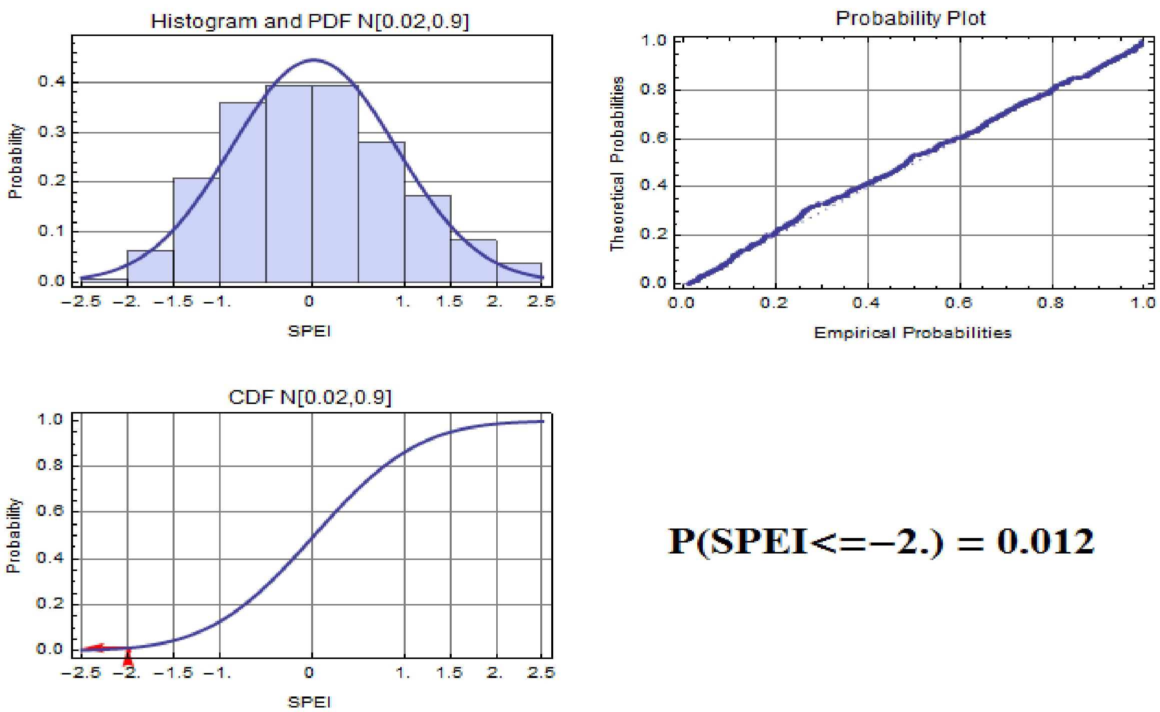
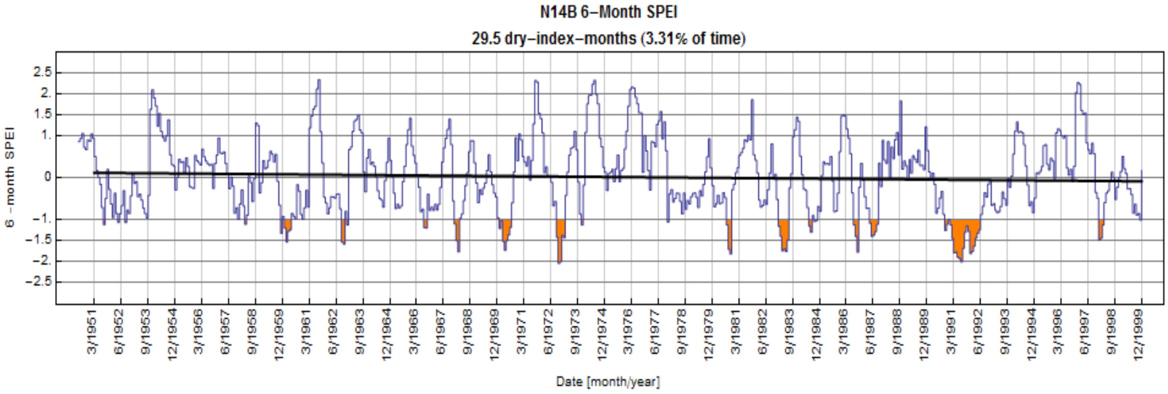


Fig 4.7: Histogram, probability and normal distribution for SPEI <=-2 in quaternary catchment N14B.

Step 5: In order to plot a SPEI time series for the whole period, simply repeat steps one to four for each month ending a 3-, 6-, 12-, or 24-month period. The results for the 6-month SPEI for tertiary catchment N14B is shown in Figure 4.6. The same methodology applies to the calculation of different time-scale SPEIs.



Indicative linear trend: 0.117878 - 0.000338354 x , p-Value=0.1161

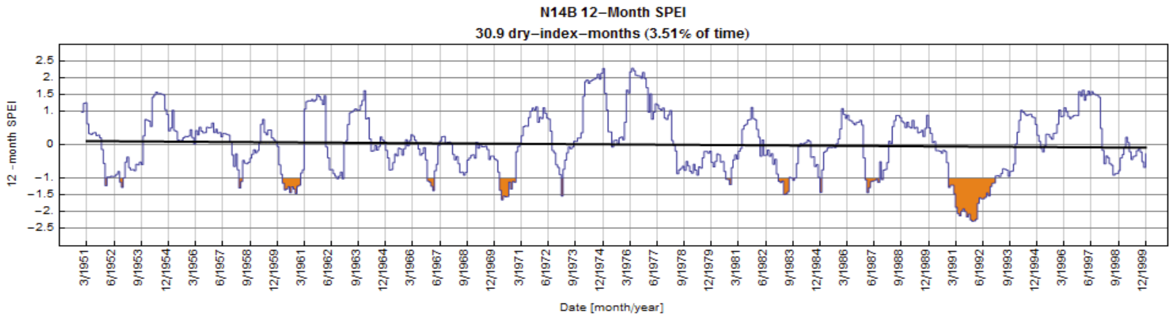
Dates	{Sep 1962, Oct 1962}	{Mar 1970, Apr 1970}	{Oct 1972, Nov 1972}	{Sep 1980, Oct 1980}	{Mar 1983, May 1983}	{Mar 1991, Aug 1991}	{Dec 1991, Feb 1992}
Duration	2	2	2	2	3	6	3
Intensity	1.55	1.62	2.01	1.75	1.73	1.84	1.72
Severity	3.1	3.24	4.02	3.5	5.19	11.04	5.16

Fig 4.8: Six-month SPEI graph for quaternary catchment N14B
(Sakulski & Jordaan, 2014)

The different SPEI time scales are useful for the analysis of different types of drought. For example, the 12-, 24- and 48-month SPI might provide a good indicator for hydrological droughts when longer term dry periods showed an impact on river flow and reservoir storage. Ji & Peters (2003) found that the 3-month SPI[16] was the most effective for monitoring drought impacts on vegetation, especially when the 3-month period coincided with the peak growing season. They compared NDVI and SPI outputs and found that the NDVI response was not sufficiently sensitive to the 1- or 2-month SPI while the scales longer than 6 months tended to reduce the covariation of SPI and vegetation vigour.

The 6-month SPEI value reflects seasonal precipitations patterns while the 12-month SPEI value reflects the annual precipitation pattern. See the 6-month and 12-month SPI values in Figures 4.8 and 4.9.

[16] SPI and SPEI results are similar in cotext of this study since no statistical change could be found on climate change



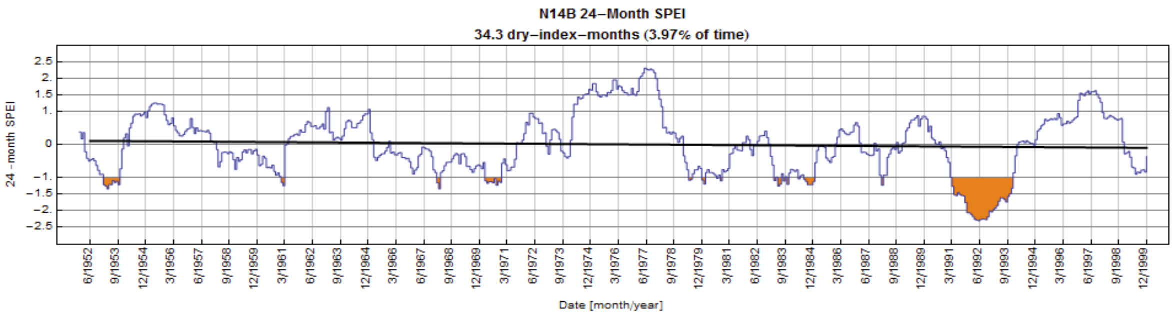
Indicative linear trend: 0.110244 - 0.000335401 x , p-Value=0.1266

Dates	{Apr 1970, Jul 1970}	{Mar 1991, Jul 1992}
Duration	4	17
Intensity	1.56	1.96
Severity	6.24	33.32

Fig 4.9: 12-month SPEI graph for tertiary catchment N14B
(Sakulski & Jordaan, 2014).

Khan *et al*. (2008) found a low correlation between shallow groundwater fluctuations with the short term SPI values. However, they found a good correlation between groundwater fluctuations at 6-, 12- and 24-month SPI values. This supports the *a-priori* expectation that groundwater and reservoir levels are better measured with long term (12-, 24- and 48-month SPI or SPEI) values.

The 12-month SPEI for tertiary catchment N14B shown in Figure 4.9 clearly shows one extreme dry period with SPEI <-2 during 1981-1982. On the same figure, the duration, intensity and severity of these different dry periods are shown. Severity is a function of duration and intensity and the SPEI provides a methodology for easy calculation of drought severity (See Figure 4.9).

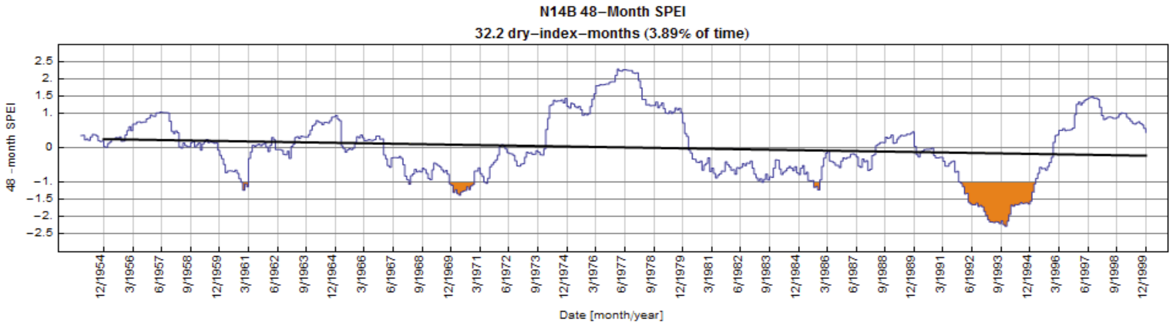


Indicative linear trend: 0.111666 - 0.000366687 x , p-Value=0.1094

Dates	{Apr 1991, May 1991}	{Jul 1991, Sep 1993}
Duration	2	27
Intensity	1.52	1.94
Severity	3.04	52.38

Fig 4.10: 24-month SPI graph for tertiary catchment N14B
(Sakulski & Jordaan, 2014)

The longer time-span (24-month; Figure 4.10, and 48-month; Figure 4.11) of the SPEI calculation smoothes the graph and only the long term severe and extreme droughts become visible. The application of the SPEI in drought risk assessment becomes simple when analysing the above-mentioned SPEI graphs. The calculation of frequency (probability) and severity of dry periods and droughts is now very easy.



Indicative linear trend: 0.251262 - 0.000864747 x , p-Value=0.0004

Dates	{Apr 1992, Dec 1994}
Duration	33
Intensity	1.83
Severity	60.39

Fig 4.11: 48-month SPI graph for tertiary catchment N14B
(Sakulski & Jordaan, 2014)

Drought frequency, or probability, is an important indicator when comparing different regions for drought risk. Since the SPEI equation expresses the data as a normal distribution, one should expect probability for severe droughts to be < 0.67 and extreme droughts to be < 0.23; in other words, to simplify the argument, one could expect approximately seven severe droughts for every 100 years and three extreme droughts for every 100 years if the 12-month SPEI were calculated. The probability for extreme and severe droughts or dry periods remains the same for the 3- and 6-month SPEI, but one should keep in mind that probability was calculated for 3- and 6-month periods; in other words the probability for severe drought according to the 3-month SPI is 7 out of (100 X 3 = 300/12 = 25) 25 years and for the 6 month SPI it would be 7 out of 50 years.

Figure 4.12 illustrates the exceedence probability using catchment D13F by way of example. The strength of the SPI and SPEI technique is illustrated here in that one can clearly see how easy it is to calculate the probabilities for dry and wet periods with positive values from 1 to 2,5 at the top of the graph (McKee *et al,* 1993; Hayes *et al.,* 1999; Wilhite, 2000a; Hayes, 2011).

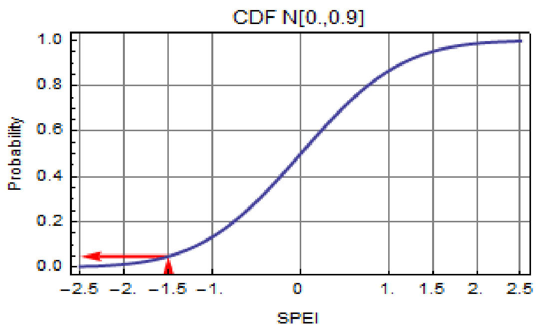


Fig 4.12: Twelve-month exceedence probability for SPEI -1,5 for D13F
(Sakulski & Jordaan, 2014)

However, the questions to be answered in drought risk assessment are (i) which of the 6-, 12-, 24- or 48-month SPEI or SPI values represent disaster droughts and (ii) at what SPEI or SPI value should disaster droughts be measured – is it at -1.5 (severe drought) or -2.0 (extreme drought)?

4.3 Analysis of Eastern Cape Meteorological Data for Drought Hazard Assessment

This section deals with the analysis of meteorological data in the Eastern Cape Province. The different drought indices were discussed in the previous section and, in accordance with the UNCCD (2009) recommendations, the use of the SPI and the SPEI seemed to be the most suitable for hazard calculation as part of the drought risk assessment. The SPEI and the SPI provided similar results, but the advantage of the SPEI is the inclusion of evapotranspiration in the algorithm.

4.3.1 Unit of Measurement

The unit of measurement is important in the methodology for drought risk assessments. At farm level, farmers might decide to separate agricultural types such as crop production and livestock production from each other. Disaster management might select municipal boundaries as the unit of measurement while the broader agricultural sector might use different criteria as a unit of measurement. All disaster management plans completed for either Provincial or District Disaster Management Centres used the politically demarcated borders such as municipal or district borders as their unit for reporting. Drought risk, however, is not contained to any man-made border and should rather follow terrain morphological features such as mountains, valleys etcetera.

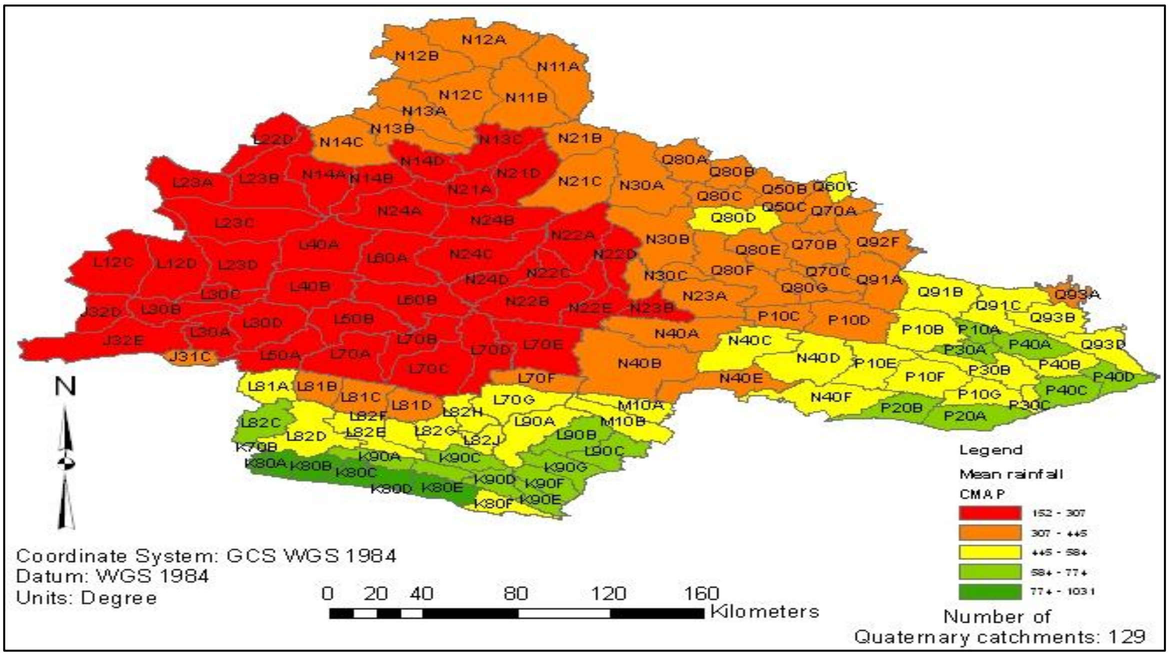


Fig 4.13: Quaternary catchments for the Cacadu District Municipality

The availability of rainfall records (from WR90) played an important role in the decision for the spatial unit of measurement. Long term normalised rainfall records existed for quaternary catchments and the availability of those records was most important in the decision to utilise quaternary catchments as the spatial unit of measurement. Easter *et al* (1985) also define a watershed as a sub-drainage system of a river basin and argue for integrated management of watersheds. The terminology for "watershed" used in this is research is "catchment". Figures 4.13 to 4.15 show the quaternary catchments and annual precipitation in Cacadu, OR Tambo and Joe Gcabi District Municipalities.

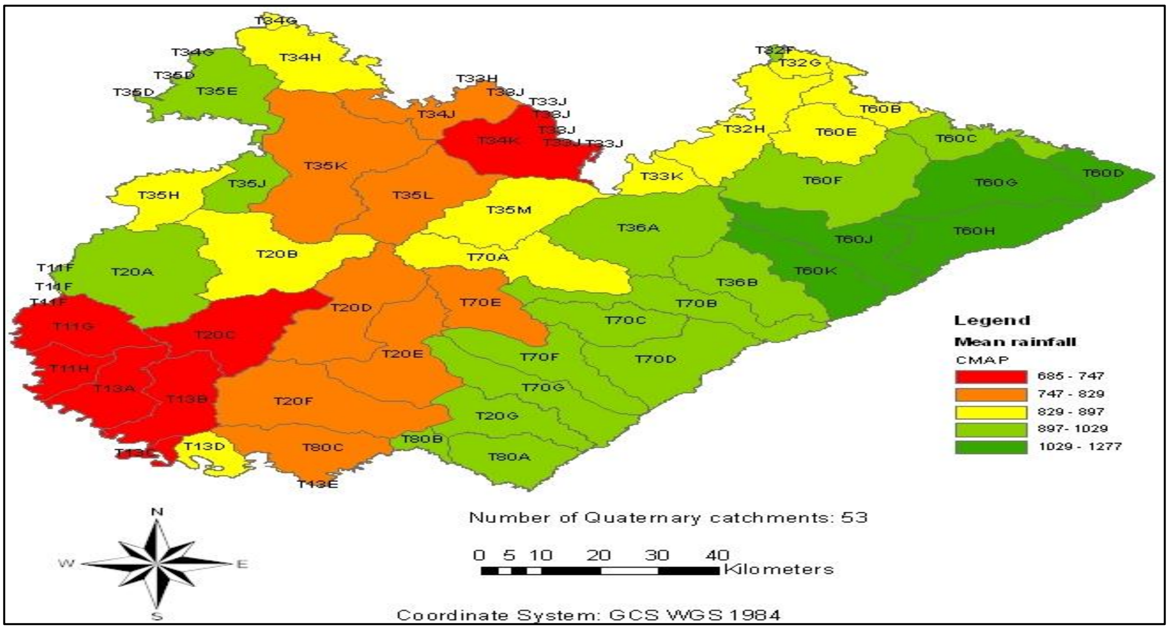


Fig 4.14: Quaternary catchments for the OR Tambo District Municipality

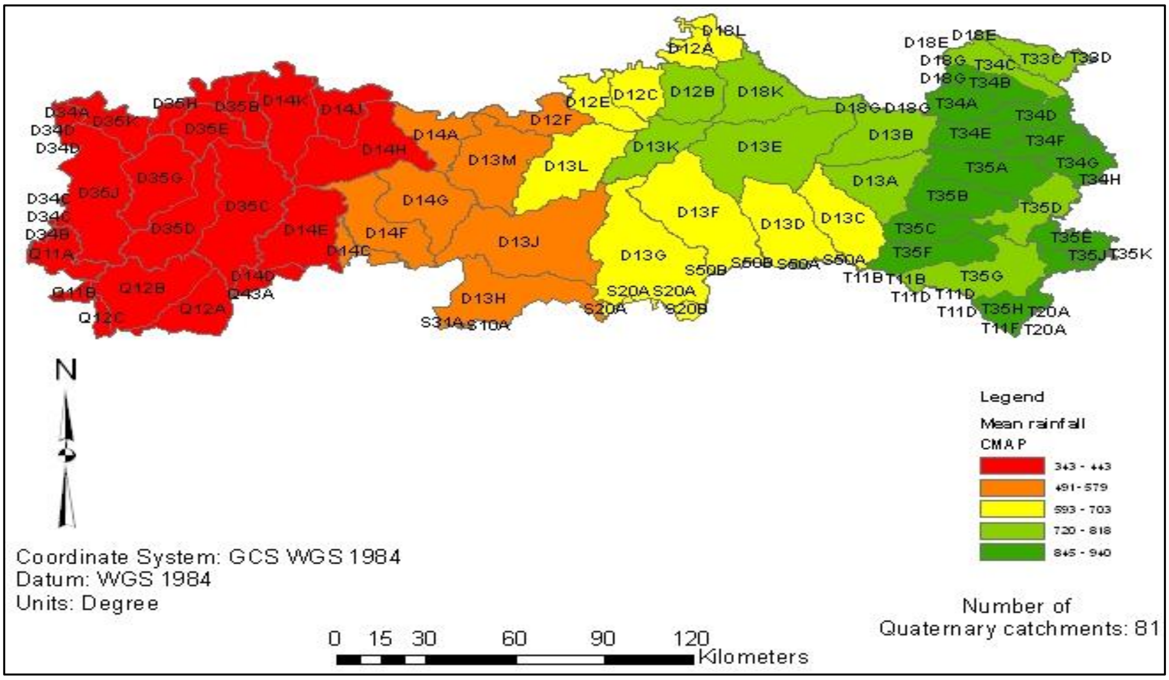


Fig 4.15: Quaternary catchments for the Joe Gqabi District Municipality

Unfortunately, reliable long term rainfall records for catchments are only available until 2000, which provided for 50 years of precipitation records. The SAWS could provide some point data mainly in the Cacadu DM, with little useful new data in OR Tambo DM and Joe Gcabi DM. The WR90 data were found to be more useful to utilise and to analyse 50 years of rainfall for all catchments, rather than using data for a few point sources with those data very unreliable for the past 20 years. The SAWS office in Port Elizabeth highlighted the gaps and discrepancies in data for the past 20 years, which is of great concern. Updating of data is a requirement for further climate research. A system was developed as part of this project where new data can be uploaded on the web-based *Mathematica*® programme available at http://dimtecrisk.ufs.ac.za/wrc_ec and hosted on the computer server of the University of the Free State. The focus of this study is on the risk assessment methodology where long term data are required to calculate probability, intensity and severity per quaternary catchment and the lack of data for the past 10 years was therefore not viewed as a serious obstacle.

Since precipitation is so unpredictable and differs from farm to farm, it would always be better to have the unit of measurements as small as possible. For decision-making at micro (farm) level this is true. This study, however, deals with risk assessment at the meso level and quaternary catchments as a unit of measurement are therefore sufficient. As a next phase and for the purpose of micro or district level planning, the use of smaller units of measurement would be more accurate. Figures 4.13 to 4.15 show the quaternary catchments in the three Districts in the Eastern Cape.

4.3.2 Meteorological Data Used for the Drought Risk Assessment

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; WMO, 2006). Figure 4.16 shows the different mean rainfall zones in South Africa and it is clear that the Eastern Cape hosts the highest rainfall zone in South Africa at the east coast and a very arid region in the Karoo.

Considering the importance to adapt to climate conditions and the development of agricultural systems and practices according the climate and natural resources, one can expect drought resistant agricultural systems the western parts of the Eastern Cape. The risk assessment performed in this study analysed the rainfall for each catchment and developed a hazard profile for the province based on precipitation patterns for a 50 year period. Precipitation patterns play an important role in drought risk assessment and long term time series data can provide insight into potential drought patterns (Wilhite *et al.,* 2000).

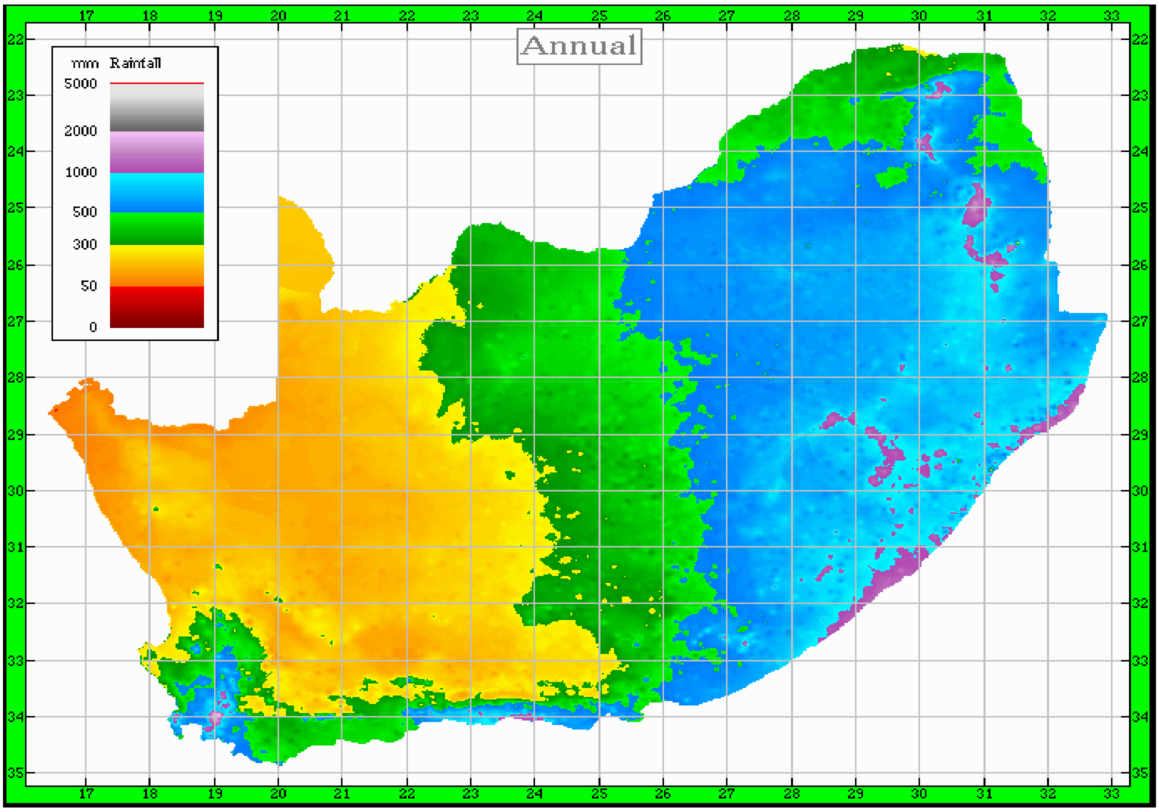
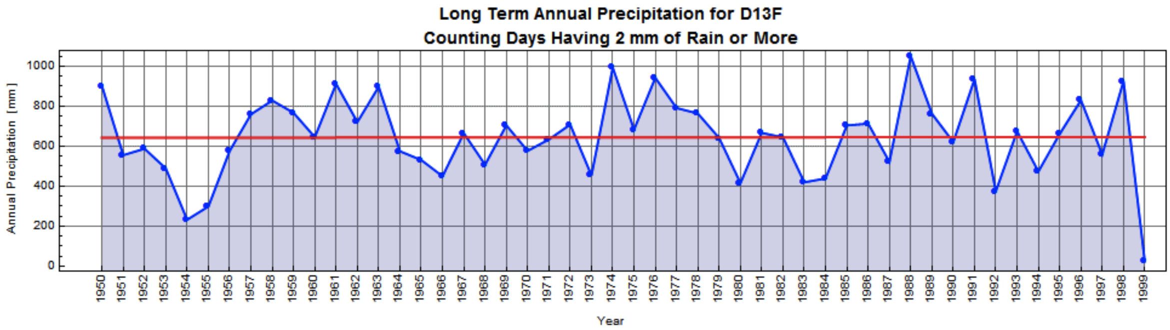


Fig 4.16: Mean Annual rainfall map for South Africa
(South Africa Rain Atlas, 2010)

Calculation and analysis of meteorological data became exhausting with the large amounts of data and for different locations. The internet on the other hand provides the user with new information and communication tools unthinkable a few years ago (Sakulski & Jordaan, 2011). Users today can easily link to various information sources and extract alpha-numerical and graphical information from any web page. Partly as a result of this project, Sakulski & Jordaan (2014) developed a website (http://dimtecrisk.ufs.ac.za/wrc_ec) consisting of a reliable database and embedded mathematical language (*Webmathematica®*, www.wolfram.com). The database (MS SQL Server, www.microsoft.com) contains relevant meteorological time series data such as rainfall and temperature. All analysis and visualizations are done *"on the fly"* and no single one index in the program is pre-calculated and the user has the opportunity to select what data to analyse for what time period and for which of a selected number of locations, and what technique of analysis should be applied. Information for EC province was programmed and developed for the purpose of analysing data for this research and it is now available at http://dimtecrisk.ufs.ac.za/wrc_ec. Almost all the hazard calculations performed in this study were done by using the web based *mathematical* tool described here.

4.3.2.1 Precipitation

The detailed analysis for each catchment is shown in Attachment B. This report only explains, by way of examples, the different variabilities and criteria used in the hazard analysis. Publication of all the detailed results and analysis per catchment will take up more than 500 pages. An example of analysis of mean annual precipitation and its long term trend is shown in Figure 4.17.



Max=1050.7 mm , Mean=644.3 mm , Median=653.7 mm , Min=24. mm , Std. Dev.=202.6 mm , Coef. of Var.=0.314

Indicative linear trend: 642.6 + 0.0666699 x , p-Value=0.974 (Trend not significant) ,
Rainfall increased 0.07 mm annualy , 20th percentile of exceedance=791.2 , 80th percentile of exceedance=473.8

Durbin-Watson=1.771 (Indication of a positive first-order autocorrelation)

Fig 4.17: Analysis of precipitation data for quaternary catchment D13F, Barkley East (1950-1999)
(Sakulski & Jordaan, 2014)

Data shown in Fig 4.17 is available for all quaternary catchments in the study area. As an example for catchment D13F, the types of data available for each catchment or rainfall station with data are the following (Sakulski & Jordaan, 2014):

• Maximum annual precipitation	1050,7 mm
• Minimum precipitation	240,0 mm
• Median	653,7 mm
• Mean	644,3 mm
• Standard Deviation	202,6 mm
• Coefficient of variance	0.314
• 20th percentile of exceedence	791,2 mm
• 80th percentile of exceedence	473,8 mm
• Trend line	y = 642,6 - 0,0666699
• P-Value (trend line)	p = 0,907 (not significant)
• Mean annual increase of rainfall	0.07 mm

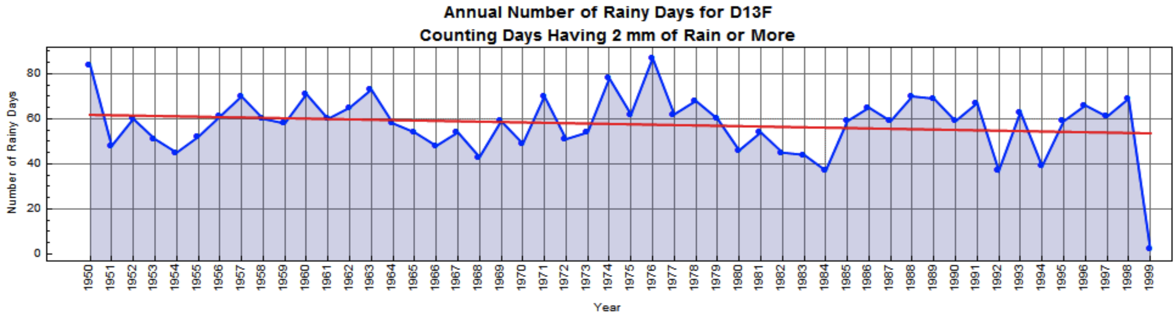


Fig 4.18: Number of rainy days with 2 mm and above for quaternary catchment D13F, Barkley East (1950-1999)
(Sakulski & Jordaan, 2014)

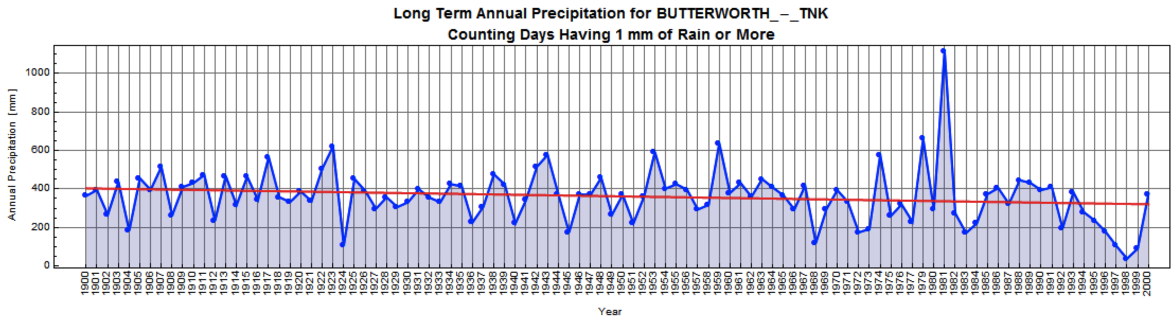
Figure 4.18 illustrates the number of rainy days with 2mm of rain and more per day. The information shown for each catchment is as follows (with data shown here for catchment D13F):

• Maximum daily precipitation	87,0 mm
• Minimum precipitation	0,0 mm
• Median	59.0 mm
• Mean	57,7 mm
• Standard Deviation	13,7 mm
• Coefficient of variance	0,237
• 20th percentile of exceedence	68,0 mm
• 80th percentile of exceedence	48,0 mm
• Trend line	y = 61,982 - 167923
• p-Value (trend line)	p = 0,214 (not significant)

Point data for a number of stations are also included on the web site. The precipitation for example for Butterworth from 1900 to 2000 is shown in Figure 4.19. Most of the point data sources have 100-year records. By way of example the results for Butterworth show the following:

• Maximum annual precipitation	1117,4 mm
• Minimum precipitation	38,0 mm
• Median	367,6 mm
• Mean	362,1 mm
• Standard Deviation	142,9 mm
• Coefficient of variance	0.395
• 20th percentile of exceedence	791,2 mm
• 80th percentile of exceedence	473,8 mm
• Trend line	y = 404,167 – 0,834059

• P-Value (trend line)	p = 0,09 (not significant)
• Mean annual decrease of rainfall	0.82 mm



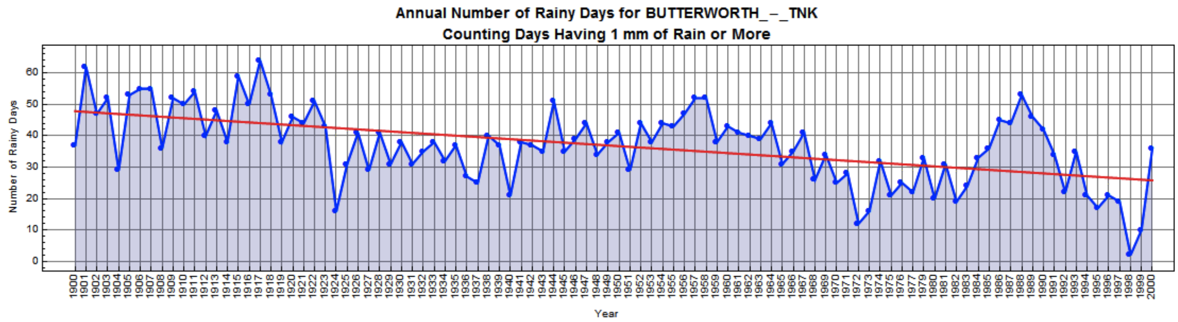
Max=1117.4 mm , Mean=362.1 mm , Median=367.6 mm , Min=38. mm , Std. Dev.=142.9 mm , Coef. of Var.=0.395

Indicative linear trend: 404.176 - 0.834059 x , p-Value=0.092 (Trend not significant) ,
Rainfall decreased -0.82 mm annualy , 20th percentile of exceedance=437.7 , 80th percentile of exceedance=260.3

Durbin-Watson=2.083 (Indication of no autocorrelation)

Fig 4.19: Annual precipitation and precipitation trend line for Butterworth (1900-2000)
(Sakulski & Jordaan, 2014)

The number of rainy days per annum is also illustrated for all point data sources from 1900 to 2000. According to the Butterworth data, number of rainy days has decreased dramatically there (See Figure 4.20). This indicates a probable increase in rainfall intensity since the mean annual precipitation in Butterworth has remained approximately the same for the past 100 years.



Max=64. mm , Mean=36.8 mm , Median=38. mm , Min=2. mm , Std. Dev.=11.9 mm , Coef. of Var.=0.322
Indicative linear trend: 48.0739 - 0.222652 x , p-Value=0. (Significant trend) ,
No. of rainy days decreased -0.21 mm annualy , 20th percentile of exceedance=46 , 80th percentile of exceedance=26

Durbin-Watson=1.219 (Indication of a positive first-order autocorrelation)

Fig 4.20: Number of rainy days with 2 mm and above for Butterworth (1900-2000)
(Sakulski & Jordaan, 2014)

The data for Butterworth are as follows:

• Maximum daily precipitation	64 mm
• Minimum precipitation	2 mm
• Median	38 mm
• Mean	36,8 mm
• Standard Deviation	11,9 mm
• Coefficient of variance	0,322

•	20th percentile of exceedence	68 mm
•	80th percentile of exceedence	48 mm
•	Trend line	y = 48,073 – 0,222652
•	p-Value (trend line)	p = 0 (significant negative trend)

Again, the above data are available on the website for all catchments, while point data and the summary of all data are shown in Attachment B.

Precipitation trends sometimes provide interesting *a priory* and statistical insights into rainfall patterns. Figures 4.21 and 4.22, for example, show the 5-year and 7-year moving average precipitation for catchment D13F. These data provide valuable information for drought hazard assessment. Some scientists are of the opinion that clear cycles can be detected, with below average rainfall periods followed by above average rainfall periods in the summer rainfall areas (Alexander, 1983; Tyson, 1987; Alexander, 2009). The purpose of this research is, however, not to analyse rainfall cycles; rather it is to determine drought risk that is based on historical trends and probabilities which, in turn, are linked to vulnerability and capacity of the farming sector to cope to and adapt to dry periods.

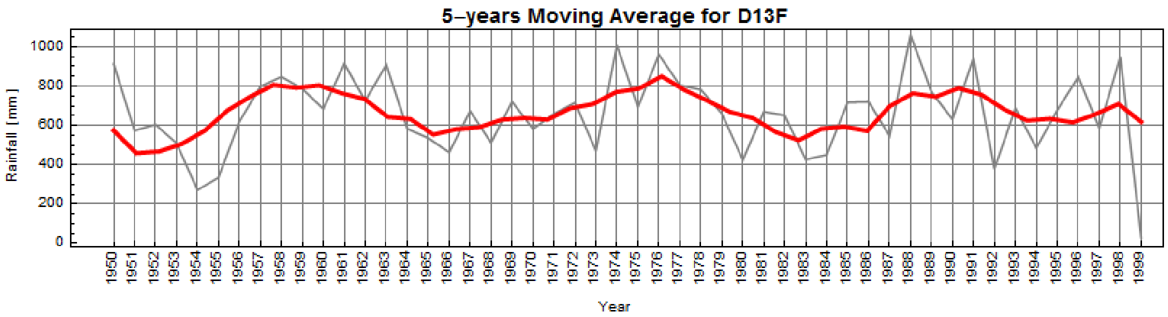


Fig 4.21: Five-year moving average for D13F
(Sakulski & Jordaan, 2014)

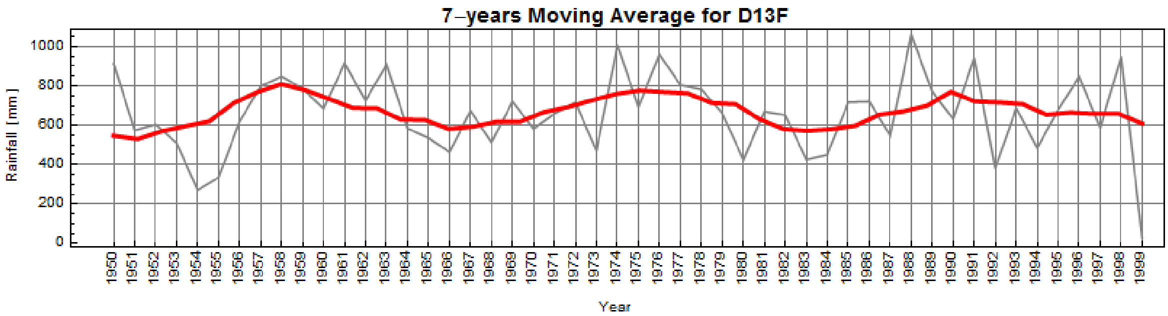


Fig 4.22: Seven-year moving average for D13F
(Sakulski & Jordaan, 2014)

Cumulative rainfall calculations can be very useful for the prediction of dry periods and drought. Fig. 4.23, for example, shows the cumulative rainfall for catchment N14B during the devastating 1992 drought. Here one can see that January already starts with a deficit from the 50-year mean (1950-2000), and that continues and even increases for the remainder of the year. Such information (which will be available at http://dimtecrisk.ufs.ac.za/wrc_ec with updated and real time data) provides farmers and officials with the necessary early warning information to act timeously and to implement the necessary risk reduction measures.

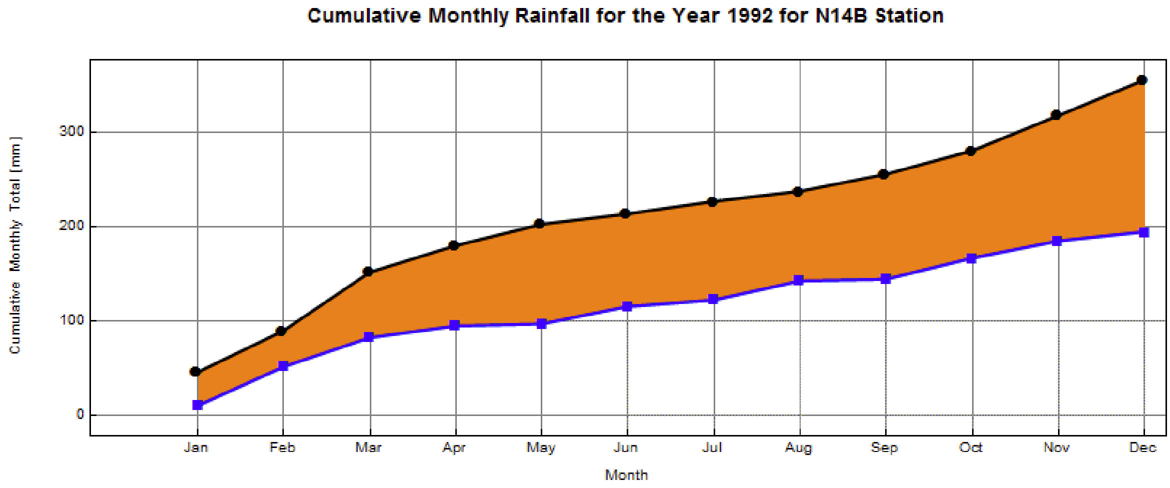


Fig 4.23: Cumulative monthly rainfall for quaternary catchment N14B (1992)
(Sakulski & Jordaan, 2014)

Also available on the web application is the long term monthly precipitation analysis for all twelve months at more than 100 locations in the EC. For example, Figure 4.24 is an illustration of the long term precipitation data for January for D13F from 1950 to 2000. The positive trend in annual precipitation for this month is evident (y = 81,4964 + 0,273776), although the trend is not significant (p = 0.6066). The exceptionally high rainfalls during 1975, 1988 and 1999 could be the reason for the positive trend. The fact is, this information is valuable in the calculation for drought hazard risk in the different areas of the EC, and it is now available for scientists, scholars, extension officers, farmers and others who are interested in the analysis of meteorological data.

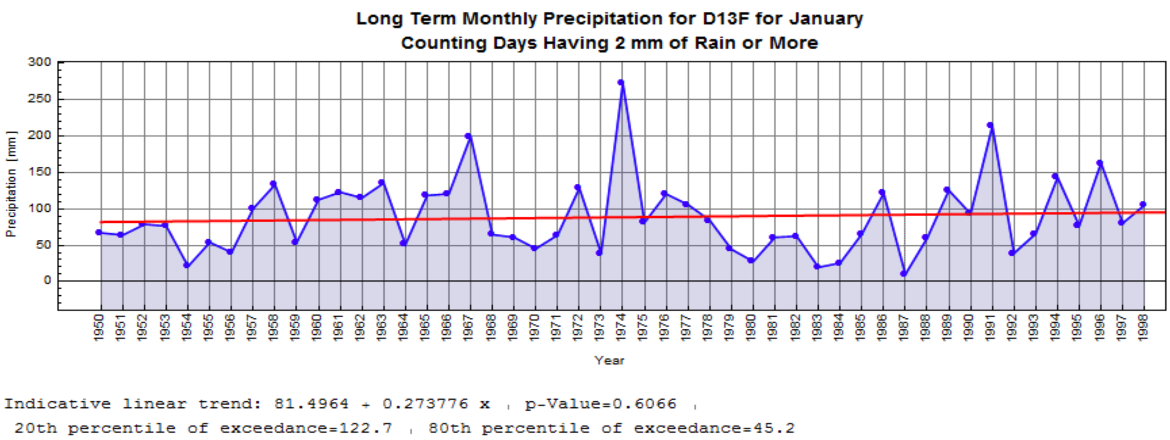
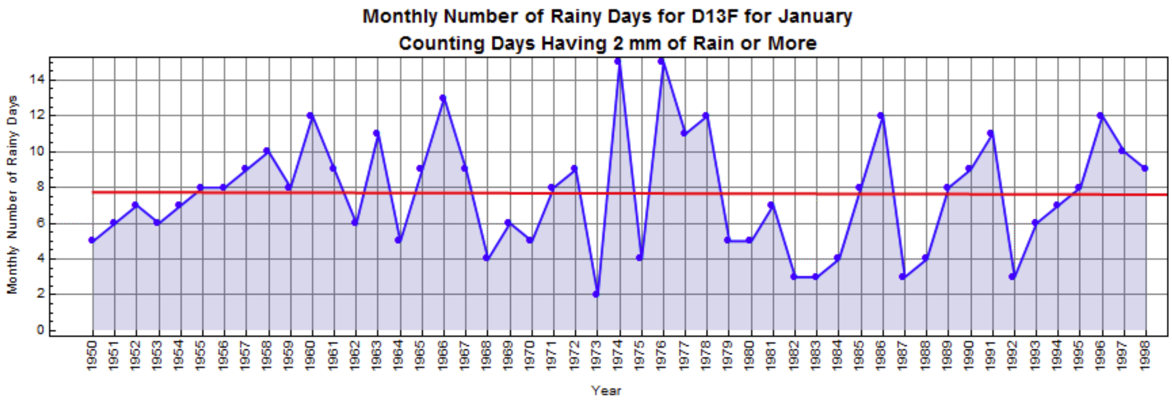


Fig 4.24: Long term monthly precipitation for January at D13F (1950-2000)
(Sakulski & Jordaan, 2014).



Indicative linear trend: 7.74235 - 0.0027551 x , p-Value=0.9332

Fig 4.25: Long term days per month with 2mm rainfall and more for January at D13F (1950-2000)
(Sakulski & Jordaan, 2014).

The precipitation data and trend for the number of rainy days during January is shown in Figure 4.25. January is the month with the highest average rainfall in D13F and the analysis of numbers of rainy days with 2mm and more precipitation shows no significant trend with p value 0,9332 (indicative of a linear trend: 7,74235 – 0,0027551).

Exceedence probability for precipitation is a useful tool for early warning and drought planning. Figure 4.26 illustrates the exceedence probability for precipitation during a 7-day period during January for quaternary catchment N14B. For example, according to this graph, there is a 15% probability of receiving 8 mm of rain in N14B during a 7-day period in January. The web-based tool allows the user to select the location, the month and the duration.

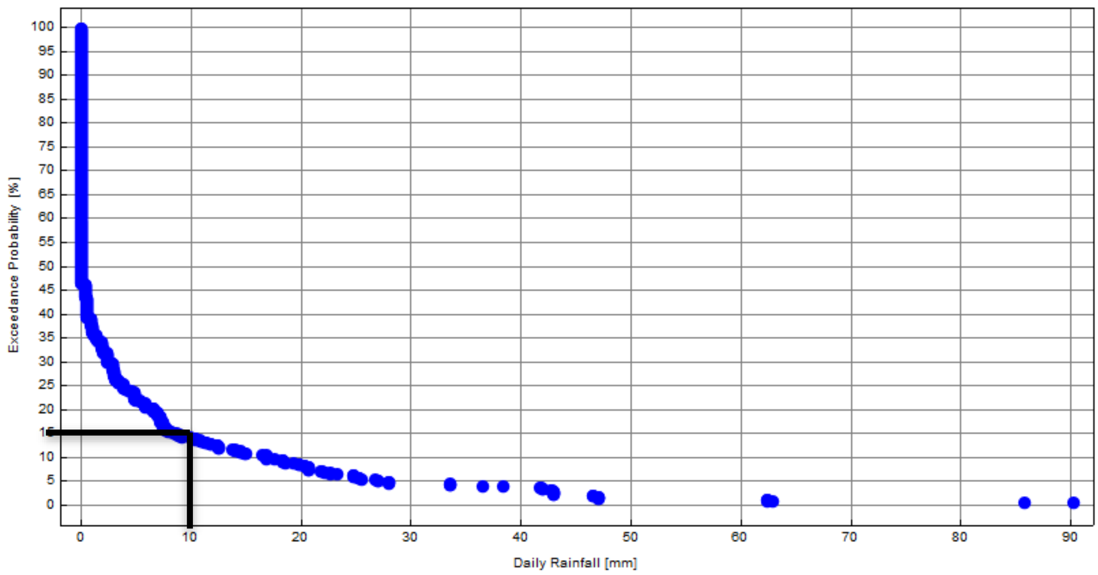
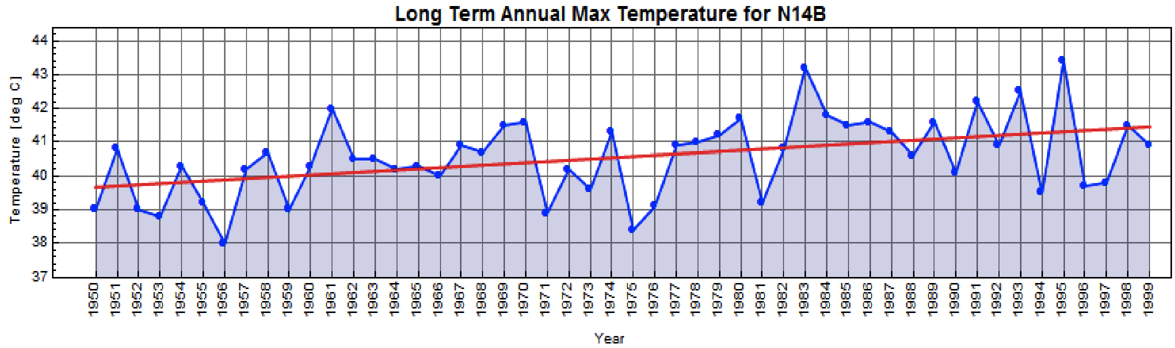


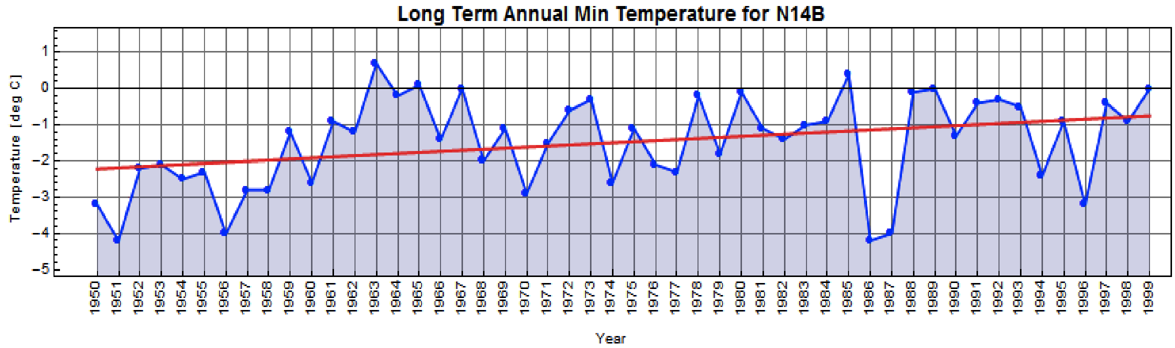
Fig 4.26. Exceedence probability for precipitation during a 7-day period in January in quaternary catchment N14B
(Sakulski & Jordaan, 2014)

4.3.2.2 *Temperature*

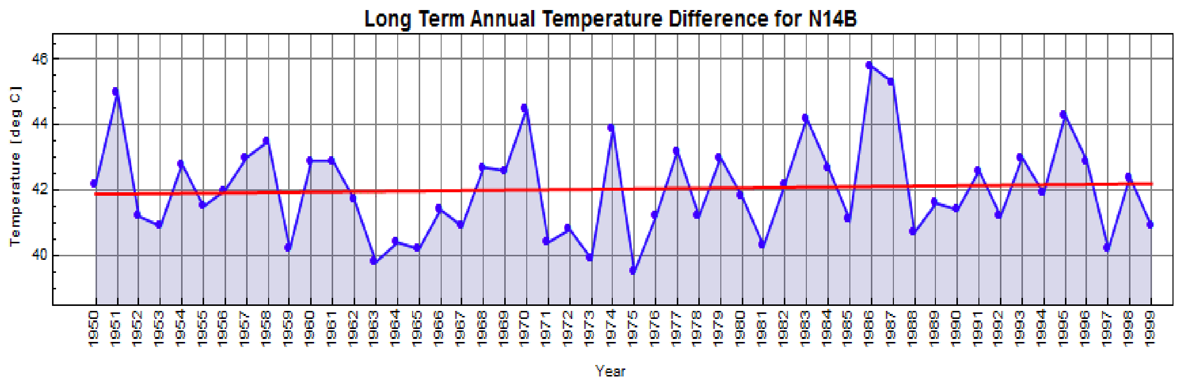
The importance of temperature in the calculation of SPEI has already been discussed and long term trends could provide provides some insight into long term climate trends, especially bearing in mind all the potential impacts of climate change. Figure 4.27 (top, middle and bottom), for example, shows the analysis for, respectively, the maximum temperature for each year, the minimum for each year and the mean temperature difference for every year from 1950 to 1999 for N14B. The indicative linear trend for maximum temperature of each year in catchment N14B is y = 39,6263 + 0,0365378x, where x is year after 1950, with a p value 0,0011, which indicates a significant positive trend in maximum temperature. The linear trend for minimum temperatures is also positive with y = -2,24335 + 0,029352x and a p value 0,0151, which is statistically not as significant as the increase in maximum temperatures, yet the long term highest temperature difference for each year remains the same for period 1950-1999. Again these results can be calculated *"on the fly"* for all quaternary catchments in the study area.



Indicative linear trend: 39.6263 + 0.0365378 x , p-Value=0.0011



Indicative linear trend: -2.24335 + 0.0299352 x , p-Value=0.0151



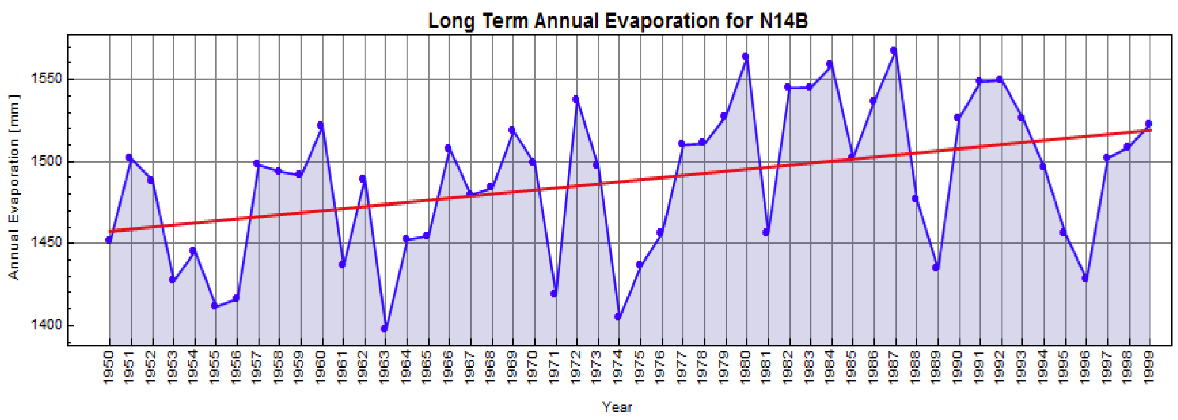
Indicative linear trend: 41.8696 + 0.00660264 x , p-Value=0.6585

Fig 4.27 (top), (middle) and (bottom): Maximum temperatures for each year, minima per year and highest temperature difference per year at N14B (1950-1999)
(Sakulski & Jordaan, 2014).

4.3.2.3 Evapotranspiration

Evapotranspiration is directly linked to precipitation. In most arid and semi-arid regions annual reference evaporation is higher than annual precipitation, which indicates a moisture deficit (Wilhite *et al.,* 2000). In the example in Figure 4.28 one can see the time series data for reference evaporation in N14B from 1950-1999. The positive linear trend is clear with y = 1456,28 + 1,25757x, where x is years after 1950, and p = 0,0037 which is indicative of a statistically significant positive trend.

The use of such analyses is especially useful to find the (statistical) truth when farmers and scientists blame the increased incidence of drought on global warming.



Indicative linear trend: 1456.28 + 1.25757 x , p-Value=0.0037 ,
20th percentile of exceedance=1526.6 , 80th percentile of exceedance=1436.9

Fig 4.28: Annual reference evaporation for N14B (1950 – 1999)
(Sakulski & Jordaan, 2014)

The results illustrated above were undertaken for all quaternary catchments[17] in the study area. Results are calculated *"on the fly"* and are shown on the website www.dimtecrisk.ufs.ac.za/nc/drought. The website now provides the opportunity for researchers, students, farmers and other specialists to make their own assessments for any location in the study area *"on the fly".* A summary of some of the important results is shown in Attachments C to F. Data were analysed and summarised by district municipality, catchment and climate zone.

4.3.3 Summary

A summary of the analysis of the different districts and rainfall zones is shown in Table 4.1. Rainfall per district is classified into three main categories, namely 700 mm plus, 400-699 mm and less than 400 mm. The objective of this analysis is to determine any differences in trends and dry period probabilities for dry and wet climate zones. The following information is included in Table 4.1: (i) district municipalities, DM (ii) rainfall category, (iii) trend value (y), (iv) p value, (v) annual mean change in precipitation, (vi) maximum annual precipitation, (vii) mean annual precipitation, (viii) median annual precipitation, (ix) minimum annual precipitation, (x) standard deviation of annual precipitation, and (xi) coefficient of variance.

Table 4.1: Precipitation analysis per district per climate zone

DM	Rainfall Category	Trend Value	p Value	Annual Change	Max (mm)	Mean (mm)	Median (mm)	Min (mm)	Standard Deviation	Coef Var
ORT	700+	-0,26	0,55	-0,73	1563,28	901,70	888,15	332,41	227,64	0,25
JG	700+	-0,58	0,30	-1,30	1281,78	816,02	805,19	294,07	198,24	0,25
Cac	700+	-0,27	0,31	-0,02	1155,75	697,50	685,19	407,70	164,59	0,24
JG	401-699	-0,47	0,56	-0,53	1021,63	532,18	515,36	194,62	172,53	0,33
Cac	401-699	-0,57	0,42	-1,10	921,53	491,82	477,64	233,19	143,49	0,29
JG	<400	-0,14	0,38	-0,26	867,61	386,32	364,71	155,59	145,13	0,37
Cac	<400	0,00	0,47	0,35	676,86	312,67	291,87	114,81	123,07	0,40

Most regions show a decline in rainfall, with the highest being 1,3 mm per annum in the high rainfall zone in the Joe Gcabi DM, indicative of a decline in annual rainfall of 8,06% during the period 1950-2000 (Table 4.2). The only exception is the most arid region in Cacadu DM with less than 400 mm per annum, where an increase of 0,35 mm per annum is detected, equivalent to an increase of 5,92% in rainfall over 50 years. The latter concurs with the risk assessment in the arid Northern Cape Province, where most catchments experienced an increase in precipitation (Jordaan, 2011).

Table 4.2: Changes in precipitation

DM	Category (mm)	Trend Value	p Value	Annual Change (mm)	Years	Total Change (mm)	Mean (mm)	% Change
ORT	700+	-0,26	0,55	-0,73	50	-36,34	888,15	-4,09%
JG	700+	-0,58	0,30	-1,30	50	-64,86	805,19	-8,06%

[17] Some of the smaller catchment at the provincial borders were eventually grouped together.

Cac	700+	-0,27	0,31	-0,02	50	-0,94	685,19	-0,14%
JG	401-699	-0,47	0,56	-0,53	50	-26,56	515,36	-5,15%
Cac	401-699	-0,57	0,42	-1,10	50	-55,02	477,64	-11,52%
JG	<400	-0,14	0,38	-0,26	50	-12,88	364,71	-3,53%
Cac	<400	0,00	0,47	0,35	50	17,29	291,87	5,92%

The most drastic decline in rainfall, when expressed as a percentage change from the mean is detected in the 400- 699 mm rainfall zone in Cacadu, DM with a decline of 11,52%. Important, however, is to note that p values for all the regions are outside the significance level and we therefore conclude that the changes, both positive and negative, are not statistically significant (See Table 4.2).

The summary of the change in number of rainy days per annum is shown in Table 4.3. The details for each catchment and calculations for >1, >2, >3, >4 and >5 mm per day are available on website http/dimtecrisk.ufs.ac.za/wrc_ec. According to this analysis, the number of rainy days increased in the more arid regions of the Cacadu DM while the largest decrease in number of rainy days took place in the high rainfall zones. This could imply higher intensity rainfall storms with potentially increased flood occurrences in the high rainfall zones. Again the changes are statistically not significant with high p values.

Table 4.3: Changes in the number of rainy days (> 3 mm/day) per annum per district

DM	Trend Value	p Value	Annual Change	Max days	Mean days	Median days	Min days	St dev	Cv
Cacadu	0,1688	0,2102	0,06	73,58	44,68	43,71	20,81	11,83	0,28
Joe Gqabi	-0,2459	0,3246	-0,07	90,80	56,52	56,13	22,30	14,49	0,26
OR Tambo	-0,6086	0,0829	-0,50	114,96	76,96	78,61	25,98	19,00	0,25

The summary for evapotranspiration is shown in Table 4.4. According to these data, the increase in evapotranspiration comes to 0,027% for OR Tambo DM, 0,10% for Joe Gcabi DM and 0,19% for Cacadu DM. Again none of these increases are statistically significant.

Table 4.4: change in evapotranspiration per district

DM	Trend Value	p Value	Annual Change	Max mm	Mean mm	Median mm	Min mm	% Change	St dev	Cv
OR T	0,913	0,362	0,338	1340,7	1248,8	1249,2	1153,6	0,027	35,24	0,029
JG	0,409	0,677	0,130	1394,3	1307,8	1313,6	1189,4	0,010	43,012	0,032
Cac	0,168	0,343	0,245	1389,0	1308,5	1312,7	1231,8	0,019	33,514	0,025

4.3.4 Use of Hazard Assessment as an Element of Risk Assessment

The hazard assessment discussed in this report is now useful for the calculation of drought risk since the probability, intensity and severity of dry periods are known for each quaternary catchment. The "*H*" in the risk equation shown below is known and available on the website for each catchment.

$$R = \left(\frac{\boldsymbol{H}}{\boldsymbol{C_H}}\right) x \left[\frac{\sum(V_{econ}V_{env}V_{Soc})}{\sum(C_{econ}C_{env}C_{soc})}\right]$$

The calculation of vulnerability, exposure and coping capacity to drought will be dealt with in forthcoming chapters.

4.4 Conclusion

Scientists and specialists today agree that the main reason for drought is the lack of precipitation or the negative deviation from the mean precipitation for a specific period (Alley, 1984; Wilhite, 2000; Vasilaides & Loukas, 2009; Beguria *et al*, 2010; Vicente-Serrano *et al.,* 2010). The impact of exogenous factors such as human activities in the creation of artificial droughts is also acknowledged (Venter, 1992; Wilhite, 2000; IPCC, 2001; UNDP, 2004; van Zyl, 2006) and this is the focus of the rest of this study.

Several drought indices measure the deviation of precipitation for a given period from historical norms, yet none of the major indices is inherently superior to the rest in all circumstances; some indices are better suited than others for certain uses (UNCCD, 2009). Examples of indices discussed in this report are the (i) Per cent of normal precipitation, (ii) Palmer Drought Severity Index (PDI) (Palmer, 1965; Alley, 1984; Karl & Knight, 1985), (iii) Rainfall Anomaly Index (Van Rooy, 1966), (iv) Mean monthly rainfall deficit, (v) Zucchini-Adamson models (Zucchini *et al*., 1991), (vi) Relative drought resistance method (Roux, 1993), (vii) Rainfall deciles method (Erasmus, 1991), (viii) Roux expert system (Roux, 1993) (ix) PUTU suite of plant models (Fouche *et al.,* 1985; Fouche, 1992), (x) ZA schrubland model (Venter, 1992) (xi) Crop Moisture Index (CMI) (xii) Surface Water Supply Index (SWSI; Shafer & Dezman, 1982) (xiii) Reclamation Drought Index (RDI) (xiv) Deciles (Gibbs & Mather, 1967) (xvi) Standard Precipitation Evapotranspiration Index (SPEI; Vicente-Serrano *et al.,* 2010) and others which are not relevant in the context of this study (Wilhite, 2000; WMO, 2006; Vasilaides & Loukas, 2009). The reasons for the use of the SPI as the preferred index in this study was given and the methodology for the calculation of the SPI and the SPEI explained.

The analysis and use of meteorological data as a key element in drought risk assessment has been discussed in this chapter. The large volumes of data and complexity of calculations for the different geographical areas saw the need for the development of a web-based mathematical tool to perform the necessary calculations. The Internet and new mathematical and statistical software provide users the opportunity to analyse data *"on the fly";* unthinkable a few years ago. The use of Webmathematica and contributions to the development of an open source website (http://dimtecrisk.ufs.ac.za/wrc_ec) for meteorological and drought assessments as part of this study is explained.

The most important conclusion as far as rainfall is concerned is the fact that for the period under review (1950-1999) the overall precipitation trend is negative in the higher rainfall zones, with a slightly positive trend in the arid zones with less than 400 mm per annum. The analyses show a decrease of up to 1,3 mm per annum in the high rainfall zone of Joe Gcabi DM with a decrease of

8% in rainfall over the 50 year period. The dry area in Cacadu, on the other hand, experienced an annual increase of 0,35 mm which represents an increase of 5,9% in rainfall over 50 years. None of the negative and positive trends, however, were statistically significant (p tests were done for all catchments and all showed statistically a non-significance trend), and one can therefore not conclude for certain that precipitation is significantly lower or higher. The trend for evapotranspiration seems to be positive; yet, for the years up to 1999 this is also not statistically significant. Also clear from the daily rainfall analyses is a decrease in number of rainy days per annum in the middle and high rainfall zones and a slight increase in the number of rainy days in the arid low rainfall zones.

An analysis of the SPEI values for all quaternary catchments confirms the precipitation analysis of less rain in the high rainfall zones over the past 50 years. Mean temperature changes are also not statistically significant, with exceptions in some of the catchments where minimum and maximum temperatures increased.

The precipitation analyses clearly show an increase in extreme weather events since the mid 1970s, with most of the extreme toward the wet side. When analysing the point data that stretches from 1900 it became clear that the mid-1920s and 1933 was the most extreme drought recorded. This severity of drought had, up to the time of writing, never been experienced since 1933. The mid-1970s wet period was the wettest period experienced for 100 years and this contributed toward the higher than normal average precipitation up to the end of the 1900s. The increase in extremes is consistent with climate change projections, yet we believe that even 100 years of data are not always sufficient to make any firm conclusions on future trends. We might, for example, see a decrease in mean precipitation over the next 100 with potential increases thereafter. The data analysed in this study are not of sufficient length for such future projections. What is important in the context of this study is that one can use probability, intensity and severity as a basis for calculating drought risk.

Some catchments show a definite dry and wet cycle, but the time-spans for these cycles are not constant and one cannot use this as a basis for forecasting dry and wet periods. These cycles vary from 12 years to 20 years and differ from catchment to catchment.

An important conclusion from the hazard analysis is that even 100-year historical meteorological data might not be sufficient to detect any trend or change in climatic conditions in the EC. The notion of a warmer and drier province could not be confirmed with the analysis done in this study. However, one should also bear in mind that the purpose of this study was not to investigate climate change, but rather to analyse data for the purpose of drought risk assessment. In the context of drought risk assessment, this research therefore concludes that other reasons (possibly man-made?) could possibly be blamed for an increase in drought frequency and intensity[18].

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[18] Research on climate change done by van Niekerk et al. (2009) suggested warmer temperatures and an increase in drought frequency and intensity. They interviewed local people and farmers and their study at best only reflect the perceptions and experiences of people.

This chapter also explained the use of the SPI and SPEI, drought exceedence probability, drought intensity and duration as factors in the drought risk assessment equation.

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Annexure 4-A: Hazard Indicators

Table 4A.1: Annual rainy days with 2mm and more per catchment

quad	trend	p	min	mean	max	var	std	cv
D12A	-1	0,0014	21	56,48	103	269,44	16,41	0,29
D12B	-1	0,0007	21	57,72	108	294,78	17,17	0,30
D12C	-1	0,0011	21	56,92	106	279,83	16,73	0,29
D12E	-1	0,0177	21	49,3	90	186,5	13,66	0,28
D12F	-1	0,3347	19	54,68	91	167,32	12,94	0,24
D13A	1	0,6921	31	72,64	101	241,30	15,53	0,21
D13B	1	0,3172	46	75,48	107	169,60	13,02	0,17
D13C	1	0,0181	13	57,56	92	297,88	17,26	0,30
D13D	-1	0,0798	5	66,56	97	259,48	16,11	0,24
D13E	-1	0,4858	42	69,34	99	176,27	13,28	0,19
D13F	-1	0,0971	5	65,96	96	255,26	15,98	0,24
D13G	-1	0,2917	13	43,70	75	246,74	15,71	0,36
D13H	1	0,0025	33	66,58	104	203,15	14,25	0,21
D13J	1	0,7764	14	48,28	75	160,65	12,67	0,26
D13K	-1	0,0865	45	69,26	98	186,40	13,65	0,20
D13L	-1	0,4038	33	54,70	86	150,17	12,25	0,22
D13M	-1	0,3454	19	54,56	90	164,70	12,83	0,24
D14A	1	0	22	45,58	83	270,58	16,45	0,36
D14C	1	0,6521	22	49,58	72	140,09	11,84	0,24
D14D	-1	0,3304	22	53,34	85	167,62	12,95	0,24
D14E	1	0,0137	25	44,50q	67	115,89	10,77	0,24
D14F	1	0,0109	27	44,80	67	115,88	10,76	0,24
D14G	1	0,0401	31	47,80	72	100,57	10,03	0,21
D14H	1	0,0747	31	47,16	72	98,26	9,91	0,21
D14J	-1	0,7315	29	45,68	76	119,81	10,95	0,24
D14K	1	0,0161	27	46,02	74	133,94	11,57	0,25
D18K	-1	0	30	64,90	133	519,32	22,79	0,35
D18L	-1	0,0005	29	56,36	86	173,13	13,16	0,23
D32A	1	0,0569	5	28,68	56	127,73	11,30	0,39
D32B	1	0,6748	24	42,72	71	127,72	11,30	0,26
D34A	1	0,3307	7	29,24	58	116,55	10,80	0,37
D35B	-1	0,1748	24	45,40	77	125,92	11,22	0,25
D35C	-1	0,7424	20	39,68	61	97,41	9,87	0,25
D35D	-1	0,4961	16	40,76	63	113,00	10,63	0,26
D35E	-1	0,9261	16	37,70	68	109,23	10,45	0,28
D35G	-1	0,9022	16	37,56	68	110,62	10,52	0,28
D35H	-1	0,151	24	45,22	77	125,40	11,20	0,25
D35J	-1	0,5849	10	32,16	73	168,14	12,97	0,40
D35K	1	0,3324	16	32,52	60	81,23	9,01	0,28

quad	trend	p	min	mean	max	var	std	cv
J31A	1	0	16	38,54	68	243,36	15,6	0,4
J31C	1	0	16	38,54	68	243,36	15,6	0,4
J32B	1	0,5397	7	18,52	31	26,58	5,16	0,28
J32C	1	0,5397	7	18,52	31	26,58	5,16	0,28
J32D	1	0	3	20,58	37	73,39	8,57	0,42
J32E	1	0	3	20,58	37	73,39	8,57	0,42
J33A	1	0,0741	11	23,64	44	57,46	7,58	0,32
K80A	-1	0	34	72,52	104	214,70	14,65	0,2
K80B	-1	0,0001	62	93,80	133	241,84	15,55	0,17
K80C	-1	0	53	74,06	95	113,08	10,63	0,14
K80D	-1	0	53	74,06	95	113,08	10,63	0,14
K80E	-1	0,0001	48	74,66	98	158,80	12,6	0,17
K80F	-1	0	26	57,94	96	136,26	11,67	0,2
K90A	-1	0,2261	27	54,54	82	114,42	10,7	0,2
K90B	-1	0	20	60,54	92	311,36	17,65	0,29
K90C	-1	0	20	60,66	92	314,35	17,73	0,29
K90D	-1	0	26	57,94	96	136,26	11,67	0,2
K90E	-1	0	26	57,94	96	136,26	11,67	0,2
K90F	-1	0	26	57,94	96	136,26	11,67	0,2
K90G	-1	0	26	57,94	96	136,26	11,67	0,2
L12C	1	0,0291	8	25,80	40	61,39	7,84	0,3
L12D	1	0,0291	8	25,80	40	61,39	7,84	0,3
L22B	1	0,3042	10	25,64	52	72,56	8,52	0,33
L22C	1	0,0679	11	26,22	44	62,30	7,89	0,3
L22D	-1	0,0402	11	24,04	44	49,55	7,04	0,29
L23A	1	0	5	32,02	59	178,51	13,36	0,42
L23B	-1	0,0402	11	24,04	44	49,55	7,04	0,29
L23C	1	0	14	34,88	60	156,48	12,51	0,36
L23D	1	0	8	26,56	45	90,90	9,53	0,36
L30A	1	0,4044	15	35,36	61	93,83	9,69	0,27
L30B	1	0,4044	15	35,36	61	93,83	9,69	0,27
L30C	1	0	8	26,56	45	90,90	9,53	0,36
L30D	1	0,2545	16	32,50	55	75,40	8,68	0,27
L40A	1	0,0002	10	29,86	61	127,02	11,27	0,38
L40B	1	0,2135	18	34,06	58	77,61	8,81	0,26
L50A	1	0	12	35,26	66	201,05	14,18	0,4
L50B	1	0,1877	16	32,44	57	75,92	8,71	0,27
L60A	1	0,0141	9	30,02	65	140,63	11,86	0,4
L60B	1	0,0141	9	30,02	65	140,63	11,86	0,4
L70A	1	0,0219	13	32,72	62	118,29	10,88	0,33
L70B	1	0,6031	11	28,66	50	72,60	8,52	0,3
L70C	1	0,6837	11	28,30	49	67,48	8,21	0,29
L70D	-1	0,0075	11	27,42	51	77,06	8,78	0,32
L70E	1	0,0002	12	33,7	66	155,64	12,48	0,37

quad	trend	p	min	mean	max	var	std	cv
L70F	-1	0,0029	12	28,14	53	82,74	9,1	0,32
L70G	-1	0,1332	14	38,46	69	182,5	13,51	0,35
L81A	-1	0,0093	41	63,16	83	94,22	9,71	0,15
L81B	1	0,9898	8	31,34	64	175,74	13,26	0,42
L81C	-1	0,9598	8	31,62	66	181,83	13,48	0,43
L81D	1	0,0393	17	35,94	67	144,18	12,01	0,33
L82B	1	0	22	52,6	81	174,65	13,22	0,25
L82C	-1	0,006	43	63,92	84	98,24	9,91	0,16
L82D	1	0,1391	27	47,56	83	137,19	11,71	0,25
L82E	-1	0,0072	26	57,2	82	169,96	13,04	0,23
L82F	-1	0,7983	26	45,98	76	165,41	12,86	0,28
L82G	-1	0,0106	27	59,9	85	177,97	13,34	0,22
L82H	1	0,0001	23	45,34	85	186,56	13,66	0,3
L82J	-1	0	22	50,98	78	147,12	12,13	0,24
L90A	-1	0,189	14	41,62	78	244,32	15,63	0,38
L90B	-1	0,0685	17	39,44	70	141,35	11,89	0,3
L90C	-1	0,0275	34	55,96	78	99,75	9,99	0,18
M10A	1	0,7455	12	48,86	71	173,96	13,19	0,27
M10B	-1	0,0787	39	69,3	99	176,17	13,27	0,19
M10C	1	0,8855	12	49,5	72	185,89	13,63	0,28
M10D	-1	0,1771	26	52,62	73	126,36	11,24	0,21
M20A	-1	0,2198	44	68,34	92	111,9	10,58	0,15
M20B	-1	0,0007	44	75,22	105	172,46	13,13	0,17
M30A	-1	0,1245	25	51,9	72	123,23	11,1	0,21
M30B	-1	0,1634	26	52,66	73	126,88	11,26	0,21
N11A	1	0,0005	10	35,06	72	252,06	15,88	0,45
N11B	-1	0,1186	20	37,68	64	79,53	8,92	0,24
N12A	1	0,7763	25	41,88	72	108,8	10,43	0,25
N12B	1	0,7519	25	41,8	72	109,1	10,45	0,25
N12C	1	0,543	12	30,98	79	116,96	10,81	0,35
N13A	-1	0,461	11	28,06	56	75,85	8,71	0,31
N13B	-1	0,4824	11	28,02	56	75,41	8,68	0,31
N13C	1	0,2699	18	30,6	49	56,9	7,54	0,25
N14A	1	0,0016	8	38,1	80	215,68	14,69	0,39
N14B	1	0,0013	8	37,96	80	214,53	14,65	0,39
N14C	1	0,5991	24	42,48	67	108,21	10,4	0,24
N14D	1	0,2716	18	30,62	49	56,98	7,55	0,25
N21A	1	0,304	18	30,48	49	56,74	7,53	0,25
N21B	-1	0,651	17	34,22	56	61,56	7,85	0,23
N21C	-1	0,8186	17	29,96	52	65,96	8,12	0,27
N21D	-1	0,798	16	29,78	52	66,66	8,16	0,27
N22A	1	0,1615	14	28,82	58	94,03	9,7	0,34
N22B	1	0	13	33,94	73	196,47	14,02	0,41
N22C	1	0,0018	13	30,58	52	86,17	9,28	0,3

quad	trend	p	min	mean	max	var	std	cv
N22D	1	0,002	13	30,3	52	85,07	9,22	0,3
N22E	1	0,0677	13	30,3	49	75,64	8,7	0,29
N23A	-1	0,0304	11	31,62	61	87,06	9,33	0,3
N23B	1	0,0659	13	30,58	49	76,09	8,72	0,29
N24A	1	0	9	28,44	70	193,07	13,89	0,49
N24B	1	0,2234	14	28,32	57	88,83	9,43	0,33
N24C	1	0,1615	14	28,82	58	94,03	9,7	0,34
N24D	1	0,0016	15	40,2	76	233,59	15,28	0,38
N30A	1	0,0089	25	42,84	68	111,44	10,56	0,25
N30B	1	0	15	41,96	99	328,41	18,12	0,43
N30C	1	0,0018	13	30,56	52	85,6	9,25	0,3
N40A	1	0,0594	13	30,92	49	76,65	8,75	0,28
N40B	1	0,0851	17	31,06	46	47,16	6,87	0,22
N40C	1	0,24	23	52,96	85	142,49	11,94	0,23
N40D	1	0,7073	21	45,44	82	201,56	14,2	0,31
N40E	1	0,0005	26	52,84	76	154,91	12,45	0,24
N40F	1	0,0096	26	46,8	69	80,08	8,95	0,19
P10A	-1	0,3882	41	65,38	86	118,2	10,87	0,17
P10B	-1	0,7471	27	62,16	83	132,18	11,5	0,18
P10C	1	0,24	23	52,96	85	142,49	11,94	0,23
P10D	-1	0,3601	19	41,58	70	109,35	10,46	0,25
P10E	-1	0,3566	19	41,54	70	109,11	10,45	0,25
P10F	1	0,7751	22	60	87	222	14,9	0,25
P10G	-1	0,2199	34	56,1	72	62,54	7,91	0,14
P20A	-1	0,3794	37	67,38	95	127,75	11,3	0,17
P20B	-1	0,3668	37	67,54	95	130,38	11,42	0,17
P30A	-1	0,6353	27	63,7	87	143,23	11,97	0,19
P30B	1	0,7862	22	60,5	87	229,23	15,14	0,25
P30C	-1	0,0349	23	65,68	87	120,88	10,99	0,17
P40A	-1	0,4099	41	64,58	85	111,23	10,55	0,16
P40B	1	0,4847	44	66,9	90	72,13	8,49	0,13
P40C	1	0,5149	44	67,14	90	72,53	8,52	0,13
P40D	-1	0,0011	42	63,12	94	109,33	10,46	0,17
Q11A	-1	0,0766	15	34,92	71	114,2	10,69	0,31
Q11B	1	0,8828	21	39,46	60	98,34	9,92	0,25
Q12A	1	0,5028	22	42,28	69	108	10,39	0,25
Q12B	1	0,4895	22	42,26	69	108,03	10,39	0,25
Q12C	1	0,0264	21	39,28	64	91,43	9,56	0,24
Q14A	1	0,6931	28	44,2	73	133,39	11,55	0,26
Q21A	1	0,6219	19	32,36	58	82,97	9,11	0,28
Q22A	1	0,0147	20	45,44	93	250,9	15,84	0,35
Q30A	1	0,0888	18	43,52	69	105,23	10,26	0,24
Q30B	1	0,079	18	43,42	69	102,82	10,14	0,23
Q50A	1	0	14	41	80	320,65	17,91	0,44

quad	trend	p	min	mean	max	var	std	cv
Q50B	1	0	28	57,14	116	437,96	20,93	0,37
Q50C	1	0	29	55,14	90	270,9	16,46	0,3
Q60B	1	0	28	56,78	138	840,75	29	0,51
Q60C	1	0,0314	31	62,96	88	113,22	10,64	0,17
Q70A	1	0,0333	31	62,92	88	113,3	10,64	0,17
Q70B	1	0	29	55,06	90	272,42	16,51	0,3
Q70C	-1	0	36	62,5	95	212,01	14,56	0,23
Q80A	-1	0,9928	24	43,6	72	93,76	9,68	0,22
Q80B	-1	0,9968	24	43,44	72	93,44	9,67	0,22
Q80C	-1	0,994	24	43,34	71	91,98	9,59	0,22
Q80D	1	0,6719	29	58,78	102	247,28	15,73	0,27
Q80E	1	0	15	38,88	68	177,54	13,32	0,34
Q80F	1	0	15	38,94	68	177,81	13,33	0,34
Q80G	-1	0	36	62,5	95	212,01	14,56	0,23
Q91A	1	0	25	66,18	145	572,44	23,93	0,36
Q91B	1	0,0051	31	53,5	86	166,74	12,91	0,24
Q91C	-1	0	18	46,78	92	298,62	17,28	0,37
Q92C	-1	0,1684	4	40,8	72	157,76	12,56	0,31
Q92E	-1	0,1696	4	40,84	72	158,46	12,59	0,31
Q92F	1	0,05	30	58,68	83	100,92	10,05	0,17
Q92G	-1	0,1868	4	40,52	69	153,4	12,39	0,31
Q93A	-1	0	15	53,3	97	512,46	22,64	0,42
Q93B	-1	0	15	53,04	97	514,65	22,69	0,43
Q93C	1	0,0002	27	57,48	117	632,05	25,14	0,44
Q93D	-1	0,0002	35	66,54	105	305,03	17,47	0,26
S20A	-1	0,7496	10	58,6	86	178,69	13,37	0,23
S20B	-1	0,0474	4	50,52	81	232,54	15,25	0,3
T11G	1	0,3354	44	92,62	157	605,34	24,6	0,27
T11H	1	0,0034	30	63,2	100	268,61	16,39	0,26
T13A	1	0,0036	30	62,96	98	260,61	16,14	0,26
T13B	1	0,0034	30	62,82	98	257,82	16,06	0,26
T13C	-1	0	39	71,38	104	302,24	17,39	0,24
T13D	-1	0,005	18	69,14	107	367,67	19,17	0,28
T20A	-1	0,1285	58	85,62	119	252,98	15,91	0,19
T20B	1	0,4622	58	86,16	118	254,42	15,95	0,19
T20C	-1	0,1339	8	78	107	243,39	15,6	0,2
T20D	-1	0,1815	8	76,6	107	240,61	15,51	0,2
T20E	-1	0,0001	35	71,68	112	415,77	20,39	0,28
T20F	-1	0,0076	9	81,76	123	463,17	21,52	0,26
T20G	-1	0,0031	29	75,26	112	402,97	20,07	0,27
T32G	-1	0,0615	65	103,68	135	245	15,65	0,15
T32H	-1	0	27	78,44	137	723,03	26,89	0,34
T33C	-1	0	24	58,7	96	260,09	16,13	0,27
T33K	-1	0	27	79,14	141	760,98	27,59	0,35

quad	trend	p	min	mean	max	var	std	cv
T34A	1	0,0187	34	61,66	108	292,72	17,11	0,28
T34B	-1	0,8647	33	65,38	118	380,89	19,52	0,3
T34C	-1	0,8332	33	65,04	114	363,39	19,06	0,29
T34D	-1	0,8332	33	65,04	114	363,39	19,06	0,29
T34E	1	0,0166	34	61,54	108	290,5	17,04	0,28
T34F	-1	0,7629	33	64,48	107	335,15	18,31	0,28
T34G	-1	0,0006	26	73,86	115	385,27	19,63	0,27
T34H	-1	0,0017	42	75,34	115	283,41	16,83	0,22
T34J	1	0,7962	38	75,7	122	331,81	18,22	0,24
T34K	-1	0,0024	36	73,46	100	178,66	13,37	0,18
T35A	1	0,3182	36	86,42	121	310,86	17,63	0,2
T35B	-1	0,61	3	65,3	96	289,77	17,02	0,26
T35C	-1	0,6026	3	65,34	96	290,51	17,04	0,26
T35D	-1	0,5985	3	65,4	98	293,22	17,12	0,26
T35E	-1	0,0033	16	90,16	122	325,61	18,04	0,2
T35F	1	0,6638	10	72,6	140	486	22,05	0,3
T35G	-1	0,0067	3	96,6	137	769,1	27,73	0,29
T35H	1	0,4263	59	88,88	122	288,56	16,99	0,19
T35J	-1	0,0038	16	88,46	117	298,54	17,28	0,2
T35K	-1	0	27	56,52	101	204,13	14,29	0,25
T35L	-1	0,001	35	71,78	98	159,07	12,61	0,18
T35M	-1	0,0021	36	73,36	99	177,95	13,34	0,18
T36A	-1	0	5	64,62	102	416,12	20,4	0,32
T36B	-1	0	17	83,44	105	320,5	17,9	0,21
T60B	-1	0	27	79,74	141	771,62	27,78	0,35
T60C	-1	0	27	78,58	139	736,33	27,14	0,35
T60D	1	0,4119	35	74,7	119	270,01	16,43	0,22
T60E	-1	0	27	78,28	138	723,27	26,89	0,34
T60F	-1	0	32	77,68	135	481,65	21,95	0,28
T60G	1	0,4394	35	74,78	119	271,15	16,47	0,22
T60H	-1	0,0004	9	83,44	125	446,29	21,13	0,25
T60J	-1	0,0004	9	83,48	125	448,38	21,17	0,25
T60K	-1	0	17	83,1	104	315,32	17,76	0,21
T70A	-1	0	5	64,62	102	416,12	20,4	0,32
T70B	-1	0	17	84,92	108	339,95	18,44	0,22
T70C	-1	0,0945	8	77,3	104	330,74	18,19	0,24
T70D	-1	0,099	8	77,26	104	328,89	18,14	0,23
T70E	-1	0	5	64,34	101	411,33	20,28	0,32
T70F	-1	0,1039	8	76,68	103	320,3	17,9	0,23
T70G	-1	0,0924	8	77,38	104	331,51	18,21	0,24
T80A	-1	0,0027	29	76,64	114	434,72	20,85	0,27
T80B	-1	0,003	29	76,22	114	421,69	20,53	0,27
T80C	-1	0,0038	18	70,9	111	400,3	20,01	0,28
Mean	-0,062	0,215377	21,9	52,71	84,48	207,94	13,673	0,271

Table 4A.2: precipitation analysis for all quaternary catchments

quad	trend	p	min	mean	max	var	std	cv
D12A	-1	0,4555	282,5	608,86	1073,3	30515,5	174,69	0,29
D12B	-1	0,3912	334,2	736,818	1295,3	44363,2	210,63	0,29
D12C	-1	0,4178	300,8	656,442	1161,4	35555,3	188,56	0,29
D12E	-1	0,0721	180,5	590,338	1002,4	29068,6	170,5	0,29
D12F	-1	0,4544	212,1	576,114	1027,8	29452,2	171,62	0,3
D13A	-1	0,2893	364,9	693,934	1056,2	24728,8	157,25	0,23
D13B	-1	0,6759	335,8	706,094	1048,8	23342,3	152,78	0,22
D13C	1	0	98,4	702,184	1575,9	92360,8	303,91	0,43
D13D	-1	0,9981	27,8	690,648	1115,8	45381,4	213,03	0,31
D13E	-1	0,5473	444,8	761,7	1246,6	35918	189,52	0,25
D13F	-1	0,9746	27,9	656,354	1060,3	40866,2	202,15	0,31
D13G	-1	0,447	294,9	645,744	1213,2	44835,6	211,74	0,33
D13H	1	0,1643	278,7	535,314	1019,5	26603,8	163,11	0,3
D13J	-1	0,8174	81,2	560,09	1020,1	33895,9	184,11	0,33
D13K	-1	0,041	368,7	755,696	1411,8	50014,1	223,64	0,3
D13L	-1	0,5773	224,4	576,924	1049,2	34051,4	184,53	0,32
D13M	-1	0,4564	201	554,522	1008,2	27199,7	164,92	0,3
D14A	-1	0,5562	217,3	513,966	994,8	26776,3	163,63	0,32
D14C	1	0,1134	149,5	525,494	1138,7	36559,6	191,21	0,36
D14D	-1	0,0123	176,5	465,702	1069,3	28645	169,25	0,36
D14E	1	0,292	182,6	448,768	876,8	22727,5	150,76	0,34
D14F	1	0,2808	206,9	502,358	985,3	28055,3	167,5	0,33
D14G	1	0,9828	240,3	523,594	968	28425,8	168,6	0,32
D14H	1	0,9691	212	446,128	819,1	20662,3	143,74	0,32
D14J	-1	0,5535	224,7	462,252	938,4	27348,1	165,37	0,36
D14K	1	0,6909	206	464,984	1014	30930,5	175,87	0,38
D18K	-1	0,2155	441,1	781,058	1365,4	33819,1	183,9	0,24
D18L	-1	0,9138	283,5	678,326	1168	32685,4	180,79	0,27
D32A	1	0,0007	113	346,296	757,8	25790,5	160,59	0,46
D32B	-1	0,9077	119	350,878	770,5	17743,4	133,2	0,38
D34A	-1	0,5994	85	412,894	973,5	37619,2	193,96	0,47
D35B	-1	0,0899	172,9	403,05	1002,5	25181,3	158,69	0,39
D35C	-1	0,8944	256,7	438,274	980,1	22256,5	149,19	0,34
D35D	-1	0,6144	149,4	415,274	960,1	25046,6	158,26	0,38
D35E	-1	0,9135	172,7	407	1055,7	26062,5	161,44	0,4
D35G	-1	0,9138	170,6	395,742	1045,9	25474,6	159,61	0,4
D35H	-1	0,0844	165,3	388,884	959,9	23063	151,87	0,39
D35J	1	0,1044	120,6	372,824	778,8	23602,5	153,63	0,41
D35K	-1	0,5267	145,8	396,662	1003,7	28334,3	168,33	0,42
J31A	1	0,5841	189,8	361,716	640,1	10489,2	102,42	0,28
J31C	1	0,5841	189,8	361,716	640,1	10489,2	102,42	0,28

quad	trend	p	min	mean	max	var	std	cv
J32B	1	0,1159	46,6	196,47	468,2	8868,79	94,17	0,48
J32C	1	0,1159	46,6	196,47	468,2	8868,79	94,17	0,48
J32D	1	0,0007	20	229,47	587,5	14921,5	122,15	0,53
J32E	1	0,0007	20	229,47	587,5	14921,5	122,15	0,53
J33A	1	0,363	116,8	301,042	585,5	12477,5	111,7	0,37
K80A	-1	0,4053	468,1	719,64	1120,6	15332,3	123,82	0,17
K80B	-1	0,3029	535,8	813,83	1243,7	17385,2	131,85	0,16
K80C	-1	0,0201	540,7	780,062	1154,4	17794,2	133,4	0,17
K80D	-1	0,0201	540,7	780,062	1154,4	17794,2	133,4	0,17
K80E	-1	0,2992	403,6	587,164	958,9	12108,6	110,04	0,19
K80F	-1	0,0028	276,7	484,362	921,7	20749,9	144,05	0,3
K90A	-1	0,0009	165,5	398,992	638,8	13722,5	117,14	0,29
K90B	-1	0,2845	199,6	519,606	836	17979,7	134,09	0,26
K90C	-1	0,2812	203,1	522,73	849,9	18093,7	134,51	0,26
K90D	-1	0,0028	276,7	484,362	921,7	20749,9	144,05	0,3
K90E	-1	0,0028	276,7	484,362	921,7	20749,9	144,05	0,3
K90F	-1	0,0028	276,7	484,362	921,7	20749,9	144,05	0,3
K90G	-1	0,0028	276,7	484,362	921,7	20749,9	144,05	0,3
L12C	1	0,2288	80,2	256,088	539,6	10863	104,23	0,41
L12D	1	0,2288	80,2	256,088	539,6	10863	104,23	0,41
L22B	1	0,7253	92,1	289,83	579,5	14053,1	118,55	0,41
L22C	1	0,9175	122,6	331,166	926,9	26121,6	161,62	0,49
L22D	-1	0,8556	157,3	347,608	811,1	20694,5	143,86	0,41
L23A	1	0,2861	72,2	257,594	448,1	7230,83	85,03	0,33
L23B	-1	0,8582	158,7	348,294	811,5	20652	143,71	0,41
L23C	-1	0,9889	109	269,134	576,8	7767,94	88,14	0,33
L23D	-1	0,0588	64,6	220,7	483,6	7414,83	86,11	0,39
L30A	-1	0,5205	112,3	329,69	781	22548,7	150,16	0,46
L30B	-1	0,5195	112,7	331,476	787,1	22762,5	150,87	0,46
L30C	-1	0,0588	64,6	220,7	483,6	7414,83	86,11	0,39
L30D	1	0,2787	140,2	301,928	680,8	14204	119,18	0,39
L40A	-1	0,0525	63,8	218,686	502,2	7670,22	87,58	0,4
L40B	1	0,1982	183,8	368,09	812,6	19726,3	140,45	0,38
L50A	1	0,8998	115	298,192	600,7	12122,8	110,1	0,37
L50B	1	0,238	142	294,45	648,1	14001,2	118,33	0,4
L60A	-1	0,8801	105,8	334,556	845,8	23399,2	152,97	0,46
L60B	-1	0,8339	103,1	322,958	826,8	22215,6	149,05	0,46
L70A	-1	0,2922	97,2	305,818	624,5	11749	108,39	0,35
L70B	-1	0,9026	103,9	265,898	611,4	11526,3	107,36	0,4
L70C	-1	0,9402	100,1	257,37	590,6	10669,1	103,29	0,4
L70D	-1	0,8172	67,2	257,232	657,5	13933,9	118,04	0,46
L70E	-1	0,4495	65,2	236,964	515,6	7994,14	89,41	0,38

quad	trend	p	min	mean	max	var	std	cv
L70F	-1	0,8273	74,1	285,998	708,2	16580,7	128,77	0,45
L70G	1	0,6403	100,9	295,894	654,5	12228,9	110,58	0,37
L81A	-1	0,8414	182,3	418,162	790,6	10182,5	100,91	0,24
L81B	-1	0,2576	86,9	297,862	614,1	16088,2	126,84	0,43
L81C	-1	0,2582	87,1	305,456	659,8	16770,9	129,5	0,42
L81D	-1	0,2129	149,3	357,216	665,4	13995,1	118,3	0,33
L82B	1	0,0267	197,5	377,178	652,2	11004,8	104,9	0,28
L82C	-1	0,7771	195,1	438,396	832,8	11329,9	106,44	0,24
L82D	-1	0,0071	140,5	347,148	595,3	10595,4	102,93	0,3
L82E	-1	0,0009	187,1	438,536	722,8	16556	128,67	0,29
L82F	-1	0,0014	141,3	344,13	656,5	15572,2	124,79	0,36
L82G	-1	0,0012	235,7	527,04	837	23609,9	153,66	0,29
L82H	-1	0,21	246,3	439,176	678,2	12445,3	111,56	0,25
L82J	-1	0	209,1	406,284	623,8	10596,8	102,94	0,25
L90A	1	0,6684	160	460,808	957,1	29076,6	170,52	0,37
L90B	-1	0,7541	240,4	526,21	857,2	23237,7	152,44	0,29
L90C	-1	0,1882	300,8	534,516	995,8	18826,4	137,21	0,26
M10A	-1	0,7263	197,7	464,906	950,1	20307,3	142,5	0,31
M10B	-1	0,5602	326,4	548,998	899	15655,1	125,12	0,23
M10C	-1	0,653	204,5	501,764	1014,4	23592,1	153,6	0,31
M10D	-1	0,2263	280,6	578,816	959,5	27743,5	166,56	0,29
M20A	-1	0,3431	273	573,644	1188,1	42915,2	207,16	0,36
M20B	1	0,8229	326,3	662,272	984,2	25144,1	158,57	0,24
M30A	-1	0,2261	269,3	574,078	938,6	27802,7	166,74	0,29
M30B	-1	0,2919	304,8	610,132	1028,6	31090,3	176,32	0,29
N11A	-1	0,8946	148	395,86	837,3	22953,3	151,5	0,38
N11B	-1	0,5355	192,5	388,346	752,5	17324,5	131,62	0,34
N12A	-1	0,4572	201,3	453,034	1343,6	38104,6	195,2	0,43
N12B	-1	0,4252	192,1	436,242	1326,6	36071,7	189,93	0,44
N12C	1	0,7873	181,3	471,518	846,3	26074,8	161,48	0,34
N13A	1	0,9168	95	427,742	778,3	22539,9	150,13	0,35
N13B	1	0,8248	87,5	394,504	744,2	20119,1	141,84	0,36
N13C	-1	0,8638	159,1	346,902	747	17162,8	131,01	0,38
N14A	1	0,6922	34,6	324,066	701,7	17941,3	133,95	0,41
N14B	1	0,7158	31,3	315,578	676,9	16995,4	130,37	0,41
N14C	-1	0,4619	148,2	401,02	831,1	22839,8	151,13	0,38
N14D	-1	0,8688	159,7	351,754	757,9	17618,3	132,73	0,38
N21A	-1	0,8577	159,3	346,79	748,3	17308,9	131,56	0,38
N21B	-1	0,2897	169,5	378,31	780,4	14665,2	121,1	0,32
N21C	1	0,9896	118,7	313,33	730,5	14997,2	122,46	0,39
N21D	-1	0,9849	117,7	308,97	725,3	14868,4	121,94	0,39
N22A	1	0,8818	123,5	304,548	726	16121,3	126,97	0,42

quad	trend	p	min	mean	max	var	std	cv
N22B	-1	0,7767	121,9	277,148	611	14708,6	121,28	0,44
N22C	1	0,063	87	322,854	718	26184,7	161,82	0,5
N22D	1	0,0807	85,2	301,934	693,9	23718,4	154,01	0,51
N22E	1	0,0195	74,4	282,008	701,6	16677,1	129,14	0,46
N23A	1	0,2791	158,9	323,958	708,5	15422,2	124,19	0,38
N23B	1	0,0165	76,9	293,122	709,9	17526,4	132,39	0,45
N24A	-1	0,8565	84,1	265,918	702	14361,4	119,84	0,45
N24B	1	0,924	122,5	288,034	696,8	15165,3	123,15	0,43
N24C	1	0,8972	123,3	300,872	721,9	15907,2	126,12	0,42
N24D	-1	0,8271	140,5	300,754	587,6	12166,1	110,3	0,37
N30A	-1	0,3465	187,2	415,864	715,2	14899,1	122,06	0,29
N30B	1	0,4679	125,9	335,808	644,3	15892,3	126,06	0,38
N30C	1	0,0696	85,8	311,986	703,2	24551,2	156,69	0,5
N40A	1	0,0209	78,4	301,58	730,8	18247	135,08	0,45
N40B	-1	0,695	95,7	308,774	626,4	9638,7	98,18	0,32
N40C	-1	0,356	241,2	500,074	820,5	13671,1	116,92	0,23
N40D	1	0,0434	137,2	355,032	873,1	20629	143,63	0,4
N40E	1	0,0618	167,2	396,528	834,3	22959,5	151,52	0,38
N40F	1	0,0275	163,8	390,404	760,9	20648,7	143,7	0,37
P10A	1	0,462	339,6	541,446	846,4	19339,6	139,07	0,26
P10B	-1	0,0363	300,2	485,754	844,1	14274,5	119,48	0,25
P10C	-1	0,356	241,2	500,074	820,5	13671,1	116,92	0,23
P10D	-1	0,6293	202	382,726	670,3	11231,4	105,98	0,28
P10E	-1	0,6103	202,9	386,432	668,6	11611,9	107,76	0,28
P10F	-1	0,1745	225	439,428	738,7	12698,8	112,69	0,26
P10G	-1	0,5912	311,2	530,992	952,1	18365,2	135,52	0,26
P20A	-1	0,1114	373,4	631,182	952,6	16680,3	129,15	0,2
P20B	-1	0,1144	391,5	657,526	1005,2	17909,6	133,83	0,2
P30A	-1	0,0471	341,3	543,684	928,6	18786,5	137,06	0,25
P30B	-1	0,2061	249,3	473,59	800,6	14821,6	121,74	0,26
P30C	-1	0,405	234,6	560,12	1017,1	19956,2	141,27	0,25
P40A	1	0,4444	318,3	508,52	809,8	16516,6	128,52	0,25
P40B	-1	0,831	301,7	486,114	811,5	13054	114,25	0,24
P40C	-1	0,7869	305,6	497,262	828,7	14066,8	118,6	0,24
P40D	-1	0,0927	318,9	513,742	1030,9	17290,7	131,49	0,26
Q11A	-1	0,103	144,8	398,176	827,5	20020,4	141,49	0,36
Q11B	-1	0,6956	185,9	407,476	835,1	21693,2	147,29	0,36
Q12A	1	0,4477	169	373,534	725,7	14330,5	119,71	0,32
Q12B	1	0,4498	173	378,432	731,8	14699	121,24	0,32
Q12C	1	0,7935	199,7	409,46	738,6	16495,2	128,43	0,31
Q14A	-1	0,9916	155,5	442,032	907,7	25321	159,13	0,36
Q21A	-1	0,0035	142,5	338,572	761,7	15733,7	125,43	0,37

quad	trend	p	min	mean	max	var	std	cv
Q22A	-1	0,5435	155,3	446,48	893	25650,2	160,16	0,36
Q30A	-1	0,1823	179,4	470,632	989,8	20894,2	144,55	0,31
Q30B	-1	0,145	158	415,354	874,8	16289	127,63	0,31
Q50A	1	0,6523	234	441,51	914,3	17943,7	133,95	0,3
Q50B	-1	0,3439	347,2	565,59	947,2	23268,7	152,54	0,27
Q50C	1	0,5091	267,1	562,118	1070,2	25097,9	158,42	0,28
Q60B	1	0,7884	287,9	617,134	1367,6	42466,4	206,07	0,33
Q60C	-1	0,9792	360,1	598,87	1267,1	28711,2	169,44	0,28
Q70A	-1	0,9786	355,6	590,69	1248,4	28028,3	167,42	0,28
Q70B	1	0,5832	253,8	546,73	1044,9	23811,4	154,31	0,28
Q70C	-1	0,2027	226,6	517,462	1017,6	21674,5	147,22	0,28
Q80A	-1	0,6933	224,1	459,4	992,9	20806,5	144,24	0,31
Q80B	-1	0,6872	223,9	456,328	989	20988,7	144,87	0,32
Q80C	-1	0,6949	218,8	452,226	980,6	20822,1	144,3	0,32
Q80D	1	0,5514	385,6	700,546	1202,9	35657,8	188,83	0,27
Q80E	1	0,0459	235,1	475,56	943,2	26581,6	163,04	0,34
Q80F	1	0,0414	237,5	481,77	948,2	26861,2	163,89	0,34
Q80G	-1	0,2027	226,6	517,462	1017,6	21674,5	147,22	0,28
Q91A	1	0,4912	279,1	467,098	735,3	14639,7	120,99	0,26
Q91B	1	0	329,9	700,064	1499,1	87194,1	295,29	0,42
Q91C	1	0,8137	204,8	446,386	748,9	19110,3	138,24	0,31
Q92C	-1	0,6294	24,8	519,108	976,7	29973,5	173,13	0,33
Q92E	-1	0,6622	24,8	522,944	992,4	30637,1	175,03	0,33
Q92F	1	0,9063	266,8	463,602	1024,7	19480,1	139,57	0,3
Q92G	-1	0,6886	24,8	493,048	939,4	28023,5	167,4	0,34
Q93A	-1	0,0035	107,7	446,086	796,5	19962,4	141,29	0,32
Q93B	-1	0,0027	100,5	429,13	786,3	18787,9	137,07	0,32
Q93C	1	0,4359	269,4	507,2	856,2	21028,7	145,01	0,29
Q93D	1	0,9067	297,5	531,69	1093,7	23240,1	152,45	0,29
S20A	-1	0,6527	40,2	695,082	1323,5	46465	215,56	0,31
S20B	-1	0,7229	29,8	733,694	1362,3	47186,4	217,22	0,3
T11G	-1	0,5613	234,4	794,046	1092,4	25426,5	159,46	0,2
T11H	1	0,8591	328,4	819,946	1377,5	48856,4	221,03	0,27
T13A	1	0,8144	326,1	793,184	1330,4	46067,6	214,63	0,27
T13B	1	0,8413	315,1	768,904	1287,6	43470,9	208,5	0,27
T13C	-1	0,5285	361,4	749,788	1103,5	28509	168,85	0,23
T13D	-1	0,8818	402,2	829,494	2123,5	85750,5	292,83	0,35
T20A	1	0,3581	523,4	839,412	1305,4	24971,5	158,02	0,19
T20B	1	0,7338	439	777,854	1256,4	22161,9	148,87	0,19
T20C	-1	0,7078	137,4	759,936	1349,1	38903,6	197,24	0,26
T20D	-1	0,7126	137	722,056	1265,4	36230,7	190,34	0,26
T20E	-1	0,3732	387,1	832,76	1482,4	47785,6	218,6	0,26

quad	trend	p	min	mean	max	var	std	cv
T20F	-1	0,0619	108,9	857,242	1377	49373	222,2	0,26
T20G	-1	0,2684	364,7	841,934	1401,7	47357,2	217,62	0,26
T32G	1	0,287	588,8	901,752	1297,8	24187,2	155,52	0,17
T32H	-1	0,8373	579,6	903,038	1744,4	47783,1	218,59	0,24
T33C	-1	0	466,7	964,714	1783,7	93286,6	305,43	0,32
T33K	-1	0,8981	577,1	915,302	1828,5	52554,1	229,25	0,25
T34A	-1	0,015	364,5	791,16	1277,2	39281,5	198,2	0,25
T34B	-1	0,0798	581,4	796,474	1095,7	18297,9	135,27	0,17
T34C	-1	0,076	559,7	770,06	1057	17017,7	130,45	0,17
T34D	-1	0,0792	544,8	753,684	1033,5	16275,4	127,57	0,17
T34E	-1	0,0127	337,5	714,894	1158,4	31361,1	177,09	0,25
T34F	-1	0,0626	529,7	727,68	990,3	15197,8	123,28	0,17
T34G	-1	0,4021	278,6	839,938	1340,2	37547,3	193,77	0,23
T34H	-1	0,065	491,4	884,198	1287,6	19959,9	141,28	0,16
T34J	1	0,2934	524	929,044	1500,5	39204,1	198	0,21
T34K	1	0,2642	515,3	980,544	1945,3	62780,7	250,56	0,26
T35A	1	0,0061	284,8	826,914	1356,8	65233,5	255,41	0,31
T35B	-1	0,509	22,6	867,01	1152,5	42260,2	205,57	0,24
T35C	-1	0,5282	22,6	936,792	1259,7	49878,9	223,34	0,24
T35D	-1	0,537	22,6	971,336	1312,8	53958,6	232,29	0,24
T35E	-1	0,1643	166,5	1011,22	1382,1	39173,4	197,92	0,2
T35F	1	0,6026	101,5	900,358	1452,6	58821,1	242,53	0,27
T35G	1	0,558	30,4	746,672	1166,5	39607,3	199,02	0,27
T35H	1	0,7503	533,9	932,276	1467	26851	163,86	0,18
T35J	-1	0,1549	157,1	856,162	1170,5	27242,6	165,05	0,19
T35K	1	0,9963	451,2	832,796	1279	27086,1	164,58	0,2
T35L	1	0,2837	383,8	740,484	1506,1	36713	191,61	0,26
T35M	1	0,2793	463,1	889,164	1795,6	52875,3	229,95	0,26
T36A	-1	0,5422	92,2	906,24	1445,5	63844,4	252,67	0,28
T36B	-1	0,0026	204,4	984,73	1587,5	61879,6	248,76	0,25
T60B	-1	0,822	617,9	986,342	2000,8	61321,2	247,63	0,25
T60C	-1	0,9019	521,1	851,32	1768,7	49616,3	222,75	0,26
T60D	1	0,3087	426,3	999,624	1847,4	66879,9	258,61	0,26
T60E	-1	0,9324	505,8	838,576	1791	52317,7	228,73	0,27
T60F	1	0,4791	432,6	1014,47	2175,1	100036	316,28	0,31
T60G	1	0,3034	433,3	1015,09	1870,6	68578,1	261,87	0,26
T60H	-1	0,8808	86,4	1050	1753,4	75754,2	275,23	0,26
T60J	-1	0,8632	93,3	1058,93	1779,2	75044,5	273,94	0,26
T60K	-1	0,0023	203,2	940,152	1479,6	53508	231,32	0,25
T70A	-1	0,5299	92,2	924,43	1462,3	65631,9	256,19	0,28
T70B	-1	0,0019	238,5	1095,72	1750	71238,2	266,9	0,24
T70C	-1	0,9713	114,2	964,22	1527,7	76914,4	277,33	0,29

quad	trend	p	min	mean	max	var	std	cv
T70D	-1	0,9573	108,2	934,344	1488,7	72681,3	269,59	0,29
T70E	-1	0,4839	92,2	893,722	1409,6	60181,6	245,32	0,27
T70F	1	0,9994	103,3	926,632	1446,8	72614,8	269,47	0,29
T70G	1	0,9893	108,2	958,772	1516,9	76331,4	276,28	0,29
T80A	-1	0,2551	434,1	1012,68	1619	68340,5	261,42	0,26
T80B	-1	0,2394	406,5	986,646	1606,5	66746,5	258,35	0,26
T80C	-1	0,8567	479,9	972,93	2628	121438	348,48	0,36
	-0,31	**0,457**	**222,8**	**549,138**	**1014,5**	**28561,65**	**161,67**	**0,317**

Table 4A.3: 3-month SPEI data per catchment

3 MONTHS								
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
D12A	3	25,081	5,977	0,678	31,736	3,54	-1	0,0123
D12B	3	24,424	6,158	0,675	31,257	3,49	-1	0,0151
D12C	3	24,032	5,923	0,575	30,53	3,41	-1	0,0138
D12E	3	25,915	3,955	0,287	30,157	3,37	-1	0
D12F	3	23,478	5,294	0,285	29,057	3,24	-1	0,0473
D13A	3	24,853	5,685	0,747	31,285	3,49	-1	0,0233
D13B	3	25,55	7,357	0,908	33,815	3,78	-1	0,1092
D13C	3	18,792	3,633	0,349	22,774	2,54	1	0
D13D	3	23,161	4,226	0,595	27,982	3,12	-1	0,6128
D13E	3	24,545	6,418	0,519	31,482	3,52	-1	0,1778
D13F	3	22,814	4,485	0,557	27,856	3,11	-1	0,5619
D13G	3	25,437	4,967	0,191	30,595	3,42	-1	0,0261
D13H	3	22,224	5,248	0,394	27,866	3,11	1	0,0756
D13J	3	25,273	5,017	0,546	30,836	3,44	-1	0,4055
D13K	3	25,772	5,584	0,426	31,782	3,55	-1	0
D13L	3	25,499	4,561	0,006	30,066	3,36	-1	0,1843
D13M	3	23,642	5,398	0,288	29,328	3,28	-1	0,0376
D14A	3	22,968	3,857	0,181	27,006	3,02	-1	0,1624
D14C	3	21,294	5,429	0,2	26,923	3,01	1	0,1818
D14D	3	24,372	4,438	0,045	28,855	3,22	-1	0
D14E	3	21,687	3,889	0	25,576	2,86	1	0,4284
D14F	3	21,62	3,964	0,055	25,639	2,86	1	0,3872
D14G	3	23,424	4,143	0,114	27,681	3,09	-1	0,4406
D14H	3	23,501	4,32	0,109	27,93	3,12	-1	0,4723
D14J	3	25,112	3,933	0,316	29,361	3,28	-1	0,0609
D14K	3	23,724	3,672	0,092	27,488	3,07	-1	0,9642
D18K	3	27,695	7,668	1,105	36,468	4,07	-1	0,0045
D18L	3	25,772	7,225	0,531	33,528	3,74	-1	0,062
D32A	3	22,877	3,345	0,087	26,309	2,94	1	0,0076

3 MONTHS								
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
D32B	3	23,944	3,422	0,21	27,576	3,08	-1	0,0116
D34A	3	22,257	2,64	0	24,897	2,78	-1	0,1211
D35B	3	23,852	4,6	0,077	28,529	3,19	-1	0,0008
D35C	3	22,353	3,317	0,042	25,712	2,87	-1	0,4519
D35D	3	23,538	3,627	0,27	27,435	3,06	-1	0,0628
D35E	3	25,289	5,02	0,086	30,395	3,39	-1	0,5089
D35G	3	25,033	5,3	0,174	30,507	3,41	-1	0,4882
D35H	3	24,705	4,506	0,007	29,218	3,26	-1	0,0015
D35J	3	23,935	4,221	0,08	28,236	3,15	1	0,0384
D35K	3	23,804	3,623	0,152	27,579	3,08	-1	0,081
J31A	3	24,276	5,01	0,586	29,872	3,34	1	0,2683
J31C	3	24,28	4,934	0,597	29,811	3,33	1	0,3527
J32B	3	25,689	5,265	0,095	31,049	3,47	1	0,0145
J32C	3	25,684	5,219	0,105	31,008	3,46	1	0,0155
J32D	3	22,531	2,567	0,08	25,178	2,81	1	0
J32E	3	21,983	2,584	0,05	24,617	2,75	1	0
J33A	3	20,398	3,321	0,066	23,785	2,66	1	0,2454
K80A	3	22,73	3,493	0,199	26,422	2,95	-1	0,062
K80B	3	22,689	4,937	0,424	28,05	3,13	-1	0,1031
K80C	3	23,297	4,608	0,012	27,917	3,12	-1	0,0004
K80D	3	23,663	4,379	0,098	28,14	3,14	-1	0,0003
K80E	3	22,978	5,128	0,304	28,41	3,17	-1	0,0218
K80F	3	22,064	5,482	0,499	28,045	3,13	-1	0
K90A	3	19,888	3,782	0,032	23,702	2,65	-1	0
K90B	3	20,836	4,716	0,588	26,14	2,92	-1	0,0054
K90C	3	20,814	4,562	0,581	25,957	2,9	-1	0,0066
K90D	3	20,468	5,771	0,399	26,638	2,97	-1	0
K90E	3	21,59	5,649	0,465	27,704	3,09	-1	0
K90F	3	20,614	5,546	0,479	26,639	2,97	-1	0
K90G	3	20,888	5,399	0,538	26,825	3	-1	0
L12C	3	24,336	4,219	0,153	28,708	3,21	1	0,0164
L12D	3	24,617	3,869	0,121	28,607	3,19	1	0,0404
L22B	3	22,845	3,636	0,08	26,561	2,97	-1	0,4631
L22C	3	19,87	1,832	0	21,702	2,42	-1	0,3951
L22D	3	20,928	2,579	0	23,507	2,63	-1	0,2945
L23A	3	24,637	7,339	0,307	32,283	3,61	1	0,1579
L23B	3	20,738	2,572	0	23,31	2,6	-1	0,4071
L23C	3	23,744	6,608	0,134	30,486	3,4	1	0,2178
L23D	3	23,78	4,745	0,503	29,028	3,24	-1	0,0685
L30A	3	21,812	4,451	0,129	26,392	2,95	-1	0,2597
L30B	3	21,529	4,606	0,151	26,286	2,94	-1	0,2832
L30C	3	23,639	4,818	0,449	28,906	3,23	-1	0,0743

3 MONTHS								
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
L30D	3	20,382	4,349	0	24,731	2,76	1	0,0317
L40A	3	24,711	5,488	0,302	30,501	3,41	-1	0,0845
L40B	3	20,314	4,401	0	24,715	2,76	1	0,0337
L50A	3	24,964	6,154	0,055	31,173	3,48	1	0,3541
L50B	3	22,079	4,125	0	26,204	2,93	1	0,1392
L60A	3	24,723	3,249	0	27,972	3,12	-1	0,3615
L60B	3	24,549	3,161	0	27,71	3,09	-1	0,2688
L70A	3	21,731	3,405	0	25,136	2,81	-1	0,09
L70B	3	23,564	2,939	0	26,503	2,96	-1	0,8478
L70C	3	23,496	2,899	0,032	26,427	2,95	-1	0,9727
L70D	3	19,642	3,284	0	22,926	2,56	-1	0,0467
L70E	3	25,226	4,8	0,182	30,208	3,37	-1	0,0492
L70F	3	19,097	3,059	0	22,156	2,47	-1	0,2475
L70G	3	21,441	2,316	0	23,757	2,65	-1	0,9647
L81A	3	22,216	5,869	0,309	28,394	3,17	-1	0,8273
L81B	3	20,016	2,709	0	22,725	2,54	-1	0,0078
L81C	3	20,516	2,575	0	23,091	2,58	-1	0,0042
L81D	3	18,901	2,226	0	21,127	2,36	-1	0,0595
L82B	3	19,618	3,427	0	23,045	2,57	1	0,0022
L82C	3	22,156	5,806	0,13	28,092	3,14	-1	0,5397
L82D	3	19,683	2,769	0,163	22,615	2,53	-1	0
L82E	3	21,41	3,458	0,203	25,071	2,8	-1	0
L82F	3	17,725	2,528	0	20,253	2,26	-1	0
L82G	3	20,756	3,267	0,194	24,217	2,7	-1	0
L82H	3	21,935	4,178	0,116	26,229	2,93	-1	0,0732
L82J	3	23,497	4,768	0,435	28,7	3,2	-1	0
L90A	3	20,378	2,346	0	22,724	2,54	-1	0,8925
L90B	3	22,335	5,399	0,002	27,736	3,1	-1	0,2575
L90C	3	22,393	3,876	0,323	26,592	2,97	-1	0,0049
M10A	3	22,26	4,966	0,123	27,349	3,05	-1	0,61
M10B	3	22,44	5,894	0,514	28,848	3,22	-1	0,0824
M10C	3	22,125	5,465	0,148	27,738	3,1	-1	0,5535
M10D	3	22,539	4,671	0,261	27,471	3,07	-1	0,0071
M20A	3	22,193	3,901	0,045	26,139	2,92	-1	0,0016
M20B	3	22,654	6,731	0,88	30,265	3,38	-1	0,6939
M30A	3	22,7	4,851	0,187	27,738	3,1	-1	0,0194
M30B	3	22,414	4,32	0,182	26,916	3,01	-1	0,0078
N11A	3	22,454	3,816	0,116	26,386	2,95	-1	0,0088
N11B	3	25,813	4,369	0,023	30,205	3,37	-1	0,0008
N12A	3	23,378	3,405	0	26,783	2,99	-1	0,0005
N12B	3	23,591	3,616	0	27,207	3,04	-1	0,0005
N12C	3	19,311	3,627	0,301	23,239	2,6	-1	0,142

3 MONTHS								
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
N13A	3	24,205	5,049	0,228	29,482	3,29	-1	0,0236
N13B	3	24,075	4,823	0,247	29,145	3,25	-1	0,024
N13C	3	24,635	4,848	0,467	29,95	3,34	-1	0,0088
N14A	3	23,568	3,273	0,002	26,843	3	-1	0,8856
N14B	3	22,582	4,443	0,066	27,091	3,03	-1	0,1505
N14C	3	23,133	3,461	0,154	26,748	2,99	-1	0,0007
N14D	3	24,531	4,753	0,487	29,771	3,32	-1	0,0099
N21A	3	24,584	4,803	0,418	29,805	3,33	-1	0,0099
N21B	3	23,634	4,608	0,084	28,326	3,16	-1	0,0001
N21C	3	23,036	5,302	0,157	28,495	3,18	-1	0,157
N21D	3	24,466	4,965	0,219	29,65	3,31	-1	0,0099
N22A	3	23,092	3,897	0,221	27,21	3,04	-1	0,2785
N22B	3	23,16	3,635	0	26,795	2,99	-1	0,2399
N22C	3	21,796	3,375	0	25,171	2,81	1	0,0916
N22D	3	22,76	3,511	0,106	26,377	2,95	1	0,1494
N22E	3	23,694	1,851	0	25,545	2,85	1	0,0269
N23A	3	22,868	3,509	0	26,377	2,95	1	0,3163
N23B	3	23,79	1,925	0	25,715	2,87	1	0,0107
N24A	3	23,057	5,05	0,084	28,191	3,15	-1	0,0592
N24B	3	21,977	3,692	0,217	25,886	2,89	-1	0,2287
N24C	3	22,66	3,689	0,151	26,5	2,96	-1	0,3283
N24D	3	23,192	4,493	0	27,685	3,09	-1	0,4344
N30A	3	24,281	4,144	0	28,425	3,17	-1	0,0113
N30B	3	23,878	5,008	0,208	29,094	3,25	1	0,9673
N30C	3	22,015	3,277	0,041	25,333	2,83	1	0,0868
N40A	3	21,185	0,96	0	22,145	2,47	1	0,0006
N40B	3	17,995	3,191	0,048	21,234	2,37	-1	0,1862
N40C	3	23,897	5,063	0,431	29,391	3,28	-1	0,0428
N40D	3	19,211	4,779	0,86	24,85	2,77	1	0,0001
N40E	3	19,436	1,963	0,159	21,558	2,41	1	0,0001
N40F	3	17,792	2,722	0,22	20,734	2,32	1	0,0006
P10A	3	20,13	3,673	0,205	24,008	2,68	-1	0,6856
P10B	3	21,093	2,949	0,226	24,268	2,71	-1	0
P10C	3	23,936	5,067	0,483	29,486	3,29	-1	0,0454
P10D	3	21,133	4,117	0,895	26,145	2,92	-1	0,1504
P10E	3	21,117	4,147	0,942	26,206	2,93	-1	0,1098
P10F	3	25,07	5,56	0,601	31,231	3,49	-1	0,0055
P10G	3	20,894	4,878	0,65	26,422	2,95	-1	0,1109
P20A	3	21,651	5,421	0,702	27,774	3,1	-1	0,0038
P20B	3	20,464	5,647	0,917	27,028	3,02	-1	0,0351
P30A	3	21,589	4,175	0,172	25,936	2,9	-1	0,0001
P30B	3	25,307	5,767	0,571	31,645	3,53	-1	0,0039

3 MONTHS								
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
P30C	3	22,162	5,871	0,563	28,596	3,19	-1	0,0124
P40A	3	20,285	4,426	0,175	24,886	2,78	-1	0,5005
P40B	3	22,958	4,737	0,462	28,157	3,14	-1	0,1026
P40C	3	22,771	4,737	0,704	28,212	3,15	-1	0,1458
P40D	3	24,572	5,137	0,164	29,873	3,34	-1	0,0005
Q11A	3	25,245	3,457	0	28,702	3,21	-1	0,0002
Q11B	3	24,965	4,303	0	29,268	3,27	-1	0,0185
Q12A	3	24,275	4,933	0	29,208	3,26	-1	0,8074
Q12B	3	23,824	5,927	0	29,751	3,32	-1	0,8404
Q12C	3	24,937	4,725	0,18	29,842	3,33	-1	0,1623
Q14A	3	24,063	3,095	0,125	27,283	3,05	-1	0,0416
Q21A	3	21,447	5,372	0,218	27,037	3,02	-1	0
Q22A	3	22,613	3,88	0,205	26,698	2,98	-1	0,0016
Q30A	3	24,961	4,159	0,13	29,25	3,27	-1	0,0003
Q30B	3	24,761	4,281	0	29,042	3,24	-1	0,0001
Q50A	3	23,583	3,661	0	27,244	3,04	-1	0,636
Q50B	3	24,335	6,829	0,971	32,135	3,59	-1	0,0129
Q50C	3	23,58	6,52	0,086	30,186	3,37	-1	0,9506
Q60B	3	22,305	5,811	0,822	28,938	3,23	-1	0,942
Q60C	3	25,573	5,208	0,571	31,352	3,5	-1	0,1364
Q70A	3	25,472	5,259	0,562	31,293	3,49	-1	0,1272
Q70B	3	23,606	6,481	0,164	30,251	3,38	-1	0,8552
Q70C	3	23,179	4,333	0	27,512	3,07	-1	0,0004
Q80A	3	20,391	3,799	0,098	24,288	2,71	-1	0,0387
Q80B	3	20,191	3,669	0,101	23,961	2,68	-1	0,0424
Q80C	3	20,271	4,207	0,189	24,667	2,75	-1	0,0524
Q80D	3	23,979	5,542	0,223	29,744	3,32	-1	0,6137
Q80E	3	22,162	3,532	0,103	25,797	2,88	1	0,0148
Q80F	3	22,036	3,601	0,118	25,755	2,88	1	0,0023
Q80G	3	23,196	4,378	0	27,574	3,08	-1	0,0004
Q91A	3	23,293	4,945	0,132	28,37	3,17	1	0,349
Q91B	3	20,319	2,242	0,111	22,672	2,53	1	0
Q91C	3	23,089	4,849	0,397	28,335	3,16	-1	0,4209
Q92C	3	24,094	4,539	0,208	28,841	3,22	-1	0,013
Q92E	3	24,299	4,621	0,206	29,126	3,25	-1	0,0811
Q92F	3	24,291	5,398	0,685	30,374	3,39	-1	0,5891
Q92G	3	24,45	5,079	0,055	29,584	3,3	-1	0,0562
Q93A	3	24,172	5,257	0	29,429	3,29	-1	0
Q93B	3	23,921	5,528	0,03	29,479	3,29	-1	0
Q93C	3	23,642	5,517	0,284	29,443	3,29	1	0,2906
Q93D	3	21,862	4,36	0,275	26,497	2,96	-1	0,1529
S20A	3	21,753	5,686	0,537	27,976	3,12	-1	0,0423

3 MONTHS								
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
S20B	3	22,368	5,078	0,694	28,14	3,14	-1	0,1103
T11G	3	22,066	6,742	1,393	30,201	3,37	-1	0,1394
T11H	3	21,538	5,579	1,089	28,206	3,15	-1	0,3123
T13A	3	21,941	5,958	1,15	29,049	3,24	-1	0,3351
T13B	3	21,74	5,879	1,108	28,727	3,21	-1	0,3076
T13C	3	23,194	5,421	0,918	29,533	3,3	-1	0,0036
T13D	3	21,075	4,28	0,709	26,064	2,91	-1	0,0313
T20A	3	23,645	6,673	0,958	31,276	3,49	1	0,6666
T20B	3	22,883	4,968	1,34	29,191	3,26	-1	0,4763
T20C	3	22,968	6,241	1,451	30,66	3,42	-1	0,0424
T20D	3	23,605	5,97	1,399	30,974	3,46	-1	0,0581
T20E	3	23,672	6,024	2,143	31,839	3,56	-1	0,007
T20F	3	19,8	6,738	1,405	27,943	3,12	-1	0
T20G	3	23,506	5,353	0,661	29,52	3,3	-1	0,0012
T32G	3	23,343	6,824	1,529	31,696	3,54	-1	0,6021
T32H	3	20,961	6,736	1,399	29,096	3,25	-1	0,0703
T33C	3	22,539	5,737	0,899	29,175	3,26	-1	0
T33K	3	19,69	6,634	1,351	27,675	3,09	-1	0,1438
T34A	3	24,632	5,025	0,199	29,856	3,33	-1	0
T34B	3	25,458	6,121	0,744	32,323	3,61	-1	0,0019
T34C	3	25,524	6,154	0,755	32,433	3,62	-1	0,0022
T34D	3	25,476	6,395	0,782	32,653	3,65	-1	0,0016
T34E	3	24,652	4,87	0,326	29,848	3,33	-1	0
T34F	3	25,503	6,625	0,662	32,79	3,66	-1	0,0021
T34G	3	22,226	6,045	1,442	29,713	3,32	-1	0,0177
T34H	3	24,137	6,213	1,42	31,77	3,55	-1	0,0007
T34J	3	22,463	4,318	0,42	27,201	3,04	1	0,6964
T34K	3	23,495	5,616	0,726	29,837	3,33	1	0,5967
T35A	3	19,938	5,367	0,939	26,244	2,93	1	0
T35B	3	25,713	5,763	0,942	32,418	3,62	-1	0,0874
T35C	3	25,933	5,491	0,945	32,369	3,61	-1	0,0746
T35D	3	25,914	5,535	0,924	32,373	3,62	-1	0,0808
T35E	3	22,005	6,234	1,528	29,767	3,32	-1	0,0066
T35F	3	24,953	7,573	0,376	32,902	3,67	-1	0,7068
T35G	3	20,931	6,038	1,32	28,289	3,16	-1	0,4915
T35H	3	22,455	4,786	0,96	28,201	3,15	-1	0,4928
T35J	3	22,692	6,186	1,464	30,342	3,39	-1	0,0028
T35K	3	24,495	6,824	0,987	32,306	3,61	-1	0,2054
T35L	3	23,817	5,958	0,697	30,472	3,4	1	0,6616
T35M	3	23,844	5,674	0,708	30,226	3,38	1	0,6803
T36A	3	19,876	5,122	0,663	25,661	2,87	-1	0,0033
T36B	3	23,408	5,79	1,047	30,245	3,38	-1	0

3 MONTHS								
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
T60B	3	20,752	6,367	1,362	28,481	3,18	-1	0,0406
T60C	3	21,196	6,282	1,262	28,74	3,21	-1	0,0853
T60D	3	23,35	5,734	0,314	29,398	3,28	1	0,3125
T60E	3	19,785	6,199	1,436	27,42	3,06	-1	0,084
T60F	3	20,714	4,932	0,607	26,253	2,93	-1	0,7166
T60G	3	23,253	5,721	0,304	29,278	3,27	1	0,2995
T60H	3	19,251	5,405	1,293	25,949	2,9	-1	0,2606
T60J	3	18,768	4,657	1,079	24,504	2,74	-1	0,2371
T60K	3	23,567	6,034	1,121	30,722	3,43	-1	0
T70A	3	19,763	5,093	0,651	25,507	2,85	-1	0,0036
T70B	3	23,587	6,056	0,951	30,594	3,42	-1	0
T70C	3	20,256	5,946	1,082	27,284	3,05	-1	0,2284
T70D	3	20,34	5,945	1,083	27,368	3,06	-1	0,1917
T70E	3	18,907	4,826	0,723	24,456	2,73	-1	0,0024
T70F	3	20,247	5,914	1,093	27,254	3,04	-1	0,1988
T70G	3	21,092	5,831	1,197	28,12	3,14	-1	0,276
T80A	3	23,665	5,407	0,669	29,741	3,32	-1	0,0012
T80B	3	23,147	5,322	0,595	29,064	3,25	-1	0,0016
T80C	3	20,89	4,33	0,695	25,915	2,89	-1	0,03
Mean		**22,7614**	**4,7366**	**0,4146**	**27,912**	**3,1169**	**-0,635**	**0,1796**
St dev		**1,8592**	**1,2180**	**0,4272**	**2,6860**	**0,2997**	**0,773**	**0,2514**

Table 4A.4: 6 months SPEI analysis per catchment

	6 MONTHS							
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
D12A	6	26,337	8,845	1,219	36,401	4,09	-1	0,0124
D12B	6	26,758	8,783	1,313	36,854	4,14	-1	0,0215
D12C	6	26,515	8,788	1,258	36,561	4,1	-1	0,0164
D12E	6	25,184	7,731	0,829	33,744	3,79	-1	0
D12F	6	24,962	8,063	0,904	33,929	3,81	-1	0,0536
D13A	6	25,31	8,905	1,278	35,493	3,98	-1	0,006
D13B	6	26,267	10,552	1,184	38,003	4,27	-1	0,1529
D13C	6	18,374	4,495	0,308	23,177	2,6	1	0
D13D	6	26,511	5,999	1,068	33,578	3,77	1	0,5054
D13E	6	26,536	9,982	0,877	37,395	4,2	-1	0,1992
D13F	6	26,051	6,223	1,055	33,329	3,74	1	0,5989
D13G	6	28,711	6,397	0,027	35,135	3,94	-1	0,0293
D13H	6	24,238	7,624	0,579	32,441	3,64	1	0,0017
D13J	6	25,632	7,976	0,9	34,508	3,87	-1	0,5167

	6 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_dim**	**total_% of time**	**trend**	**p**
D13K	6	27,417	8,186	0,564	36,167	4,06	-1	0
D13L	6	25,91	7,718	0,397	34,025	3,82	-1	0,222
D13M	6	24,843	8,143	0,919	33,905	3,81	-1	0,0401
D14A	6	25,983	6,07	0,939	32,992	3,7	-1	0,1264
D14C	6	24,211	7,772	1,451	33,434	3,75	1	0,0018
D14D	6	25,556	7,523	0,605	33,684	3,78	-1	0
D14E	6	22,962	7,204	0,659	30,825	3,46	1	0,0831
D14F	6	22,204	7,161	0,7	30,065	3,37	1	0,0857
D14G	6	25,909	5,975	0,623	32,507	3,65	-1	0,7898
D14H	6	25,474	5,783	0,65	31,907	3,58	-1	0,857
D14J	6	25,116	8,003	0,414	33,533	3,76	-1	0,0593
D14K	6	24,797	7,28	0,528	32,605	3,66	1	0,6304
D18K	6	27,815	10,307	1,141	39,263	4,41	-1	0,0027
D18L	6	27,356	9,333	1,057	37,746	4,24	-1	0,1772
D32A	6	23,897	6,505	0,515	30,917	3,47	1	0
D32B	6	22,406	4,95	0,586	27,942	3,14	-1	0,0094
D34A	6	26,455	4,844	0,165	31,464	3,53	-1	0,1777
D35B	6	25,192	8,552	0,426	34,17	3,84	-1	0,0001
D35C	6	26,185	7,332	0,512	34,029	3,82	-1	0,6744
D35D	6	24,656	7,314	0,253	32,223	3,62	-1	0,0938
D35E	6	26,108	7,074	0,841	34,023	3,82	-1	0,8117
D35G	6	25,641	7,064	0,867	33,572	3,77	-1	0,8383
D35H	6	25,242	8,417	0,28	33,939	3,81	-1	0,0001
D35J	6	23,661	8,342	0,685	32,688	3,67	1	0,0004
D35K	6	25,827	6,378	0,151	32,356	3,63	-1	0,0741
J31A	6	24,675	7,39	0,407	32,472	3,64	1	0,0865
J31C	6	24,787	7,431	0,398	32,616	3,66	1	0,1429
J32B	6	23,674	5,237	0,433	29,344	3,29	1	0,0015
J32C	6	23,709	5,403	0,44	29,552	3,32	1	0,0017
J32D	6	23,601	2,801	0	26,402	2,96	1	0
J32E	6	23,104	2,944	0	26,048	2,92	1	0
J33A	6	23,917	7,178	0,583	31,678	3,56	1	0,0965
K80A	6	24,306	3,594	0,18	28,08	3,15	-1	0,0105
K80B	6	22,225	5,55	0,195	27,97	3,14	-1	0,0117
K80C	6	24,876	5,605	0,311	30,792	3,46	-1	0
K80D	6	24,654	5,755	0,448	30,857	3,46	-1	0
K80E	6	24,518	4,455	0,089	29,062	3,26	-1	0,0008
K80F	6	24,647	4,683	0,439	29,769	3,34	-1	0
K90A	6	23,98	6,353	0,228	30,561	3,43	-1	0
K90B	6	24,93	6,47	0,921	32,321	3,63	-1	0,0016
K90C	6	25,068	6,281	0,947	32,296	3,62	-1	0,002
K90D	6	23,77	4,863	0,103	28,736	3,23	-1	0

	6 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_dim**	**total_% of time**	**trend**	**p**
K90E	6	23,133	4,887	0,551	28,571	3,21	-1	0
K90F	6	23,313	4,826	0,213	28,352	3,18	-1	0
K90G	6	22,945	4,865	0,246	28,056	3,15	-1	0
L12C	6	24,201	7,098	0,635	31,934	3,58	1	0,0018
L12D	6	23,913	6,958	0,44	31,311	3,51	1	0,0094
L22B	6	22,745	4,674	0,268	27,687	3,11	-1	0,4958
L22C	6	19,452	4,279	0,071	23,802	2,67	-1	0,4208
L22D	6	19,012	3,772	0,115	22,899	2,57	-1	0,2345
L23A	6	24,907	8,397	1,289	34,593	3,88	1	0,1668
L23B	6	18,911	3,722	0,119	22,752	2,55	-1	0,3821
L23C	6	24,52	6,621	0,666	31,807	3,57	1	0,1478
L23D	6	22,528	5,82	0,325	28,673	3,22	-1	0,0053
L30A	6	22,545	5,801	0,082	28,428	3,19	-1	0,4164
L30B	6	22,208	5,745	0,145	28,098	3,15	-1	0,4349
L30C	6	22,557	5,853	0,342	28,752	3,23	-1	0,0068
L30D	6	22,37	6,484	0,508	29,362	3,3	1	0,0006
L40A	6	22,66	6,719	0,318	29,697	3,33	-1	0,0055
L40B	6	22,71	6,433	0,725	29,868	3,35	1	0,0004
L50A	6	22,643	8,285	0,778	31,706	3,56	1	0,2356
L50B	6	24,238	6,732	0,359	31,329	3,52	1	0,0132
L60A	6	24,121	4,328	0,278	28,727	3,22	-1	0,1754
L60B	6	23,753	4,322	0,295	28,37	3,18	-1	0,1026
L70A	6	23,716	5,872	0,007	29,595	3,32	-1	0,0489
L70B	6	23,156	4,954	0,417	28,527	3,2	-1	0,8602
L70C	6	23,2	5,038	0,527	28,765	3,23	1	0,9377
L70D	6	23,567	4,332	0	27,899	3,13	-1	0,04
L70E	6	26,022	6,342	0,228	32,592	3,66	-1	0,0236
L70F	6	23,239	4,375	0,01	27,624	3,1	-1	0,3807
L70G	6	26,747	4,652	0	31,399	3,52	1	0,5746
L81A	6	24,386	5,82	1,103	31,309	3,51	-1	0,6576
L81B	6	23,789	4,676	0	28,465	3,19	-1	0,0033
L81C	6	24,06	5,088	0	29,148	3,27	-1	0,0014
L81D	6	19,201	2,9	0	22,101	2,48	-1	0,0097
L82B	6	24,226	4,898	0,306	29,43	3,3	1	0
L82C	6	24,299	6,049	1,121	31,469	3,53	-1	0,3393
L82D	6	25,681	5,363	0,128	31,172	3,5	-1	0
L82E	6	24,384	5,588	0,272	30,244	3,39	-1	0
L82F	6	22,22	2,211	0,107	24,538	2,75	-1	0
L82G	6	24,175	4,847	0,313	29,335	3,29	-1	0
L82H	6	22,491	5,146	0,006	27,643	3,1	-1	0,0103
L82J	6	24,812	6,765	0,094	31,671	3,55	-1	0
L90A	6	26,495	4,766	0	31,261	3,51	1	0,7628

	6 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_dim**	**total_% of time**	**trend**	**p**
L90B	6	24,1	5,007	0,06	29,167	3,27	-1	0,2858
L90C	6	24,016	4,205	0	28,221	3,17	-1	0,001
M10A	6	23,651	7,328	0,512	31,491	3,53	-1	0,4575
M10B	6	23,76	4,787	0,074	28,621	3,21	-1	0,0475
M10C	6	23,852	7,242	1,116	32,21	3,62	-1	0,3444
M10D	6	24,332	4,956	0,239	29,527	3,31	-1	0,0016
M20A	6	24,812	4,408	0,156	29,376	3,3	-1	0,0003
M20B	6	24,862	7,129	1,075	33,066	3,71	-1	0,6036
M30A	6	22,891	5,878	0,462	29,231	3,28	-1	0,008
M30B	6	24,751	5,184	0,201	30,136	3,38	-1	0,0026
N11A	6	22,359	4,506	0,835	27,7	3,11	-1	0,0074
N11B	6	25,217	6,418	0,348	31,983	3,59	-1	0,0002
N12A	6	23,957	4,098	0,301	28,356	3,18	-1	0,0001
N12B	6	23,997	4,119	0,257	28,373	3,18	-1	0,0001
N12C	6	21,357	5,356	0,646	27,359	3,07	-1	0,1512
N13A	6	24,745	7,196	0,3	32,241	3,62	-1	0,0119
N13B	6	24,912	6,566	0,242	31,72	3,56	-1	0,0193
N13C	6	23,258	6,435	0,391	30,084	3,38	-1	0,0041
N14A	6	22,49	5,092	0,033	27,615	3,1	1	0,9974
N14B	6	23,642	5,784	0,035	29,461	3,31	-1	0,1161
N14C	6	22,66	5,196	0,449	28,305	3,18	-1	0,0001
N14D	6	23,254	6,262	0,389	29,905	3,36	-1	0,0049
N21A	6	23,244	6,34	0,36	29,944	3,36	-1	0,005
N21B	6	24,923	5,253	0,308	30,484	3,42	-1	0
N21C	6	25,614	6,864	0,608	33,086	3,71	-1	0,1489
N21D	6	25,602	6,572	0,296	32,47	3,64	-1	0,0036
N22A	6	22,615	5,181	0,62	28,416	3,19	-1	0,226
N22B	6	26,448	4,666	0,421	31,535	3,54	-1	0,1159
N22C	6	23,089	4,919	0,14	28,148	3,16	1	0,0045
N22D	6	23,697	4,948	0,111	28,756	3,23	1	0,0086
N22E	6	24,556	4,573	0,01	29,139	3,27	1	0,0002
N23A	6	22,713	5,989	0,544	29,246	3,28	1	0,1343
N23B	6	23,275	4,81	0,081	28,166	3,16	1	0,0001
N24A	6	23,702	6,26	0,381	30,343	3,41	-1	0,0067
N24B	6	22,271	5,261	0,649	28,181	3,16	-1	0,1634
N24C	6	22,637	5,26	0,622	28,519	3,2	-1	0,2633
N24D	6	25,048	6,051	0,403	31,502	3,54	-1	0,3692
N30A	6	24,406	6,141	0,426	30,973	3,48	-1	0,0013
N30B	6	23,061	6,857	0,761	30,679	3,44	1	0,7889
N30C	6	23,338	4,793	0,115	28,246	3,17	1	0,0036
N40A	6	22,674	3,867	0	26,541	2,98	1	0
N40B	6	22,888	5,703	0,273	28,864	3,24	-1	0,1312

	6 MONTHS							
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
N40C	6	24,271	6,298	0,553	31,122	3,49	-1	0,0492
N40D	6	21,207	4,392	0,856	26,455	2,97	1	0
N40E	6	20,914	1,352	0	22,266	2,5	1	0
N40F	6	19,521	2,121	0	21,642	2,43	1	0
P10A	6	22,454	3,357	0,306	26,117	2,93	1	0,9165
P10B	6	23,888	6,305	0,429	30,622	3,44	-1	0
P10C	6	24,654	6,249	0,556	31,459	3,53	-1	0,0489
P10D	6	21,084	6,082	1,179	28,345	3,18	-1	0,3026
P10E	6	21,482	6,117	1,261	28,86	3,24	-1	0,2237
P10F	6	27,402	9,631	0,848	37,881	4,25	-1	0,0013
P10G	6	21,866	4,408	0,529	26,803	3,01	-1	0,0489
P20A	6	24,388	5,199	0,231	29,818	3,35	-1	0,0001
P20B	6	22,358	4,61	0,718	27,686	3,11	-1	0,0022
P30A	6	24,461	5,914	0,744	31,119	3,49	-1	0
P30B	6	27,388	9,249	1,083	37,72	4,23	-1	0,0007
P30C	6	23,071	5,515	1,197	29,783	3,34	-1	0,0015
P40A	6	23,083	3,576	0,431	27,09	3,04	-1	0,784
P40B	6	26,641	4,768	1,101	32,51	3,65	-1	0,0637
P40C	6	25,971	4,908	1,053	31,932	3,58	-1	0,0949
P40D	6	24,522	6,21	0,31	31,042	3,48	-1	0
Q11A	6	25,325	7,376	0,314	33,015	3,71	-1	0,0001
Q11B	6	26,083	7,056	0,069	33,208	3,73	-1	0,0424
Q12A	6	24,894	7,408	0,761	33,063	3,71	1	0,478
Q12B	6	24,894	7,374	0,744	33,012	3,71	1	0,3866
Q12C	6	25,352	6,977	0,445	32,774	3,68	-1	0,3244
Q14A	6	21,774	5,313	0,526	27,613	3,1	-1	0,0337
Q21A	6	23,373	6,547	1,269	31,189	3,5	-1	0
Q22A	6	24,021	6,153	0,467	30,641	3,44	-1	0,001
Q30A	6	25,79	6,235	0,734	32,759	3,68	-1	0
Q30B	6	25,553	6,404	0,533	32,49	3,65	-1	0
Q50A	6	23,241	5,855	1,034	30,13	3,38	-1	0,9054
Q50B	6	22,66	7,378	1,527	31,565	3,54	-1	0,006
Q50C	6	25,606	5,549	0,551	31,706	3,56	1	0,642
Q60B	6	24,441	5,265	0,468	30,174	3,39	1	0,3096
Q60C	6	23,804	6,374	0,59	30,768	3,45	-1	0,2866
Q70A	6	23,7	6,549	0,656	30,905	3,47	-1	0,2566
Q70B	6	25,334	5,65	0,584	31,568	3,54	1	0,7309
Q70C	6	25,338	6,589	0,228	32,155	3,61	-1	0
Q80A	6	26,152	4,748	0,534	31,434	3,53	-1	0,0258
Q80B	6	26,1	4,56	0,501	31,161	3,5	-1	0,0337
Q80C	6	24,817	5,504	0,587	30,908	3,47	-1	0,0583
Q80D	6	26,071	6,426	0,468	32,965	3,7	1	0,9527

	6 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_dim**	**total_% of time**	**trend**	**p**
Q80E	6	20,71	5,705	0,569	26,984	3,03	1	0,0003
Q80F	6	20,741	6,065	0,401	27,207	3,05	1	0
Q80G	6	25,395	6,624	0,231	32,25	3,62	-1	0
Q91A	6	24,157	7,835	0,457	32,449	3,64	1	0,1696
Q91B	6	18,497	3,192	0,083	21,772	2,44	1	0
Q91C	6	22,176	4,826	0,329	27,331	3,07	-1	0,7949
Q92C	6	22,047	8,794	0,644	31,485	3,53	-1	0,0517
Q92E	6	22,206	8,426	0,743	31,375	3,52	-1	0,3537
Q92F	6	23,485	6,206	0,758	30,449	3,42	1	0,7118
Q92G	6	21,48	8,48	0,828	30,788	3,46	-1	0,2287
Q93A	6	27,067	6,336	0,332	33,735	3,79	-1	0
Q93B	6	27,27	6,657	0,438	34,365	3,86	-1	0
Q93C	6	25,588	7,051	0,778	33,417	3,75	1	0,1362
Q93D	6	24,153	6,198	0,572	30,923	3,47	-1	0,1797
S20A	6	23,954	6,801	1,078	31,833	3,57	-1	0,1464
S20B	6	25,449	6,859	2,07	34,378	3,86	-1	0,3578
T11G	6	23,626	7,491	1,752	32,869	3,69	-1	0,1767
T11H	6	23,437	6,608	1,713	31,758	3,56	-1	0,899
T13A	6	23,28	6,837	1,8	31,917	3,58	-1	0,9759
T13B	6	23,347	6,755	1,838	31,94	3,58	-1	0,885
T13C	6	24,274	6,744	1,202	32,22	3,62	-1	0,0064
T13D	6	23,073	4,505	0,2	27,778	3,12	-1	0,0736
T20A	6	27,615	7,904	1,455	36,974	4,15	1	0,1611
T20B	6	25,686	7,164	1,484	34,334	3,85	-1	0,9481
T20C	6	24,812	7,257	1,355	33,424	3,75	-1	0,1453
T20D	6	24,887	7,103	1,239	33,229	3,73	-1	0,1718
T20E	6	25,419	8,855	2,537	36,811	4,13	-1	0,0126
T20F	6	23,223	7,903	1,575	32,701	3,67	-1	0
T20G	6	27,993	7,196	1,757	36,946	4,15	-1	0,0007
T32G	6	26,378	9,233	1,752	37,363	4,19	1	0,6308
T32H	6	25,555	9,51	1,593	36,658	4,11	-1	0,1092
T33C	6	24,839	7,548	1,579	33,966	3,81	-1	0
T33K	6	25,835	9,514	1,555	36,904	4,14	-1	0,2271
T34A	6	22,895	6,733	0,96	30,588	3,43	-1	0
T34B	6	25,873	7,229	0,559	33,661	3,78	-1	0,0002
T34C	6	25,983	7,166	0,573	33,722	3,78	-1	0,0002
T34D	6	25,612	7,03	0,829	33,471	3,76	-1	0,0001
T34E	6	21,732	6,5	0,985	29,217	3,28	-1	0
T34F	6	25,822	7,014	0,712	33,548	3,77	-1	0,0002
T34G	6	21,16	7,922	1,854	30,936	3,47	-1	0,032
T34H	6	25,84	9,072	2,155	37,067	4,16	-1	0,0002
T34J	6	26,691	4,862	0	31,553	3,54	1	0,1406

	6 MONTHS							
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
T34K	6	25,966	7,5	0,801	34,267	3,85	1	0,0525
T35A	6	21,022	5,685	1,398	28,105	3,15	1	0
T35B	6	27,074	8,31	1,639	37,023	4,16	-1	0,1878
T35C	6	26,89	8,505	1,719	37,114	4,17	-1	0,1542
T35D	6	26,921	8,571	1,681	37,173	4,17	-1	0,1683
T35E	6	26,499	7,617	1,969	36,085	4,05	-1	0,0084
T35F	6	24,132	9,369	1,026	34,527	3,88	1	0,4318
T35G	6	25,179	7,119	1,433	33,731	3,79	1	0,7474
T35H	6	25,377	6,866	0,99	33,233	3,73	-1	0,9243
T35J	6	26,898	7,453	1,899	36,25	4,07	-1	0,0015
T35K	6	26,224	7,93	1,955	36,109	4,05	-1	0,4095
T35L	6	25,745	7,745	0,828	34,318	3,85	1	0,074
T35M	6	25,99	7,346	0,868	34,204	3,84	1	0,0777
T36A	6	21,462	5,633	0,954	28,049	3,15	-1	0,0217
T36B	6	26,14	8,207	1,927	36,274	4,07	-1	0
T60B	6	25,469	9,324	1,557	36,35	4,08	-1	0,0433
T60C	6	25,522	8,333	1,444	35,299	3,96	-1	0,0985
T60D	6	26,544	8,529	1,409	36,482	4,09	1	0,1299
T60E	6	24,998	7,962	1,581	34,541	3,88	-1	0,1047
T60F	6	22,161	6,141	0,67	28,972	3,25	1	0,6082
T60G	6	26,492	8,481	1,43	36,403	4,09	1	0,1192
T60H	6	21,601	5,385	1,773	28,759	3,23	-1	0,4222
T60J	6	22,348	5,364	2,028	29,74	3,34	-1	0,3556
T60K	6	26,049	8,351	1,842	36,242	4,07	-1	0
T70A	6	21,657	5,627	0,953	28,237	3,17	-1	0,0231
T70B	6	26,131	8,179	1,971	36,281	4,07	-1	0
T70C	6	25,213	7,972	1,435	34,62	3,89	-1	0,434
T70D	6	25,216	7,946	1,436	34,598	3,88	-1	0,3535
T70E	6	21,793	5,521	0,967	28,281	3,17	-1	0,0116
T70F	6	25,349	7,871	1,334	34,554	3,88	-1	0,4398
T70G	6	25,099	7,924	1,327	34,35	3,86	-1	0,6134
T80A	6	27,364	7,269	1,648	36,281	4,07	-1	0,0006
T80B	6	27,325	6,999	1,604	35,928	4,03	-1	0,0008
T80C	6	23,239	4,934	0,065	28,238	3,17	-1	0,0586
Mean	**6**	**24,27**	**6,35**	**0,71**	**31,33**	**3,51**	**-0,488**	**0,1759**
Med	**6**	**24,38**	**6,34**	**0,57**	**31,44**	**3,53**	**-1**	**0,0368**
Max	**6**	**28,71**	**10,55**	**2,53**	**39,26**	**4,41**	**1**	**0,9974**
Min	**6**	**18,37**	**1,35**	**0**	**21,64**	**2,43**	**-1**	**0**
St Dev	**0**	**1,8302724**	**1,575770**	**0,5509**	**3,2955**	**0,3702**	**0,874**	**0,2644**

Table 4A.5: 12-month SPEI analysis per catchment

	12 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_ dim**	**total_% of time**	**trend**	**p**
D12A	12	23,419	9,814	1,133	34,366	3,9	-1	0,006
D12B	12	24,688	9,666	1,274	35,628	4,04	-1	0,0103
D12C	12	24,04	9,567	1,25	34,857	3,95	-1	0,0054
D12E	12	25,702	9,985	1,183	36,87	4,18	-1	0
D12F	12	28,372	7,923	0,818	37,113	4,21	-1	0,0595
D13A	12	25,619	8,045	0,307	33,971	3,85	-1	0,004
D13B	12	26,735	8,685	1,146	36,566	4,15	-1	0,2691
D13C	12	18,859	2,697	0	21,556	2,44	1	0
D13D	12	28,355	5,472	0,296	34,123	3,87	1	0,0228
D13E	12	27,094	7,537	0,443	35,074	3,98	-1	0,2536
D13F	12	28,164	5,389	0,304	33,857	3,84	1	0,0407
D13G	12	28,993	6,14	0,177	35,31	4	-1	0,018
D13H	12	23,871	9,383	1,279	34,533	3,92	1	0
D13J	12	28,011	8,59	0,63	37,231	4,22	-1	0,8356
D13K	12	25,154	10,511	0,712	36,377	4,12	-1	0
D13L	12	27,894	6,586	0,358	34,838	3,95	-1	0,2614
D13M	12	28,824	7,764	0,753	37,341	4,23	-1	0,0402
D14A	12	26,191	7,507	1,16	34,858	3,95	-1	0,1894
D14C	12	26,187	8,517	1,954	36,658	4,16	1	0
D14D	12	26,85	8,438	1,127	36,415	4,13	-1	0
D14E	12	21,572	6,413	0,553	28,538	3,24	1	0,0005
D14F	12	22,68	6,591	0,527	29,798	3,38	1	0,0008
D14G	12	26,682	7,945	0,395	35,022	3,97	1	0,5349
D14H	12	26,087	7,462	0,409	33,958	3,85	1	0,5009
D14J	12	22,707	7,903	1,171	31,781	3,6	-1	0,0758
D14K	12	22,606	6,548	0,67	29,824	3,38	1	0,2396
D18K	12	26,552	9,517	1,164	37,233	4,22	-1	0,0007
D18L	12	24,246	8,438	2,365	35,049	3,97	-1	0,4982
D32A	12	25,243	4,458	0,507	30,208	3,42	1	0
D32B	12	19,67	4,552	0	24,222	2,75	-1	0,0037
D34A	12	26,056	8,341	0,612	35,009	3,97	-1	0,226
D35B	12	23,759	7,19	1,086	32,035	3,63	-1	0
D35C	12	22,801	5,375	0,701	28,877	3,27	-1	0,9732
D35D	12	23,207	6,41	0,794	30,411	3,45	-1	0,0538
D35E	12	25,651	7,92	0,841	34,412	3,9	1	0,9577
D35G	12	25,326	7,86	0,702	33,888	3,84	1	0,8436
D35H	12	24,24	7,456	0,987	32,683	3,71	-1	0
D35J	12	26,317	6,72	0,927	33,964	3,85	1	0
D35K	12	22,884	5,839	0,508	29,231	3,31	-1	0,0652
J31A	12	23,124	9,058	1,894	34,076	3,86	1	0,0036
J31C	12	23,028	9,237	1,908	34,173	3,87	1	0,0109

	12 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_ dim**	**total_% of time**	**trend**	**p**
J32B	12	23,709	6,649	1,937	32,295	3,66	1	0
J32C	12	23,707	6,779	1,976	32,462	3,68	1	0
J32D	12	20,501	3,441	0,059	24,001	2,72	1	0
J32E	12	20,265	3,601	0,056	23,922	2,71	1	0
J33A	12	25,725	7,98	2,094	35,799	4,06	1	0,0058
K80A	12	27,32	5,983	0,128	33,431	3,79	-1	0,0014
K80B	12	28,48	7,932	0,019	36,431	4,13	-1	0,0007
K80C	12	26,261	5,531	0,158	31,95	3,62	-1	0
K80D	12	26,718	5,409	0,062	32,189	3,65	-1	0
K80E	12	26,771	6,293	0,225	33,289	3,77	-1	0
K80F	12	25,642	4,731	0,242	30,615	3,47	-1	0
K90A	12	24,666	5,951	0,325	30,942	3,51	-1	0
K90B	12	24,916	9,401	2,267	36,584	4,15	-1	0,0006
K90C	12	24,939	9,382	2,291	36,612	4,15	-1	0,0007
K90D	12	26,546	4,534	0,073	31,153	3,53	-1	0
K90E	12	23,205	5,463	0,277	28,945	3,28	-1	0
K90F	12	26,053	4,691	0,118	30,862	3,5	-1	0
K90G	12	25,483	4,902	0,14	30,525	3,46	-1	0
L12C	12	25,568	7,122	0,398	33,088	3,75	1	0,0001
L12D	12	25,714	6,942	0,338	32,994	3,74	1	0,0014
L22B	12	22,219	3,496	0	25,715	2,92	-1	0,7657
L22C	12	23,299	3,776	0,081	27,156	3,08	-1	0,6643
L22D	12	19,687	2,125	0	21,812	2,47	-1	0,1734
L23A	12	24,053	6,02	0,548	30,621	3,47	1	0,1604
L23B	12	19,707	2,073	0	21,78	2,47	-1	0,366
L23C	12	28,413	5,181	0,528	34,122	3,87	1	0,1616
L23D	12	25,169	5,827	0,111	31,107	3,53	-1	0,0002
L30A	12	23,873	5,421	0,814	30,108	3,41	-1	0,7991
L30B	12	23,502	5,343	0,817	29,662	3,36	-1	0,8151
L30C	12	25,335	5,735	0,078	31,148	3,53	-1	0,0003
L30D	12	21,553	5,348	0,117	27,018	3,06	1	0
L40A	12	25,518	6,662	0,038	32,218	3,65	-1	0,0001
L40B	12	20,746	4,904	0,13	25,78	2,92	1	0
L50A	12	22,939	7,313	1,071	31,323	3,55	1	0,1002
L50B	12	21,5	4,784	0,195	26,479	3	1	0,0004
L60A	12	23,86	4,115	0,288	28,263	3,2	-1	0,1214
L60B	12	23,852	4,052	0,247	28,151	3,19	-1	0,0472
L70A	12	23,454	8,087	0,223	31,764	3,6	-1	0,0237
L70B	12	19,929	6,491	0,629	27,049	3,07	-1	0,9306
L70C	12	19,9	6,938	0,83	27,668	3,14	1	0,7494
L70D	12	21,04	7,942	0,166	29,148	3,3	-1	0,0365
L70E	12	22,682	7,718	0,523	30,923	3,51	-1	0,006

	12 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_ dim**	**total_% of time**	**trend**	**p**
L70F	12	21,31	8,467	0,375	30,152	3,42	-1	0,7632
L70G	12	28,407	7,04	0	35,447	4,02	1	0,1826
L81A	12	25,931	8,948	1,725	36,604	4,15	-1	0,964
L81B	12	22,555	5,951	0,349	28,855	3,27	-1	0,0004
L81C	12	23,379	6,256	0,357	29,992	3,4	-1	0,0001
L81D	12	21,932	6,659	0,089	28,68	3,25	-1	0,0005
L82B	12	27,833	9,123	1,675	38,631	4,38	1	0
L82C	12	25,592	8,732	1,742	36,066	4,09	-1	0,4317
L82D	12	24,243	5,784	0,336	30,363	3,44	-1	0
L82E	12	24,277	5,763	0,608	30,648	3,47	-1	0
L82F	12	24,079	4,649	0,355	29,083	3,3	-1	0
L82G	12	24,234	5,046	0,497	29,777	3,38	-1	0
L82H	12	24,642	5,029	0,097	29,768	3,38	-1	0,0007
L82J	12	26,801	5,707	0,005	32,513	3,69	-1	0
L90A	12	27,545	7,261	0,089	34,895	3,96	1	0,2562
L90B	12	25,329	4,77	0,226	30,325	3,44	-1	0,7126
L90C	12	26,275	4,614	0,435	31,324	3,55	-1	0,0001
M10A	12	25,14	8,321	1,411	34,872	3,95	-1	0,5029
M10B	12	23,446	5,884	0,509	29,839	3,38	-1	0,0895
M10C	12	25,027	9,115	1,552	35,694	4,05	-1	0,3242
M10D	12	25,318	6,717	0,043	32,078	3,64	-1	0,0001
M20A	12	25,56	4,633	0	30,193	3,42	-1	0
M20B	12	27,276	9,504	1,085	37,865	4,29	-1	0,9187
M30A	12	25,821	7,007	0,703	33,531	3,8	-1	0,0012
M30B	12	25,441	6,7	0,128	32,269	3,66	-1	0,0003
N11A	12	23,872	4,158	0,134	28,164	3,19	-1	0,0057
N11B	12	23,811	5,272	0,145	29,228	3,31	-1	0
N12A	12	19,998	0,751	0	20,749	2,35	-1	0
N12B	12	20,423	0,833	0	21,256	2,41	-1	0
N12C	12	22,066	4,025	0	26,091	2,96	-1	0,232
N13A	12	22,545	8,358	1,709	32,612	3,7	-1	0,0162
N13B	12	23,113	8,662	1,286	33,061	3,75	-1	0,0261
N13C	12	20,973	4,857	0,017	25,847	2,93	-1	0,0014
N14A	12	22,056	6,023	0,92	28,999	3,29	1	0,6612
N14B	12	22,891	6,662	1,386	30,939	3,51	-1	0,1266
N14C	12	19,89	5,303	0,007	25,2	2,86	-1	0
N14D	12	21,029	4,864	0,034	25,927	2,94	-1	0,0019
N21A	12	21,135	4,99	0,031	26,156	2,97	-1	0,0019
N21B	12	26,109	5,578	0	31,687	3,59	-1	0
N21C	12	22,253	6,954	0,411	29,618	3,36	-1	0,1272
N21D	12	22,553	7,175	0,144	29,872	3,39	-1	0,0013
N22A	12	25,22	5,293	0,197	30,71	3,48	-1	0,3016

	12 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_ dim**	**total_% of time**	**trend**	**p**
N22B	12	26,415	7,603	0,292	34,31	3,89	-1	0,0378
N22C	12	23,295	4,292	0,083	27,67	3,14	1	0
N22D	12	21,907	4,089	0	25,996	2,95	1	0
N22E	12	25,966	4,481	0	30,447	3,45	1	0
N23A	12	24,902	7,459	0,206	32,567	3,69	1	0,0278
N23B	12	26,061	4,512	0	30,573	3,47	1	0
N24A	12	24,115	4,748	0	28,863	3,27	-1	0,0002
N24B	12	24,692	5,346	0,133	30,171	3,42	-1	0,1732
N24C	12	25,046	5,705	0,349	31,1	3,53	-1	0,3288
N24D	12	27,478	6,211	0,14	33,829	3,84	-1	0,434
N30A	12	24,788	7,496	0,983	33,267	3,77	-1	0
N30B	12	23,79	5,294	0,539	29,623	3,36	1	0,2359
N30C	12	23,007	4,056	0,008	27,071	3,07	1	0
N40A	12	23,529	4,303	0	27,832	3,16	1	0
N40B	12	23,151	6,963	1,285	31,399	3,56	-1	0,1343
N40C	12	22,388	7,514	1,002	30,904	3,5	-1	0,0791
N40D	12	27,07	2,81	0,058	29,938	3,39	1	0
N40E	12	28,67	1,356	0	30,026	3,4	1	0
N40F	12	25,696	2,092	0	27,788	3,15	1	0
P10A	12	21,746	3,784	0,048	25,578	2,9	1	0,2117
P10B	12	26,235	5,184	0,101	31,52	3,57	-1	0
P10C	12	22,09	7,262	1,016	30,368	3,44	-1	0,0752
P10D	12	25,832	7,256	1,799	34,887	3,96	-1	0,4829
P10E	12	26,453	7,491	1,809	35,753	4,05	-1	0,3429
P10F	12	27,41	9,057	1,902	38,369	4,35	-1	0,0004
P10G	12	22,785	6,494	0,646	29,925	3,39	-1	0,0188
P20A	12	26,466	4,682	0,435	31,583	3,58	-1	0
P20B	12	23,654	6,259	0,734	30,647	3,47	-1	0,0002
P30A	12	24,953	4,427	0,253	29,633	3,36	-1	0
P30B	12	27,52	8,499	1,786	37,805	4,29	-1	0,0001
P30C	12	22,947	6,857	0,83	30,634	3,47	-1	0,0001
P40A	12	20,058	4,644	0,13	24,832	2,82	1	0,5148
P40B	12	21,132	6,157	0,502	27,791	3,15	-1	0,0462
P40C	12	20,61	5,873	0,592	27,075	3,07	-1	0,1154
P40D	12	24,544	6,016	0,34	30,9	3,5	-1	0
Q11A	12	26,758	7,2	2,41	36,368	4,12	-1	0
Q11B	12	27,084	6,229	0,991	34,304	3,89	-1	0,061
Q12A	12	25,948	7,062	0,755	33,765	3,83	1	0,0242
Q12B	12	25,593	7,321	0,757	33,671	3,82	1	0,0142
Q12C	12	20,807	8,304	1,455	30,566	3,47	-1	0,679
Q14A	12	22,123	5,066	0,047	27,236	3,09	-1	0,0306
Q21A	12	23,723	4,309	0,74	28,772	3,26	-1	0

	12 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_ dim**	**total_% of time**	**trend**	**p**
Q22A	12	23,398	7,415	0,283	31,096	3,53	-1	0,0013
Q30A	12	25,456	5,864	0,424	31,744	3,6	-1	0
Q30B	12	25,11	5,958	0,388	31,456	3,57	-1	0
Q50A	12	19,755	5,051	0,347	25,153	2,85	1	0,5949
Q50B	12	24,462	7,143	0,951	32,556	3,69	-1	0,0015
Q50C	12	26,888	9,08	1,549	37,517	4,25	1	0,0604
Q60B	12	22,859	6,008	0,201	29,068	3,3	1	0,0022
Q60C	12	23,974	5,671	0,012	29,657	3,36	1	0,8273
Q70A	12	24,199	5,708	0	29,907	3,39	1	0,9597
Q70B	12	26,146	9,199	1,517	36,862	4,18	1	0,1006
Q70C	12	24,402	7,053	0,977	32,432	3,68	-1	0
Q80A	12	25,966	8,305	0	34,271	3,89	-1	0,0178
Q80B	12	25,788	8,25	0	34,038	3,86	-1	0,0291
Q80C	12	26,042	7,266	0	33,308	3,78	-1	0,0863
Q80D	12	24,893	5,91	0,216	31,019	3,52	1	0,2407
Q80E	12	23,564	3,312	0	26,876	3,05	1	0
Q80F	12	23,169	3,959	0,022	27,15	3,08	1	0
Q80G	12	24,565	7,185	0,947	32,697	3,71	-1	0
Q91A	12	21,526	4,56	0,198	26,284	2,98	1	0,0091
Q91B	12	17,551	2,475	0,123	20,149	2,28	1	0
Q91C	12	24,1	6,618	0,377	31,095	3,53	1	0,3975
Q92C	12	23,156	6,408	1,631	31,195	3,54	-1	0,6657
Q92E	12	22,605	6,819	1,551	30,975	3,51	1	0,335
Q92F	12	22,49	3,815	0,005	26,31	2,98	1	0,0205
Q92G	12	22,24	7,067	1,472	30,779	3,49	1	0,555
Q93A	12	28,957	8,427	0,396	37,78	4,28	-1	0
Q93B	12	28,697	8,53	0,564	37,791	4,28	-1	0
Q93C	12	25,022	7,676	0,068	32,766	3,71	1	0,0168
Q93D	12	24,154	6,367	0,794	31,315	3,55	-1	0,227
S20A	12	28,546	6,576	0,515	35,637	4,04	-1	0,8848
S20B	12	26,393	8,363	2,967	37,723	4,28	1	0,7424
T11G	12	24,78	7,575	1,824	34,179	3,88	-1	0,532
T11H	12	23,622	7,74	2,706	34,068	3,86	1	0,1807
T13A	12	23,202	7,551	2,767	33,52	3,8	1	0,1443
T13B	12	23,008	7,755	2,763	33,526	3,8	1	0,2009
T13C	12	26,951	7,821	1,195	35,967	4,08	-1	0,0296
T13D	12	24	5,472	0,169	29,641	3,36	-1	0,1242
T20A	12	29,607	10,602	1,053	41,262	4,68	1	0,0046
T20B	12	25,604	9,42	2,885	37,909	4,3	1	0,2422
T20C	12	26,576	7,711	0,296	34,583	3,92	-1	0,4473
T20D	12	26,399	7,965	0,176	34,54	3,92	-1	0,4987
T20E	12	23,005	10,464	2,524	35,993	4,08	-1	0,016

	12 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_ dim**	**total_% of time**	**trend**	**p**
T20F	12	27,197	8,862	0,584	36,643	4,15	-1	0
T20G	12	26,687	8,837	1,694	37,218	4,22	-1	0,0002
T32G	12	25,814	9,751	1,972	37,537	4,26	1	0,0709
T32H	12	27,23	10,006	0,793	38,029	4,31	-1	0,2116
T33C	12	23,641	7,373	1,021	32,035	3,63	-1	0
T33K	12	25,812	10,021	0,987	36,82	4,17	-1	0,4236
T34A	12	21,087	7,276	1,766	30,129	3,42	-1	0
T34B	12	27,48	9,32	1,423	38,223	4,33	-1	0
T34C	12	27,717	9,319	1,343	38,379	4,35	-1	0
T34D	12	27,149	9,889	1,673	38,711	4,39	-1	0
T34E	12	19,539	7,176	1,599	28,314	3,21	-1	0
T34F	12	27,347	9,551	1,457	38,355	4,35	-1	0
T34G	12	26,775	5,574	0,997	33,346	3,78	-1	0,1676
T34H	12	23,204	10,777	2,118	36,099	4,09	-1	0,0001
T34J	12	31,093	5,993	0,287	37,373	4,24	1	0,0004
T34K	12	24,304	6,97	1,315	32,589	3,69	1	0,0001
T35A	12	22,594	4,618	0,364	27,576	3,13	1	0
T35B	12	28,656	8,582	0,84	38,078	4,32	-1	0,8767
T35C	12	28,623	8,966	0,892	38,481	4,36	-1	0,7048
T35D	12	28,533	8,998	0,876	38,407	4,35	-1	0,7395
T35E	12	26,548	8,138	1,297	35,983	4,08	-1	0,0338
T35F	12	25,55	9,611	1,574	36,735	4,16	1	0,0017
T35G	12	25,929	5,566	0,994	32,489	3,68	1	0,0199
T35H	12	25,687	9,276	1,41	36,373	4,12	1	0,2268
T35J	12	26,359	8,322	1,286	35,967	4,08	-1	0,0045
T35K	12	21,622	6,704	3,164	31,49	3,57	1	0,959
T35L	12	23,667	7,36	1,365	32,392	3,67	1	0,0001
T35M	12	24,363	6,873	1,255	32,491	3,68	1	0,0001
T36A	12	26,119	5,008	0,689	31,816	3,61	-1	0,1859
T36B	12	28,555	9,599	2,042	40,196	4,56	-1	0
T60B	12	26,934	9,455	0,664	37,053	4,2	-1	0,0775
T60C	12	26,348	9,066	0,579	35,993	4,08	-1	0,1764
T60D	12	24,676	10,138	1,487	36,301	4,12	1	0,0096
T60E	12	25,976	8,24	0,407	34,623	3,93	-1	0,1715
T60F	12	21,603	7,739	1,739	31,081	3,52	1	0,1358
T60G	12	24,807	10,064	1,527	36,398	4,13	1	0,0076
T60H	12	22,894	6,917	1,519	31,33	3,55	-1	0,8624
T60J	12	20,728	7,862	1,564	30,154	3,42	-1	0,8597
T60K	12	28,748	9,604	2,198	40,55	4,6	-1	0
T70A	12	26,217	4,887	0,666	31,77	3,6	-1	0,2008
T70B	12	28,933	8,998	2,355	40,286	4,57	-1	0
T70C	12	24,396	8,642	0,455	33,493	3,8	1	0,9741

	12 MONTHS							
quad	period	moderate_dim	extreme_dim	severe_dim	total_ dim	total_% of time	trend	p
T70D	12	24,43	8,643	0,465	33,538	3,8	-1	0,8619
T70E	12	27,044	5,042	0,623	32,709	3,71	-1	0,0903
T70F	12	24,653	8,526	0,396	33,575	3,81	1	0,9722
T70G	12	24,643	8,343	0,47	33,456	3,79	1	0,6902
T80A	12	27,557	8,501	1,872	37,93	4,3	-1	0,0003
T80B	12	27,212	8,536	1,736	37,484	4,25	-1	0,0004
T80C	12	25,141	5,013	0,143	30,297	3,44	-1	0,1089
Mean	**12**	**24,644**	**6,749**	**0,769**	**32,163**	**3,646**	**-0,325**	**0,169**
Med	**12**	**24,784**	**6,895**	**0,543**	**32,133**	**3,645**	**-1**	**0,0099**
Max	**12**	**31,093**	**10,777**	**3,164**	**41,262**	**4,68**	**1**	**0,9741**
Min	**12**	**17,551**	**0,751**	**0**	**20,149**	**2,28**	**-1**	**0**
St Dev	**0**	**2,3784**	**1,958**	**0,722**	**3,982**	**0,451**	**0,947**	**0,2782**

Table 4A.6: 24-month SPEI analysis

	24 MONTHS							
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
D12A	24	24,694	4,017	0,004	28,715	3,32	-1	0,0083
D12B	24	24,911	4,263	0	29,174	3,38	-1	0,009
D12C	24	23,881	3,777	0	27,658	3,2	-1	0,0047
D12E	24	24,845	6,538	0,533	31,916	3,69	-1	0
D12F	24	25,884	4,012	0,01	29,906	3,46	-1	0,1425
D13A	24	22,908	8,642	0,033	31,583	3,66	-1	0,0005
D13B	24	24,457	4,193	0,049	28,699	3,32	1	0,9771
D13C	24	12,366	0,807	0	13,173	1,52	1	0
D13D	24	22,981	10,907	1,202	35,09	4,06	1	0
D13E	24	23,593	7,417	0,187	31,197	3,61	-1	0,7569
D13F	24	22,435	10,705	1,201	34,341	3,97	1	0,0001
D13G	24	22,616	9,552	0,664	32,832	3,8	-1	0,032
D13H	24	21,187	5,943	0,428	27,558	3,19	1	0
D13J	24	23,059	5,749	0	28,808	3,33	1	0,4064
D13K	24	17,433	3,713	0,064	21,21	2,45	-1	0
D13L	24	21,317	5,483	0,311	27,111	3,14	-1	0,7207
D13M	24	25,546	3,631	0	29,177	3,38	-1	0,0925
D14A	24	19,057	6,27	0,598	25,925	3	-1	0,1798
D14C	24	26,008	5,962	0,302	32,272	3,74	1	0
D14D	24	26,622	8,85	1,846	37,318	4,32	-1	0
D14E	24	19,618	2,161	0	21,779	2,52	1	0
D14F	24	20,504	2,551	0	23,055	2,67	1	0
D14G	24	28,145	7,259	0,399	35,803	4,14	1	0,0587

	24 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_dim**	**total_% of time**	**trend**	**p**
D14H	24	28,473	6,56	0,222	35,255	4,08	1	0,0485
D14J	24	21,54	3,648	0	25,188	2,92	-1	0,1038
D14K	24	24,103	3,526	0,08	27,709	3,21	1	0,0008
D18K	24	21,667	1,971	0	23,638	2,74	-1	0,0007
D18L	24	27,859	6,325	1,286	35,47	4,11	1	0,9159
D32A	24	22,085	2,959	0,077	25,121	2,91	1	0
D32B	24	21,185	6,267	0,474	27,926	3,23	-1	0,0006
D34A	24	23,679	6,165	0,958	30,802	3,57	-1	0,4642
D35B	24	21,41	5,253	0,404	27,067	3,13	-1	0
D35C	24	26,114	7,402	0,493	34,009	3,94	1	0,8124
D35D	24	23,908	6,094	0,878	30,88	3,57	-1	0,0302
D35E	24	23,972	2,981	0,111	27,064	3,13	1	0,4016
D35G	24	22,98	2,7	0,062	25,742	2,98	1	0,2604
D35H	24	21,423	4,372	0,089	25,884	3	-1	0
D35J	24	24,003	9,463	0,971	34,437	3,99	1	0
D35K	24	20,674	4,163	0,254	25,091	2,9	-1	0,1538
J31A	24	19,116	6,777	0,921	26,814	3,1	1	0
J31C	24	19,336	7,153	0,968	27,457	3,18	1	0
J32B	24	24,523	9,335	2,224	36,082	4,18	1	0
J32C	24	24,504	9,427	2,269	36,2	4,19	1	0
J32D	24	21,445	4,343	0	25,788	2,98	1	0
J32E	24	21,035	4,162	0	25,197	2,92	1	0
J33A	24	20,203	5,62	2,33	28,153	3,26	1	0
K80A	24	27,253	7,432	0,8	35,485	4,11	-1	0,0006
K80B	24	27,74	9,49	2,276	39,506	4,57	-1	0,0006
K80C	24	27,747	7,71	1,255	36,712	4,25	-1	0
K80D	24	27,313	7,81	0,677	35,8	4,14	-1	0
K80E	24	28,65	10,018	0,633	39,301	4,55	-1	0
K80F	24	28,7	6,267	0,013	34,98	4,05	-1	0
K90A	24	26,629	7,067	0,264	33,96	3,93	-1	0
K90B	24	29,134	10,399	2,628	42,161	4,88	-1	0,0004
K90C	24	29,116	10,361	2,663	42,14	4,88	-1	0,0006
K90D	24	26,295	6,61	0	32,905	3,81	-1	0
K90E	24	28,271	7,736	0,402	36,409	4,21	-1	0
K90F	24	26,787	6,268	0,025	33,08	3,83	-1	0
K90G	24	27,304	6,138	0,083	33,525	3,88	-1	0
L12C	24	20,814	5,917	0,172	26,903	3,11	1	0
L12D	24	20,072	5,968	0,137	26,177	3,03	1	0
L22B	24	23,85	3,602	0,11	27,562	3,19	-1	0,8733
L22C	24	16,356	3,228	0	19,584	2,27	1	0,6857
L22D	24	20,388	3,956	0,739	25,083	2,9	-1	0,0997
L23A	24	20,926	2,24	0	23,166	2,68	1	0,052

	24 MONTHS							
quad	period	moderate_dim	extreme_dim	severe_dim	total_dim	total_% of time	trend	p
L23B	24	20,527	3,895	0,941	25,363	2,94	-1	0,3204
L23C	24	19,228	4,208	0,05	23,486	2,72	1	0,0498
L23D	24	21,147	4,535	0,952	26,634	3,08	-1	0
L30A	24	22,613	5,979	0,109	28,701	3,32	-1	0,8365
L30B	24	22,542	6,139	0,137	28,818	3,34	-1	0,8498
L30C	24	21,437	4,489	0,847	26,773	3,1	-1	0
L30D	24	25,083	4,002	0,056	29,141	3,37	1	0
L40A	24	20,874	4,04	0,028	24,942	2,89	-1	0
L40B	24	25,582	4,182	0,016	29,78	3,45	1	0
L50A	24	25,614	9,071	0,918	35,603	4,12	1	0,0048
L50B	24	26,763	2,703	0	29,466	3,41	1	0
L60A	24	24,88	3,478	0,298	28,656	3,32	-1	0,3552
L60B	24	25,029	3,393	0,231	28,653	3,32	-1	0,1321
L70A	24	25,281	5,919	0,68	31,88	3,69	-1	0,0254
L70B	24	24,641	6,106	0,634	31,381	3,63	1	0,5544
L70C	24	24,402	6,525	0,801	31,728	3,67	1	0,2163
L70D	24	25,295	3,612	0	28,907	3,35	-1	0,1042
L70E	24	25,128	4,865	0	29,993	3,47	-1	0,017
L70F	24	25,407	4,848	0,088	30,343	3,51	1	0,2472
L70G	24	31,004	7,118	0,113	38,235	4,43	1	0,0102
L81A	24	26,22	7,497	2,351	36,068	4,17	1	0,1005
L81B	24	24,213	8,249	0,153	32,615	3,77	-1	0
L81C	24	24,24	7,957	0,151	32,348	3,74	-1	0
L81D	24	24,417	5,825	0,495	30,737	3,56	-1	0,0003
L82B	24	24,407	6,575	1,939	32,921	3,81	1	0
L82C	24	26,275	7,159	2,42	35,854	4,15	1	0,5625
L82D	24	27,771	7,078	0	34,849	4,03	-1	0
L82E	24	25,786	5,455	0,133	31,374	3,63	-1	0
L82F	24	21,064	5,663	0,666	27,393	3,17	-1	0
L82G	24	26,443	5,171	0,162	31,776	3,68	-1	0
L82H	24	26,214	5,51	0,044	31,768	3,68	-1	0,0001
L82J	24	28,156	6,657	0,031	34,844	4,03	-1	0
L90A	24	31,162	7,536	0,08	38,778	4,49	1	0,0204
L90B	24	21,716	4,114	0,433	26,263	3,04	1	0,3709
L90C	24	22,114	8,091	0,915	31,12	3,6	-1	0,0001
M10A	24	23,203	9,85	1,168	34,221	3,96	1	0,84
M10B	24	24,8	7,638	1,434	33,872	3,92	-1	0,6751
M10C	24	23,235	8,825	1,883	33,943	3,93	-1	0,8452
M10D	24	24,618	7,117	0,097	31,832	3,68	-1	0
M20A	24	23,539	5,967	0,7	30,206	3,5	-1	0
M20B	24	27,385	10,521	1,701	39,607	4,58	1	0,0739
M30A	24	22,686	7,735	0,331	30,752	3,56	-1	0,0002

	24 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_dim**	**total_% of time**	**trend**	**p**
M30B	24	24,241	6,973	0,03	31,244	3,62	-1	0
N11A	24	24,117	7,496	0,283	31,896	3,69	-1	0,0051
N11B	24	22,239	6,294	0,232	28,765	3,33	-1	0
N12A	24	20,208	7,055	0	27,263	3,16	-1	0
N12B	24	19,903	6,755	0	26,658	3,09	-1	0
N12C	24	27,458	6,226	0,837	34,521	4	-1	0,7278
N13A	24	21,067	10,309	2,794	34,17	3,95	-1	0,0621
N13B	24	20,574	10,21	2,808	33,592	3,89	-1	0,0671
N13C	24	24,313	5,1	0	29,413	3,4	-1	0,0002
N14A	24	21,817	8,298	2,381	32,496	3,76	1	0,3023
N14B	24	22,325	9,509	2,435	34,269	3,97	-1	0,1094
N14C	24	23,229	8,067	0,379	31,675	3,67	-1	0
N14D	24	24,114	4,714	0	28,828	3,34	-1	0,0002
N21A	24	24,027	4,707	0	28,734	3,33	-1	0,0002
N21B	24	23,611	10,044	1,033	34,688	4,01	-1	0
N21C	24	22,075	3,624	0	25,699	2,97	-1	0,0758
N21D	24	24,437	5,301	0	29,738	3,44	-1	0,0001
N22A	24	21,648	3,619	0	25,267	2,92	-1	0,1687
N22B	24	22,879	6,271	0,936	30,086	3,48	-1	0,0501
N22C	24	22,261	2,257	0	24,518	2,84	1	0
N22D	24	20,367	0,438	0	20,805	2,41	1	0
N22E	24	18,965	2,524	0	21,489	2,49	1	0
N23A	24	21,437	2,555	0	23,992	2,78	1	0,0001
N23B	24	19,921	3,964	0	23,885	2,76	1	0
N24A	24	20,216	3,594	0,032	23,842	2,76	-1	0
N24B	24	23,493	4,212	0	27,705	3,21	-1	0,0536
N24C	24	22,977	4,546	0,024	27,547	3,19	-1	0,1735
N24D	24	21,437	2,591	0,213	24,241	2,81	-1	0,8332
N30A	24	27,229	6,551	0,544	34,324	3,97	-1	0
N30B	24	20,829	4,063	0,184	25,076	2,9	1	0,0145
N30C	24	22,801	0,659	0	23,46	2,72	1	0
N40A	24	20,072	2,698	0	22,77	2,64	1	0
N40B	24	24,436	5,929	0,018	30,383	3,52	-1	0,4789
N40C	24	21,49	6,196	0,53	28,216	3,27	-1	0,2013
N40D	24	32,399	3,115	0	35,514	4,11	1	0
N40E	24	31,662	4,458	0	36,12	4,18	1	0
N40F	24	29,105	5,742	0	34,847	4,03	1	0
P10A	24	20,687	5,956	0,588	27,231	3,15	1	0,0004
P10B	24	28,131	8,474	1,62	38,225	4,42	-1	0
P10C	24	21,385	5,071	0,292	26,748	3,1	-1	0,163
P10D	24	24,627	5,736	0,194	30,557	3,54	1	0,6742
P10E	24	24,266	6,236	0,321	30,823	3,57	1	0,9755

	24 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_dim**	**total_% of time**	**trend**	**p**
P10F	24	27,322	8,556	3,279	39,157	4,53	-1	0,0029
P10G	24	27,14	6,288	0,073	33,501	3,88	-1	0,029
P20A	24	28,034	7,233	1,185	36,452	4,22	-1	0
P20B	24	26,963	8,857	1,056	36,876	4,27	-1	0,0002
P30A	24	28,345	8,359	1,09	37,794	4,37	-1	0
P30B	24	26,683	8,346	3,167	38,196	4,42	-1	0,0005
P30C	24	24,946	5,36	0,528	30,834	3,57	-1	0
P40A	24	20,067	6,973	0,552	27,592	3,19	1	0,0083
P40B	24	23,729	3,43	0,066	27,225	3,15	-1	0,0553
P40C	24	24,054	2,994	0,06	27,108	3,14	-1	0,2008
P40D	24	22,484	7,133	0,656	30,273	3,5	-1	0
Q11A	24	25,533	6,187	0,526	32,246	3,73	-1	0
Q11B	24	27,909	6,42	0,338	34,667	4,01	-1	0,0661
Q12A	24	25,362	7,417	0,597	33,376	3,86	1	0
Q12B	24	25,022	8,222	0,649	33,893	3,92	1	0
Q12C	24	26,98	6,717	1,079	34,776	4,02	1	0,9929
Q14A	24	22,047	7,614	0,966	30,627	3,54	-1	0,0256
Q21A	24	23,419	1,225	0	24,644	2,85	-1	0
Q22A	24	21,391	4,976	0	26,367	3,05	-1	0
Q30A	24	22,097	4,326	0,711	27,134	3,14	-1	0
Q30B	24	23,52	3,718	0,757	27,995	3,24	-1	0
Q50A	24	19,61	5,041	0,222	24,873	2,88	1	0,0182
Q50B	24	24,014	4,112	0,254	28,38	3,28	-1	0
Q50C	24	25,61	9,634	1,231	36,475	4,22	1	0,0059
Q60B	24	24,228	6,757	0,213	31,198	3,61	1	0
Q60C	24	25,984	8,071	0,185	34,24	3,96	1	0,631
Q70A	24	26,062	7,933	0,143	34,138	3,95	1	0,8248
Q70B	24	25,558	9,681	1,322	36,561	4,23	1	0,02
Q70C	24	25,939	8,78	1,776	36,495	4,22	-1	0
Q80A	24	25,836	8,546	0,352	34,734	4,02	-1	0,0091
Q80B	24	25,876	8,572	0,284	34,732	4,02	-1	0,0198
Q80C	24	26,219	8,904	0,301	35,424	4,1	-1	0,0924
Q80D	24	22,595	5,767	0,491	28,853	3,34	1	0,0276
Q80E	24	21,135	3,913	0,055	25,103	2,91	1	0
Q80F	24	21,476	4,149	0,057	25,682	2,97	1	0
Q80G	24	25,977	8,766	1,653	36,396	4,21	-1	0
Q91A	24	26,139	6,246	0,344	32,729	3,79	1	0
Q91B	24	10,391	0,527	0	10,918	1,26	1	0
Q91C	24	19,526	4,391	0,156	24,073	2,79	1	0,1942
Q92C	24	21,672	8,13	1,415	31,217	3,61	-1	0,5608
Q92E	24	22,408	7,159	1,178	30,745	3,56	1	0,2066
Q92F	24	27,4	6,663	0,176	34,239	3,96	1	0,0004

	24 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_dim**	**total_% of time**	**trend**	**p**
Q92G	24	22,133	6,221	1,051	29,405	3,4	1	0,4687
Q93A	24	26,898	8,886	0,153	35,937	4,16	-1	0
Q93B	24	26,835	9,328	0,122	36,285	4,2	-1	0
Q93C	24	25,411	5,332	0,409	31,152	3,61	1	0
Q93D	24	27,932	5,231	0	33,163	3,84	-1	0,592
S20A	24	30,119	4,192	0	34,311	3,97	1	0,5711
S20B	24	23,796	7,092	1,624	32,512	3,76	1	0,0689
T11G	24	26,183	6,555	1,264	34,002	3,94	-1	0,878
T11H	24	27,289	10,05	1,212	38,551	4,46	1	0,0132
T13A	24	27,355	10,044	1,087	38,486	4,45	1	0,0078
T13B	24	27,323	9,949	1,159	38,431	4,45	1	0,0125
T13C	24	27,855	8,602	2,989	39,446	4,57	-1	0,0157
T13D	24	24,264	2,745	0	27,009	3,13	-1	0,1692
T20A	24	27,435	8,603	1,619	37,657	4,36	1	0,0003
T20B	24	28,292	9,227	0,003	37,522	4,34	1	0,0734
T20C	24	29,765	5,503	0,131	35,399	4,1	-1	0,7159
T20D	24	30,312	5,701	0,103	36,116	4,18	-1	0,7581
T20E	24	26,695	11,806	0,003	38,504	4,46	-1	0,0035
T20F	24	24,918	9,688	0,899	35,505	4,11	-1	0
T20G	24	24,901	9,877	0,902	35,68	4,13	-1	0
T32G	24	21,181	8,641	0,582	30,404	3,52	1	0,0035
T32H	24	26,922	5,958	0,262	33,142	3,84	-1	0,5538
T33C	24	21,167	3,762	0	24,929	2,89	-1	0
T33K	24	26,78	7,148	0,032	33,96	3,93	1	0,8822
T34A	24	24,152	7,29	1,405	32,847	3,8	-1	0
T34B	24	25,304	8,185	1,302	34,791	4,03	-1	0
T34C	24	25,423	8,176	1,255	34,854	4,03	-1	0
T34D	24	25,34	8,257	1,963	35,56	4,12	-1	0
T34E	24	23,132	6,558	1,008	30,698	3,55	-1	0
T34F	24	25,36	7,926	1,718	35,004	4,05	-1	0
T34G	24	28,546	5,565	0,404	34,515	3,99	-1	0,3636
T34H	24	26,665	8,119	0,654	35,438	4,1	-1	0
T34J	24	30,711	10,034	0,221	40,966	4,74	1	0
T34K	24	27,001	7,039	0,492	34,532	4	1	0
T35A	24	27,81	2,14	0	29,95	3,47	1	0
T35B	24	25,234	9,773	1,758	36,765	4,26	1	0,6152
T35C	24	25,231	9,784	1,839	36,854	4,27	1	0,8523
T35D	24	25,394	9,842	1,77	37,006	4,28	1	0,7673
T35E	24	25,382	9,614	1,191	36,187	4,19	-1	0,0172
T35F	24	26,237	9,531	3,224	38,992	4,51	1	0,0001
T35G	24	27,915	7,613	0,319	35,847	4,15	1	0,0002
T35H	24	27,369	9,807	0,075	37,251	4,31	1	0,0631

	24 MONTHS							
quad	**period**	**moderate_dim**	**extreme_dim**	**severe_dim**	**total_dim**	**total_% of time**	**trend**	**p**
T35J	24	25,459	9,709	1,389	36,557	4,23	-1	0,0004
T35K	24	26,071	7,195	0,695	33,961	3,93	1	0,3512
T35L	24	27,72	7,7	0,786	36,206	4,19	1	0
T35M	24	27,343	7,442	0,489	35,274	4,08	1	0
T36A	24	27,932	6,129	0,162	34,223	3,96	-1	0,4349
T36B	24	29,522	10,014	0,747	40,283	4,66	-1	0
T60B	24	25,892	6,066	0,113	32,071	3,71	-1	0,2179
T60C	24	24,315	6,103	0,068	30,486	3,53	-1	0,5817
T60D	24	28,63	9,984	2,143	40,757	4,72	1	0,0001
T60E	24	24,184	7,451	0,508	32,143	3,72	-1	0,4829
T60F	24	23,399	9,042	3,237	35,678	4,13	1	0,0075
T60G	24	28,567	9,986	2,191	40,744	4,72	1	0,0001
T60H	24	20,051	6,958	1,942	28,951	3,35	1	0,3123
T60J	24	20,174	7,021	2,103	29,298	3,39	1	0,4132
T60K	24	29,712	9,655	0,545	39,912	4,62	-1	0
T70A	24	28,377	6,105	0,146	34,628	4,01	-1	0,4934
T70B	24	29,521	9,371	0,272	39,164	4,53	-1	0
T70C	24	24,048	4,424	0	28,472	3,3	1	0,3654
T70D	24	24,207	4,267	0	28,474	3,3	1	0,459
T70E	24	27,926	5,863	0,117	33,906	3,92	-1	0,1377
T70F	24	23,762	3,878	0	27,64	3,2	1	0,2994
T70G	24	23,445	4,699	0,018	28,162	3,26	1	0,1317
T80A	24	24,317	9,561	1,593	35,471	4,11	-1	0
T80B	24	24,066	9,611	1,256	34,933	4,04	-1	0
T80C	24	21,852	1,593	0	23,445	2,71	-1	0,1657
Mean	**24**	**24,420**	**6,387**	**0,637**	**31,445**	**3,639**	**-0,147**	**0,147**
Med	**24**	**24,436**	**6,279**	**0,306**	**31,772**	**3,68**	**-1**	**0,0005**
Max	**24**	**32,399**	**11,806**	**3,279**	**42,161**	**4,88**	**1**	**0,9929**
Min	**24**	**10,391**	**0,438**	**0**	**10,918**	**1,26**	**-1**	**0**
St Dev	**0**	**3,1195**	**2,3676**	**0,7733**	**5,0084**	**0,5794**	**0,991**	**0,2619**

Annexure 4 B: Internet Application for Disaster Risk Reduction

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1.1 Rationale

Primary condition for successful disaster risk reduction is availability of the adequate data and information, when needed and where needed. At all level of governance, most of the disaster risk reduction activities are related to horizontal and vertical coordination. Data and information are the primary "food" for the coordination.

Internet (Web) has become a data and information communication standard. Text, images, and videos are distributed globally via the Internet. On top of that, Internet has become a standard for applications distribution. That was the main reason why the Internet was chosen as the disaster risk reduction information distribution platform. Users can easily link to various information sources and extract alpha-numeric and graphical information from any web page of the application.

Main rationale behind this application was to have a tool, which can enable continuous spatial and temporal disaster risk assessment and monitoring for Eastern Cape. Risk is a function of many parameters, and the most significant are hazard, vulnerability, exposure, coping capacity and resilience.

Continuous risk assessment requires continuous monitoring and assessment of those major input parameters, spatially and temporarily.

The basic principles behind this web application were to link to existing web information where available, and to develop all those not available for this particular purpose.

The web address of the application is: http://dimtecrisk.ufs.ac.za/wrc_ec/

1.2 Input Data

Assessments of hazard, vulnerability and other risk parameters require calculation of various indicators and/or indices. For all those indicators input data are required. For some of them input data are freely available and accessible via Internet. For others, input data are not freely available and significant amount of funds are required to be able to have a continuous access to those data.

Meteorological data is the major data source for hazard related indicator calculations. For a limited number of stations in the Eastern Cape, meteo data are freely available from international data sources, and those data are updated continuously, on monthly basis.

Water Resources 2000 (WR2000, Water Research Commission) data was the major data source for the calculation of a historical spatial and temporal distribution of hazard related indicators, such as rainfall trends or the SPEI.

Unfortunately WR2000 data time span is January 1950 - December 1999. Presently, there is an initiative to extend those data. When data extension is available, it will be included into this Web application.

1.3 Application Components

The existing web application is an independent operating system. It can run on any operating system such as Microsoft Windows, Linux or Mac OS. At present, the application is installed on the Microsoft Windows Server.

Two major application components are a relational database and an imbedded mathematical language. The relational database (presently MS SQL Server, http://www.microsoft.com) contains all relevant time series data, such as rainfall, temperature and evaporation. It is a safe and convenient way to manage large amounts of time series data.

All analyses and visualization are done on the fly. There is not a single index pre-calculated. It would not have been possible to do this using any of the existing conventional web development languages. This application uses an imbedded mathematical language *Mathematica* (http://www.wolfram.com).

1.4 Frame-Based Menu

The Internet application is a frame based one. The top frame (Figure 4B.1) contains main menu items, such as RAINFALL, TEMPERATURE, etc. Selecting any of those main menu items will open a left-side content menu. As the Internet application grows, the number of top main menu items will increase.

SPEI | RAINFALL | TEMPERATURE | EVAPORATION

Fig. 4B.1: The main (Top) menu

The left menu consists of main topics (all in upper case) and sub-topics. If the main topic content is closed, it shows a “+” sign before the topic title (e.g. “+SPEI”). Once selected, the content of the main topic will open, showing its sub-content, and having a “-” sign in front (e.g. “-SPEI”). If any of the sub-content items starts with the “+” sign, it indicates them having a sub-sub-content.

1.4.1 SPEI (Standardized Precipitation and Evaporation Index)

The Standardized Precipitation and Evaporation Index is becoming one of the most accepted drought related indicators. It is a "*newer / extended*" version of the Standardized Precipitation Index (SPI). The mathematical model (calculation) is the same as that of the SPI. A major difference is that input data for the SPI is a monthly rainfall, and for the SPEI it is the difference between rainfall and evaporation. Most authors state that the SPEI is "more realistic" by taking evaporation into account.

Figure 4B.2 shows a SPEI Legend, separating Wet, Near Normal and Dry periods.

SPEI Values						
-2.0 and less	-1.99 to -1.5	-1.49 to -1.0	-0.99 to 0.99	1.0 to 1.49	1.5 to 1.99	2.0+
extremely dry	severely dry	moderately dry	near normal	moderately wet	very vet	extremely wet

Fig. 4B.2: Example of a SPEI legend

Table 4B.1 is a summary of the left frame content that shows some of the different maps obtainable from this section. The different maps are developed “*on the fly*” for different selected months.

Table 4B.1: The SPEI left frame content

Left Frame Menu Item	Description	Figure
- Spatial		
O.R. Tambo	O.R. Tambo District Municipality SPEI spatial distribution for the selected period, Year and Month	5.3
Cacadu	Cacadu District Municipality SPEI spatial distribution for the selected period, Year and Month	5.4
Joe Gqabi	Joe Gqabi District Municipality SPEI spatial distribution for the selected period, Year and Month	5.5
Temporal	SPEI temporal distribution for selected Quaternary Catchment (Quad) and period	5.6
Probability	Probability of SPEI being below selected value (period)	5.7

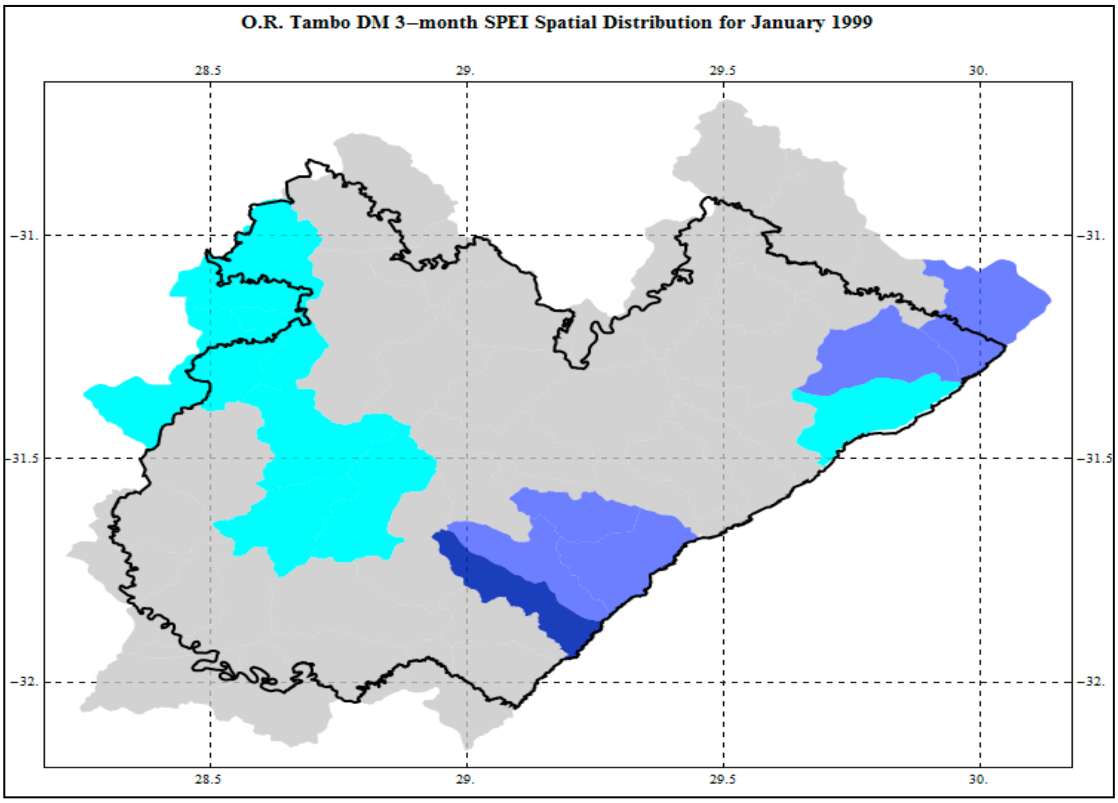


Fig. 4B.3: Example of an OR Tambo DM 3-month SPEI spatial distribution

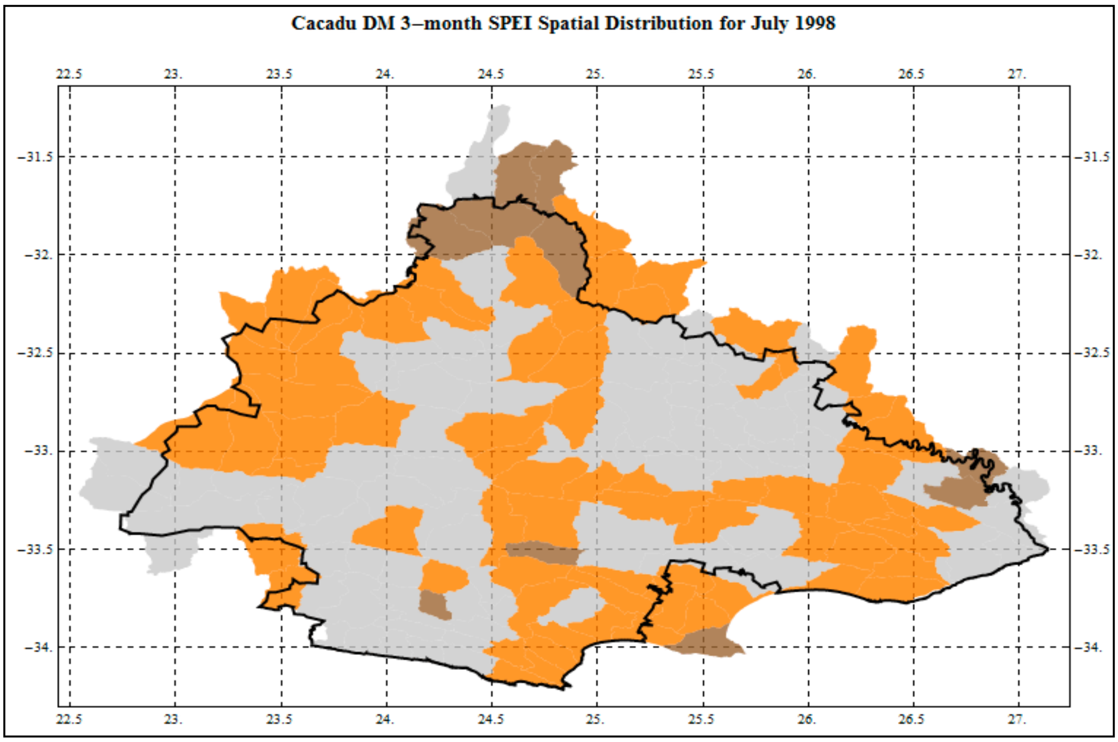


Fig. 4B.4: An example of a Cacadu DM 3-month SPEI spatial distribution

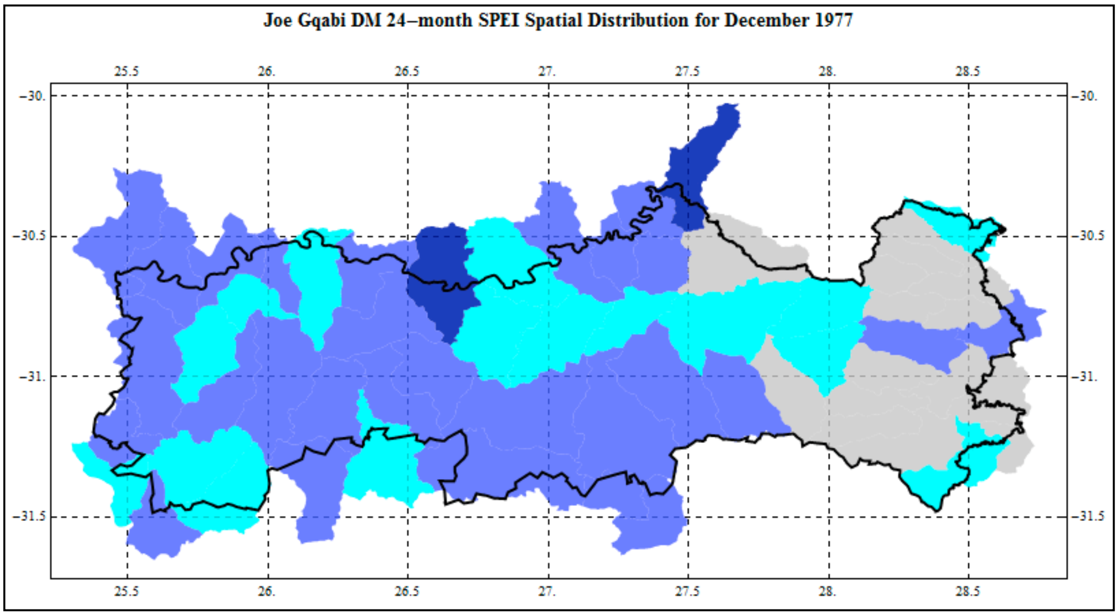
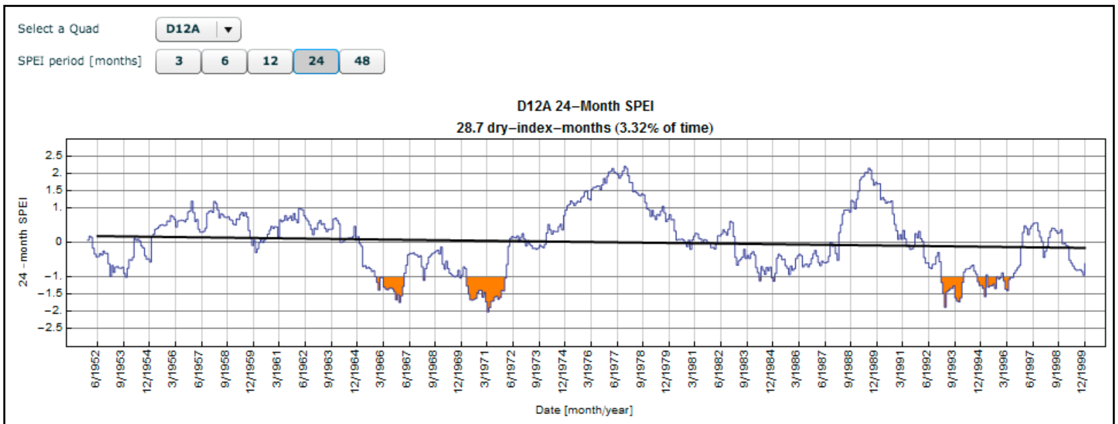


Fig. 4B.5: Example of a Joe Gqabi DM 24-month SPEI spatial distribution



Indicative linear trend: 0.183857 - 0.000589439 x , p-Value=0.0083

Dates	{Dec 1966, Jan 1967}	{May 1970, Aug 1970}	{Feb 1971, Oct 1971}	{Sep 1993, Dec 1993}
Duration	2	4	9	4
Intensity	1.64	1.65	1.71	1.65
Severity	3.28	6.6	15.39	6.6

Note:
- Dry period duration (in months) is the total number of consecutive months of SPI having value of -1.5 and below.
- Dry period intensity is the average value of all SPIs having value of -1.5 and below, for the duration of dry period.
- Dry period severity = duration * intensity.

Fig. 4B.6: Example of a D21A quaternary catchment 24-month SPEI temporal distribution

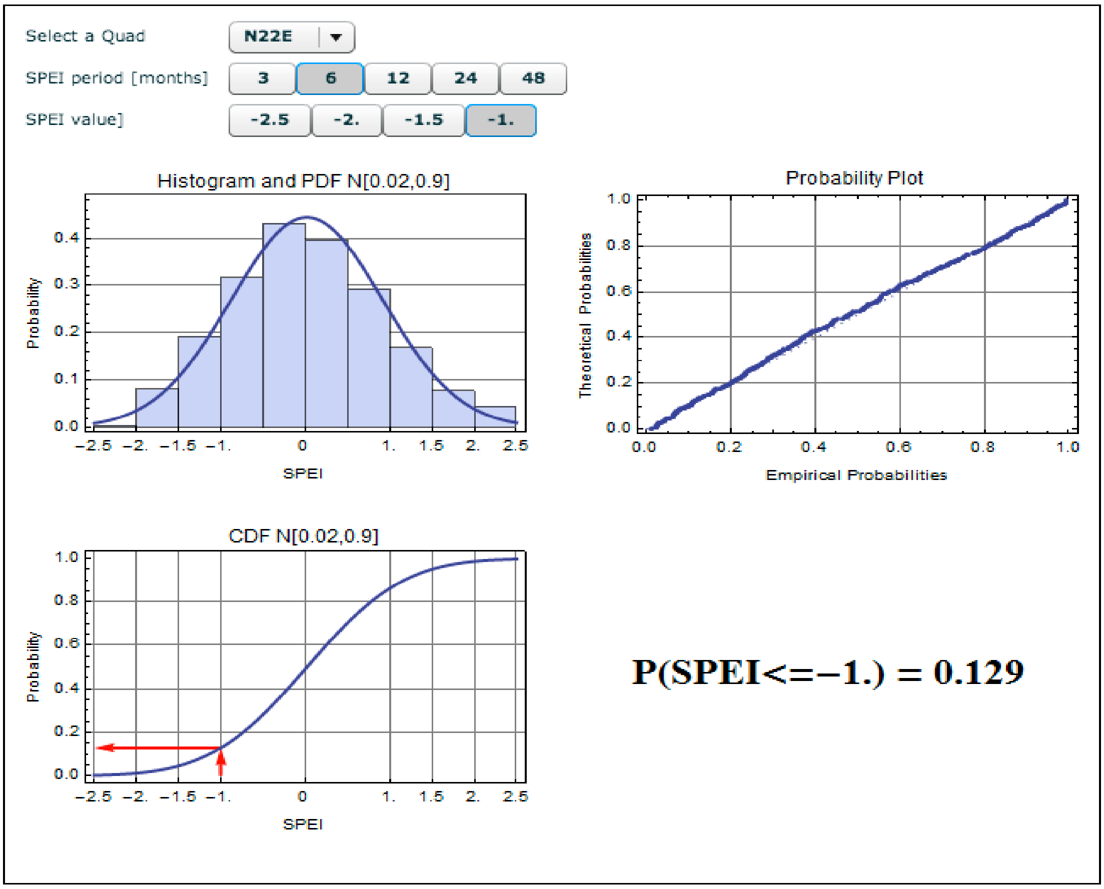


Fig. 4B.7: Example of a N22E quaternary catchment 6-month rainfall probability distribution

1.4.2 Rainfall Menu

The Rainfall Menu consists of two major sections, namely, the:

- Annual sub-menu, and the
- Monthly sub-menu.

Table 4B.2: The Rainfall sub-menu content

Left Frame Menu Item	Description	Figure
- QUAD ANNUAL		
- Spatial		
O.R. Tambo	O.R. Tambo DM annual rainfall spatial distribution for selected year	4B.9
Cacadu	Cacadu DM annual rainfall spatial distribution for selected year	4B.10
Joe Gqabi	Joe Gqabi DM annual rainfall spatial distribution for selected year	4B.11
- Temporal		
Linear Trend	Linear trend (annual rainfall and number of rainy days) for selected quad for total timeframe	4B.12
Partial Trend	Partial trend f(annual rainfall and number of rainy days) or selected quad and time interval	4B.13
Moving Avg.	Moving average for selected quad and	4B.14
Around Mean	Annual rainfall oscillation around mean / median	4B.15
Rain Regime	Annual rainfall regime	4B.16
Cumulative	Cumulative rainfall for selected Year and Quad	4B.17
- POINT ANNUAL		
- Temporal		
Linear Trend	Long term temporal distribution and linear trend for selected station	4B.18
Partial Trend	Partial trend for selected station and time interval	4B.19
- QUAD MONTHLY		
- Spatial		
O.R. Tambo	O.R. Tambo DM rainfall spatial distribution for selected Quad and Month	4B.20

Cacadu	Cacadu DM rainfall spatial distribution for selected Quad and Month	4B.21
Joe Gqabi	Joe Gqabi DM rainfall spatial distribution for selected Quad and Month	4B.22
- Temporal		
Per Month	Monthly rainfall temporal distribution for selected Quad and Month	4B.23
Moving Avg.	Rainfall moving average for selected Quad and Month	4B.24
Box Plot	Box Plot for selected Quad and month	4B.25

The Annual sub-menu also contains temporal information for some of selected point gauging stations having longer time series (minimum 80 years) data than the quaternary catchments.

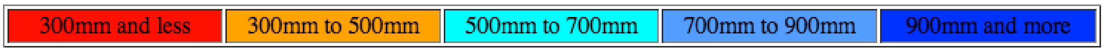


Fig. 4B.8: The rainfall spatial distribution intensity legend

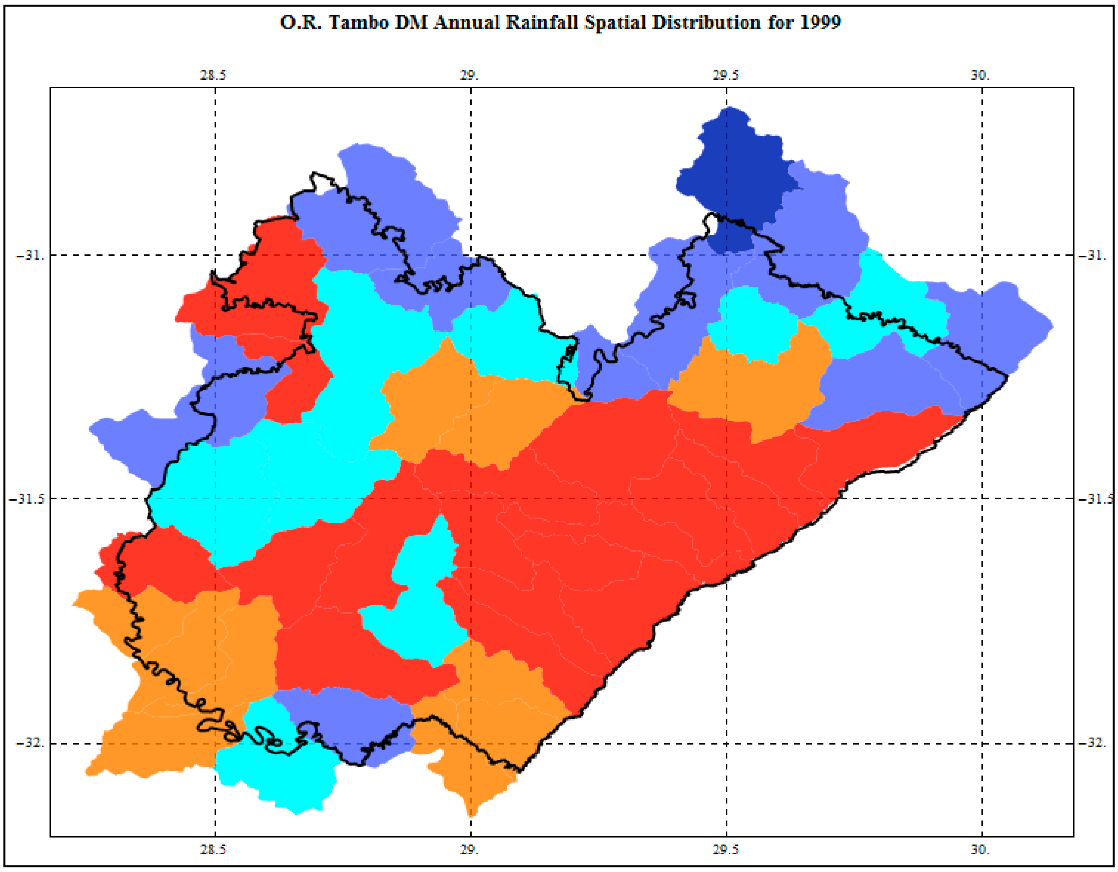


Fig. 4B.9: Example of the OR Tambo DM annual rainfall spatial distribution for 1999

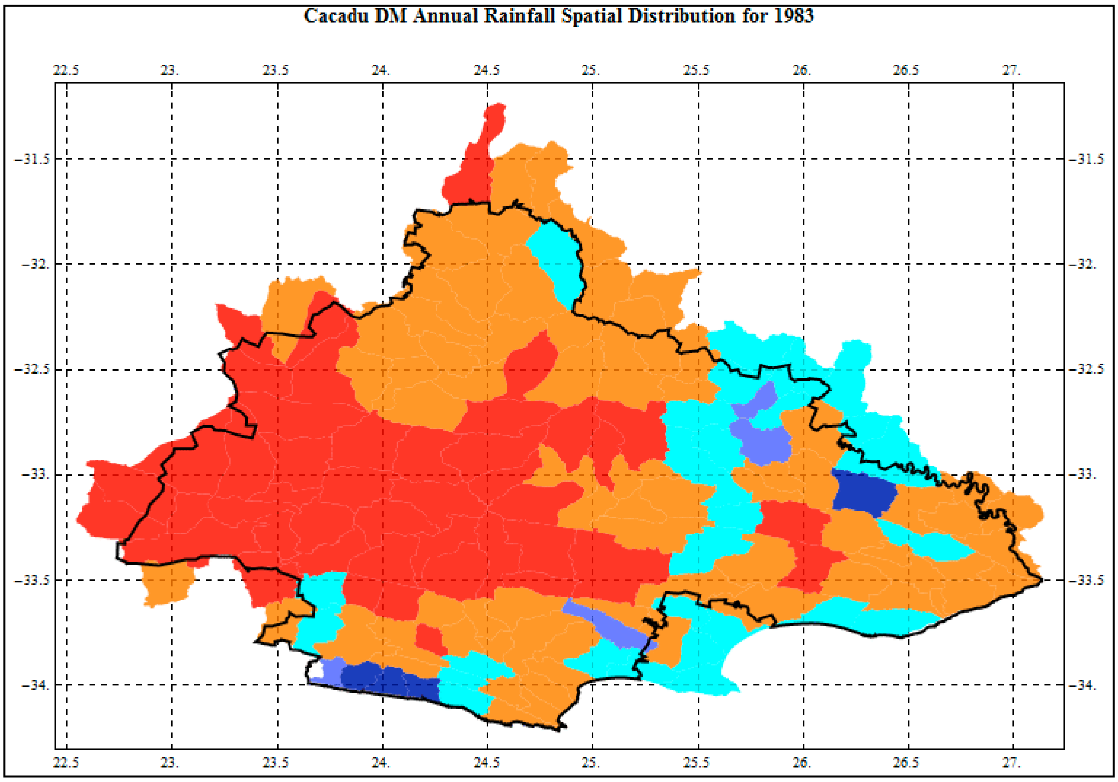


Fig. 4B.10: Example of the Cacadu DM annual rainfall spatial distribution for 1985

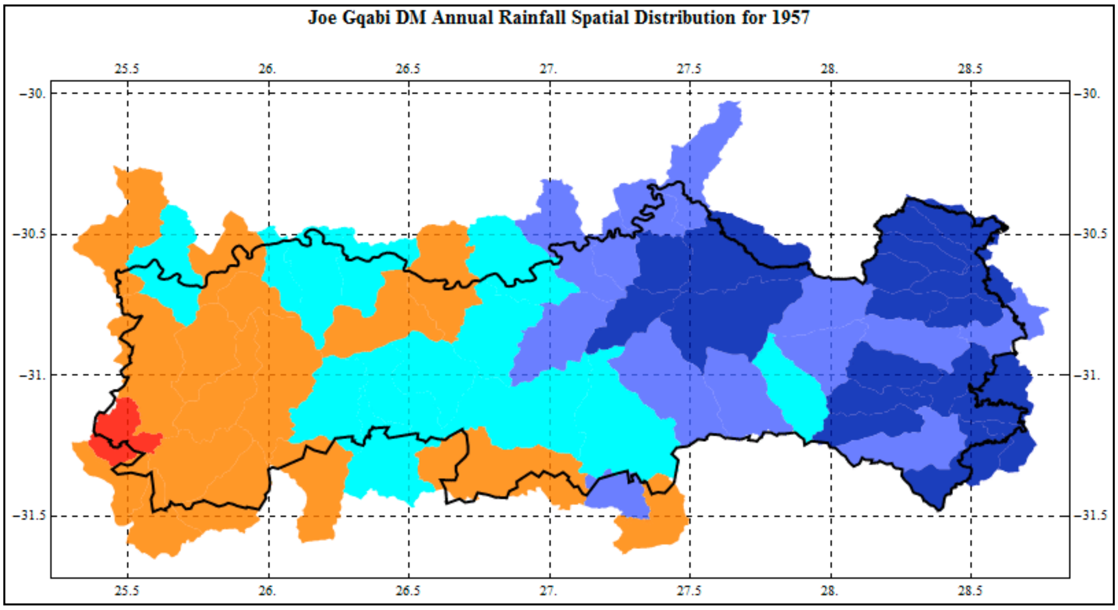


Fig. 4B.11: Example of the Joe Gqabi DM annual rainfall spatial distribution for 1957

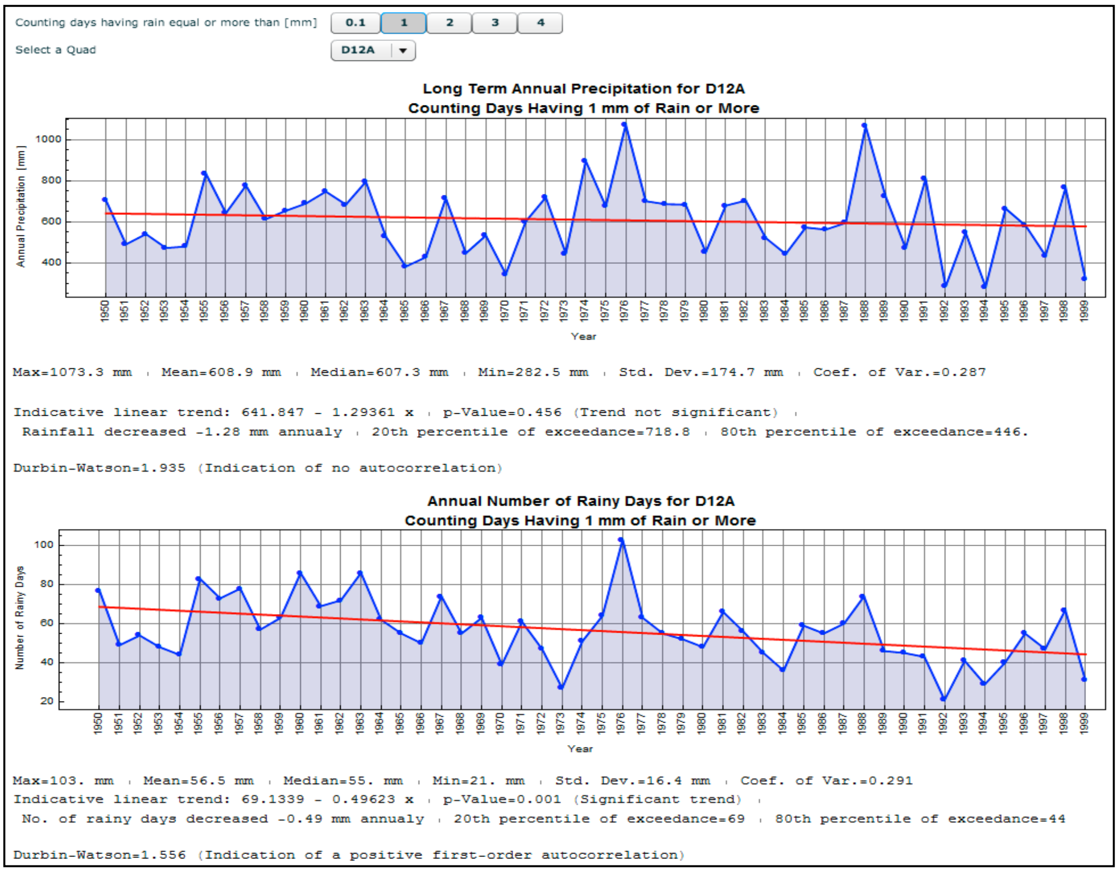


Fig. 4B.12: Example of an annual rainfall trend and temporal distribution for D12A

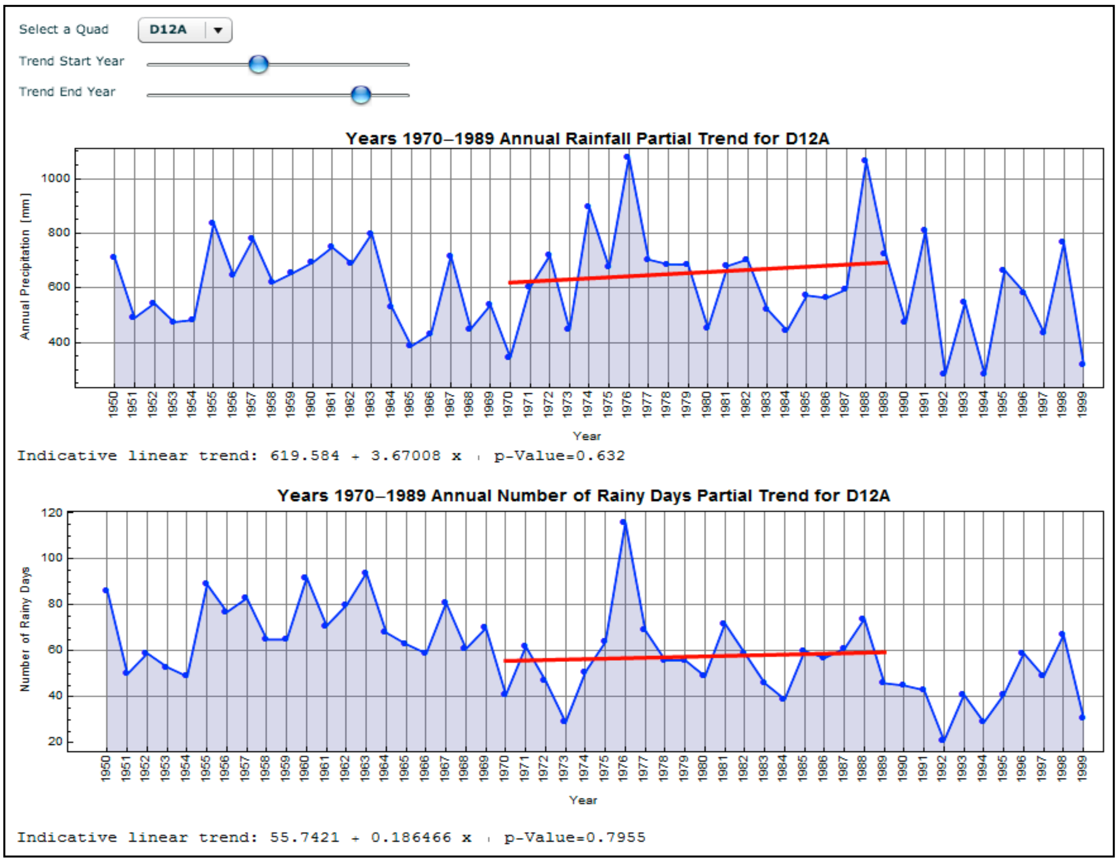


Fig. 4B.13: Examples of annual rainfall and number of rainy days partial trends and temporal distribution

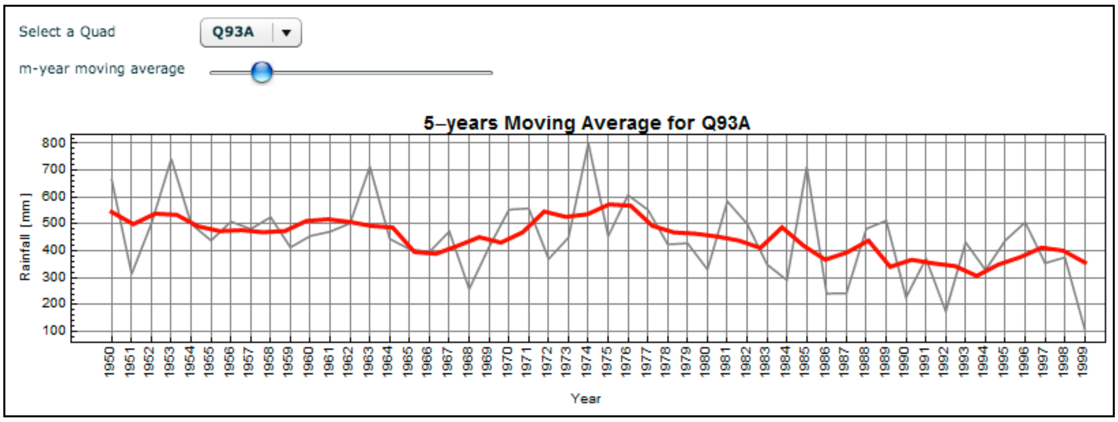


Fig. 4B.14: Example of a long term annual rainfall moving average for Q93A

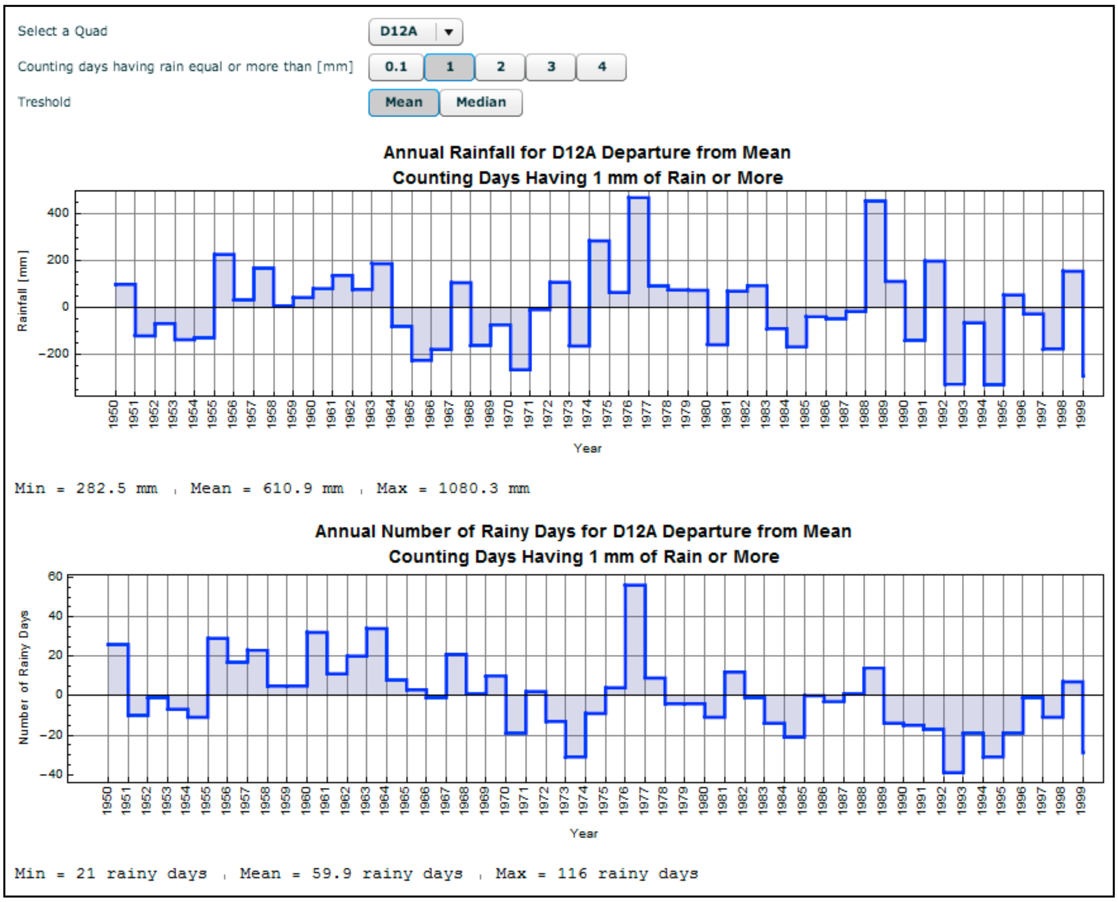
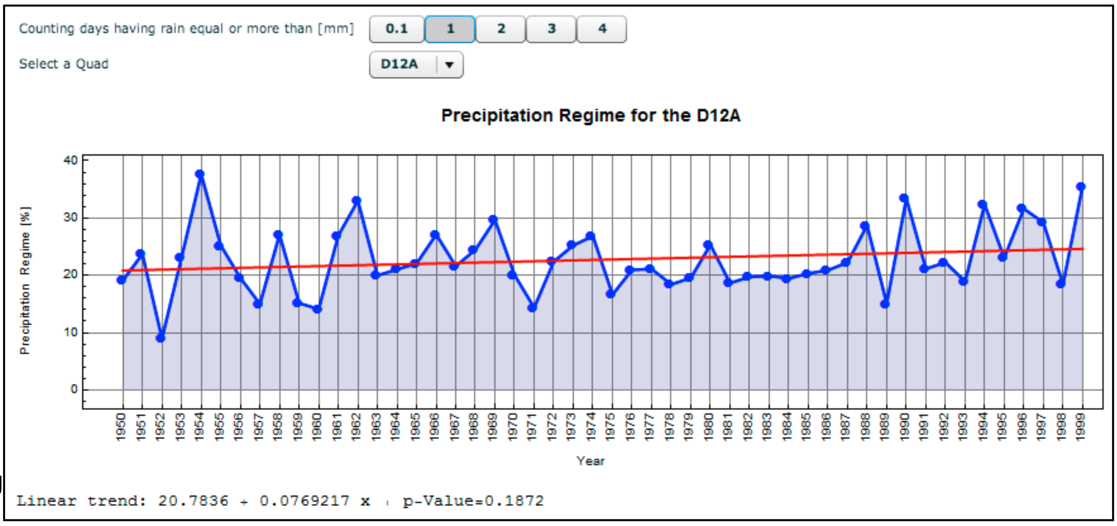


Fig. 4B.15: Examples of annual rainfall and rainy days departures around the mean



Fig

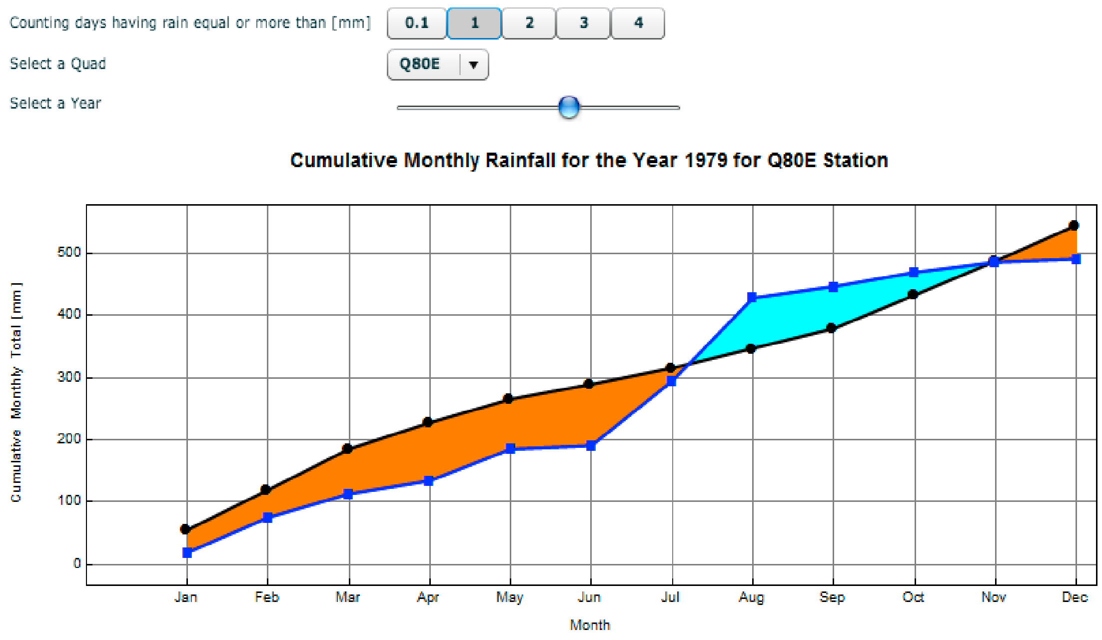


Fig. 4B.17: Example of cumulative rainfall for a selected quaternary catchment and year

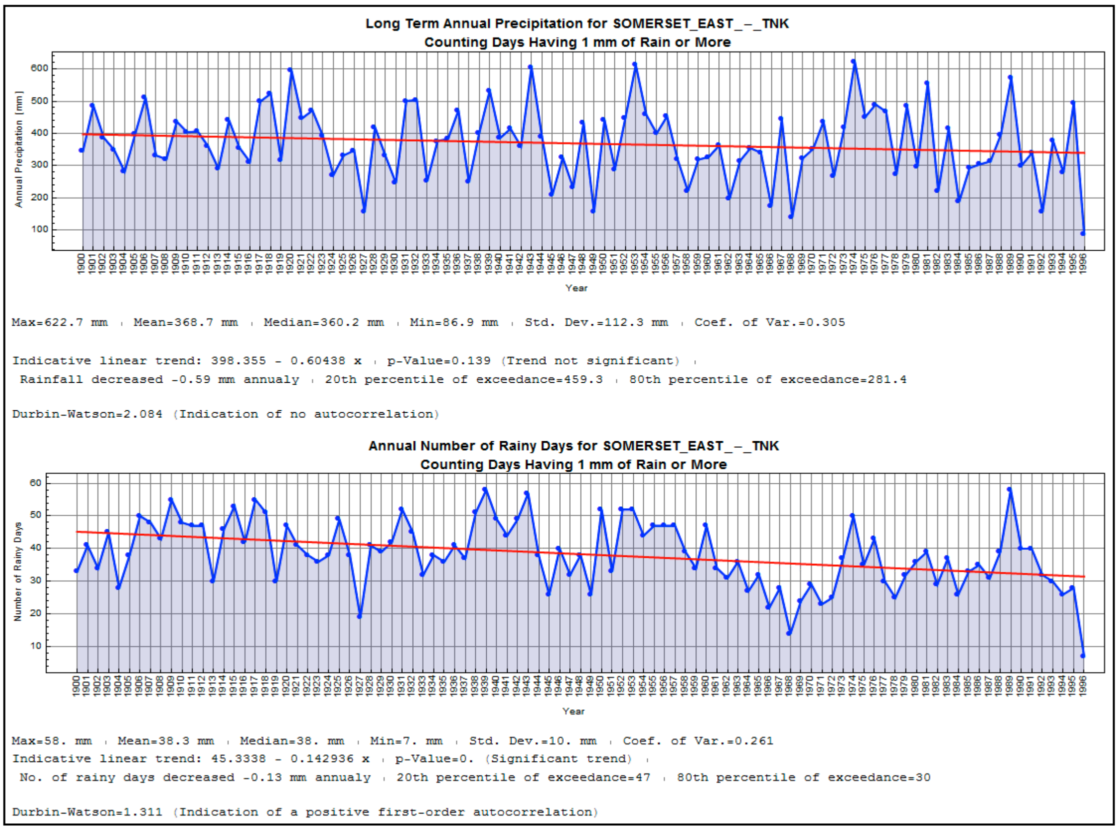


Fig. 4B.18: Examples of long term annual rainfall and linear trend for a selected station

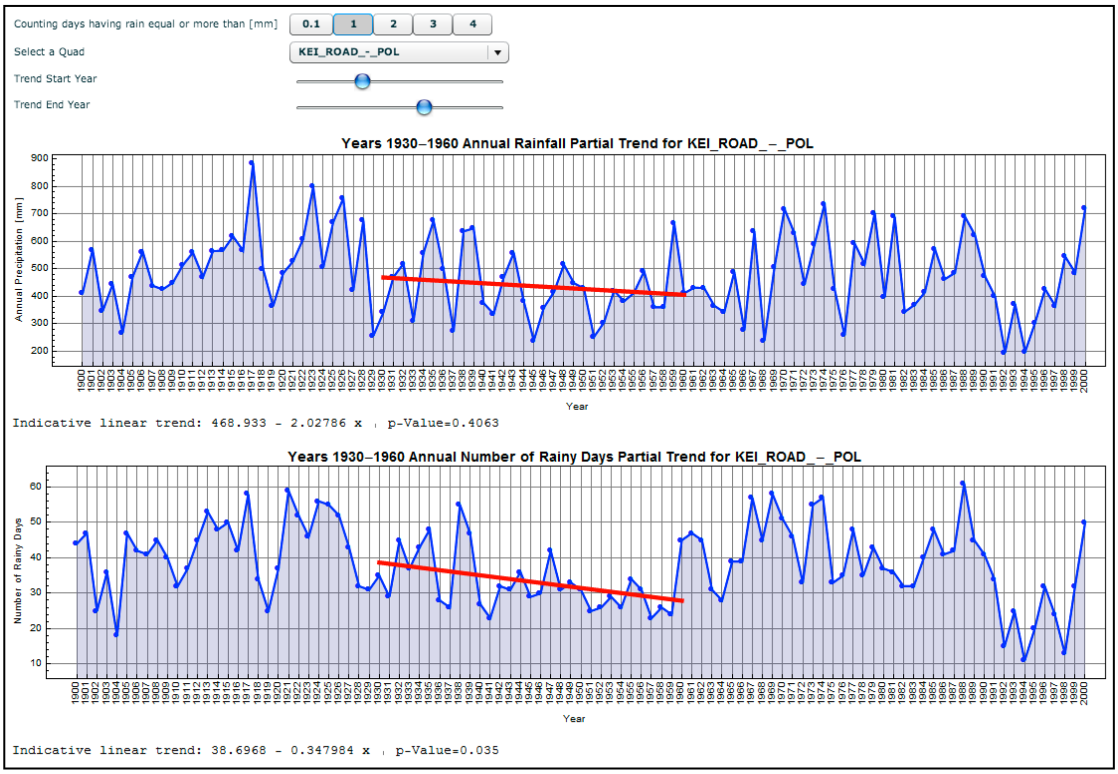
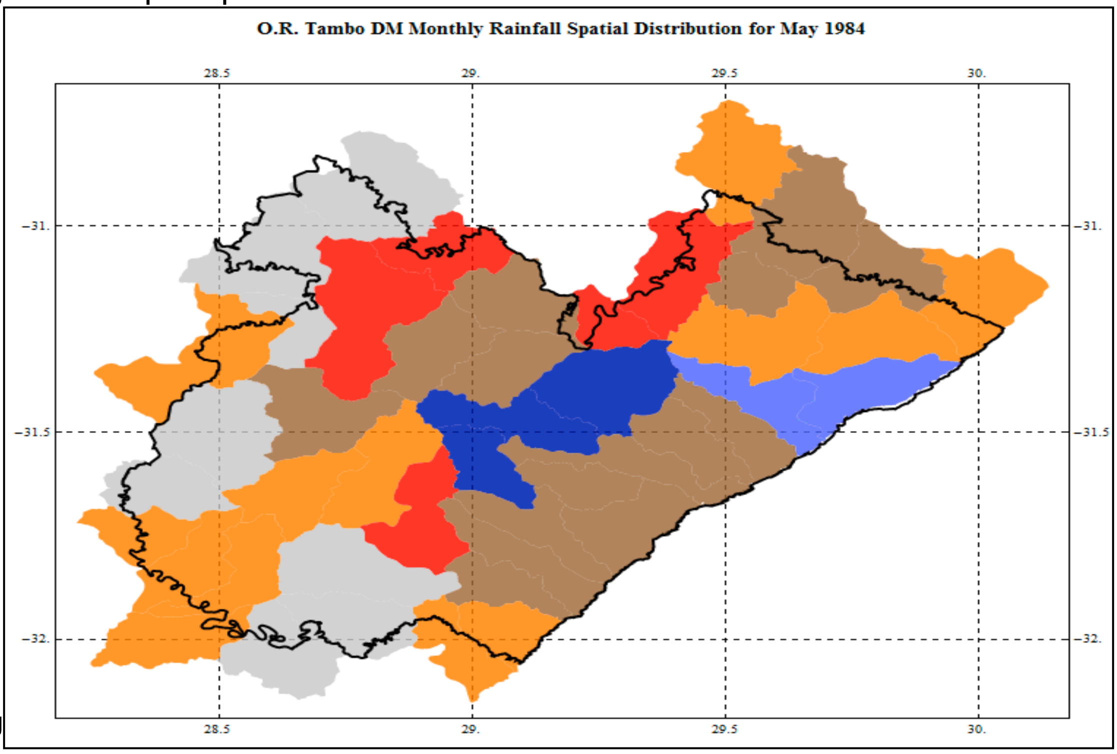


Fig. 4B.19: Examples of partial trends for a selected station and time interval



Fig

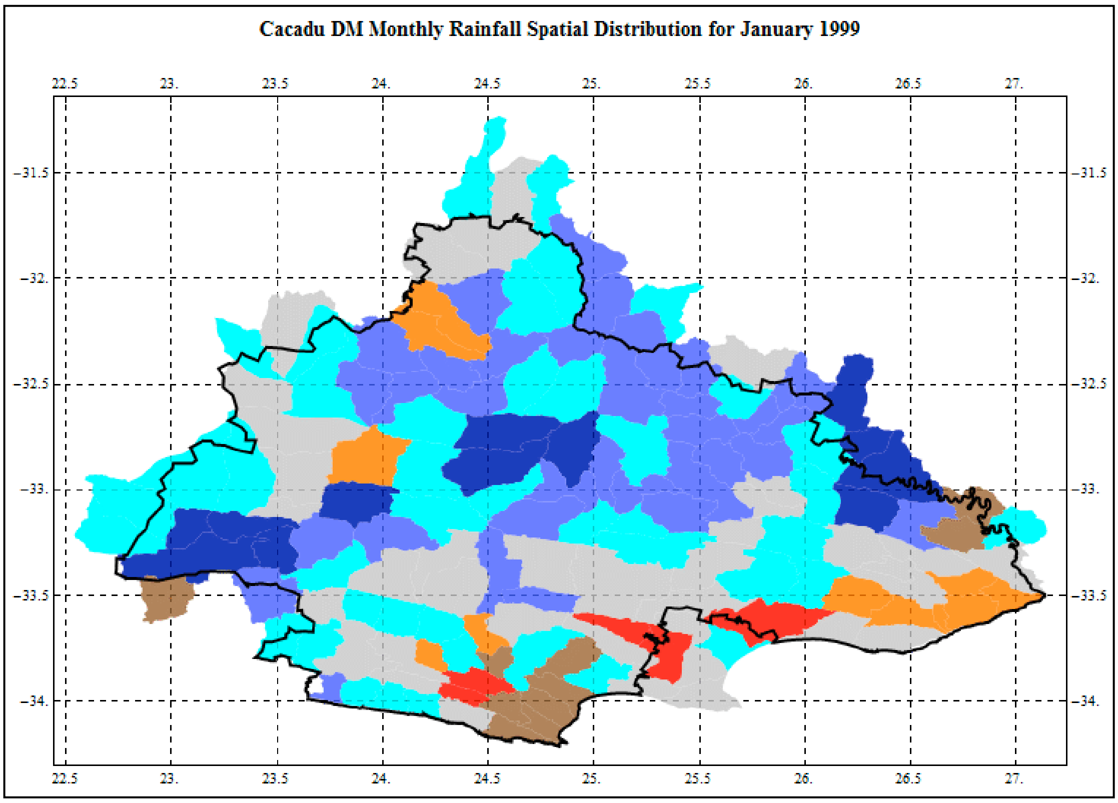
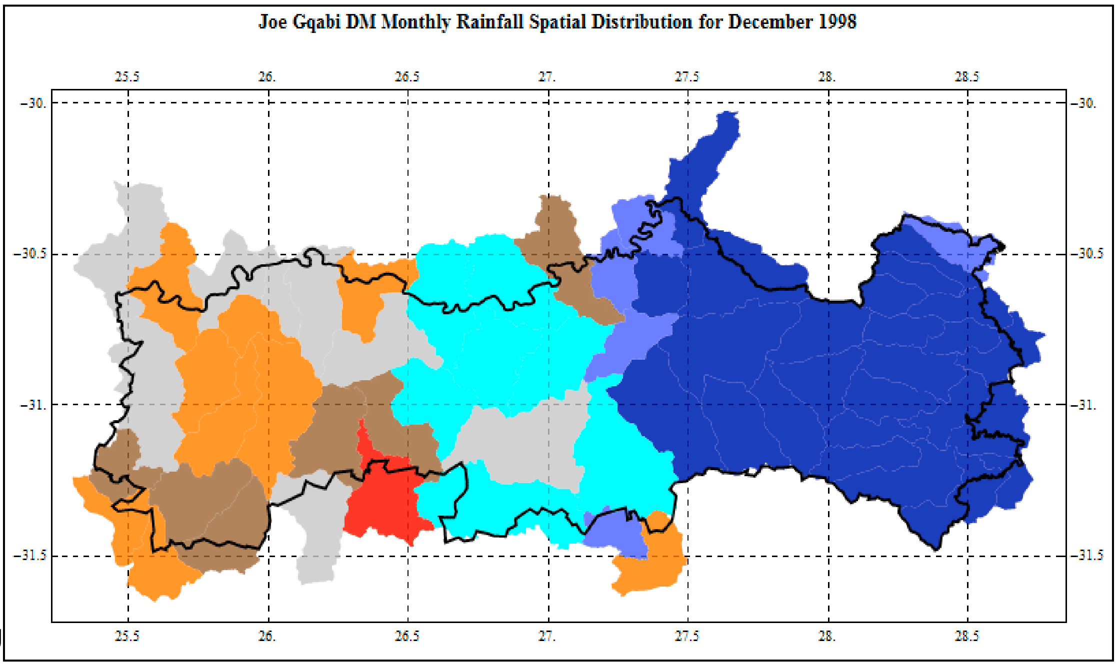


Fig. 4B.21: Example of Cacadu DM monthly rainfall spatial distribution



Fig

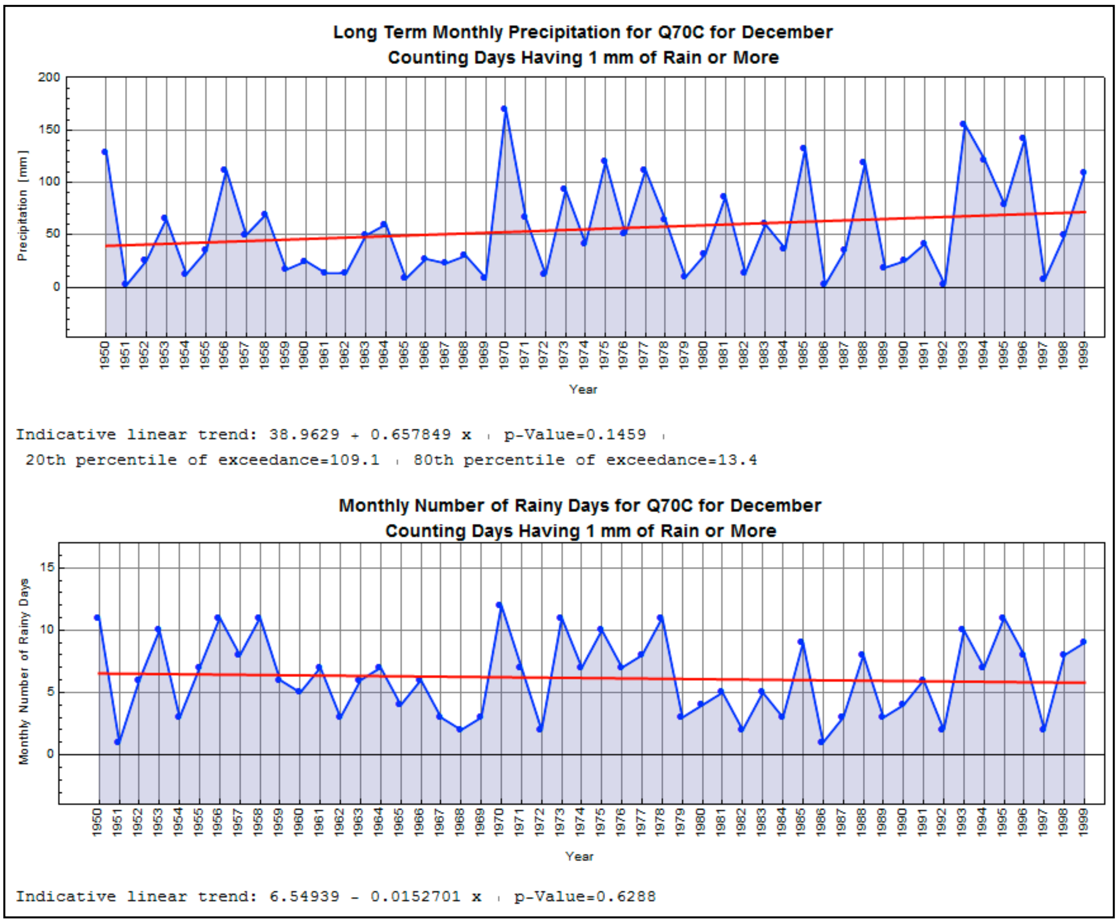


Fig. 4B.23: Example of long term monthly rainfall and trend

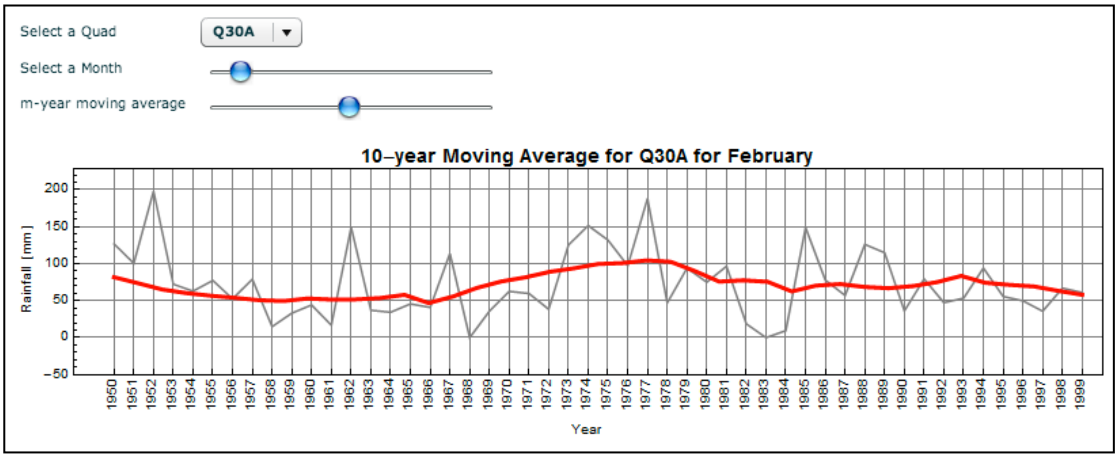


Fig. 4B.24: Example of monthly rainfall moving average

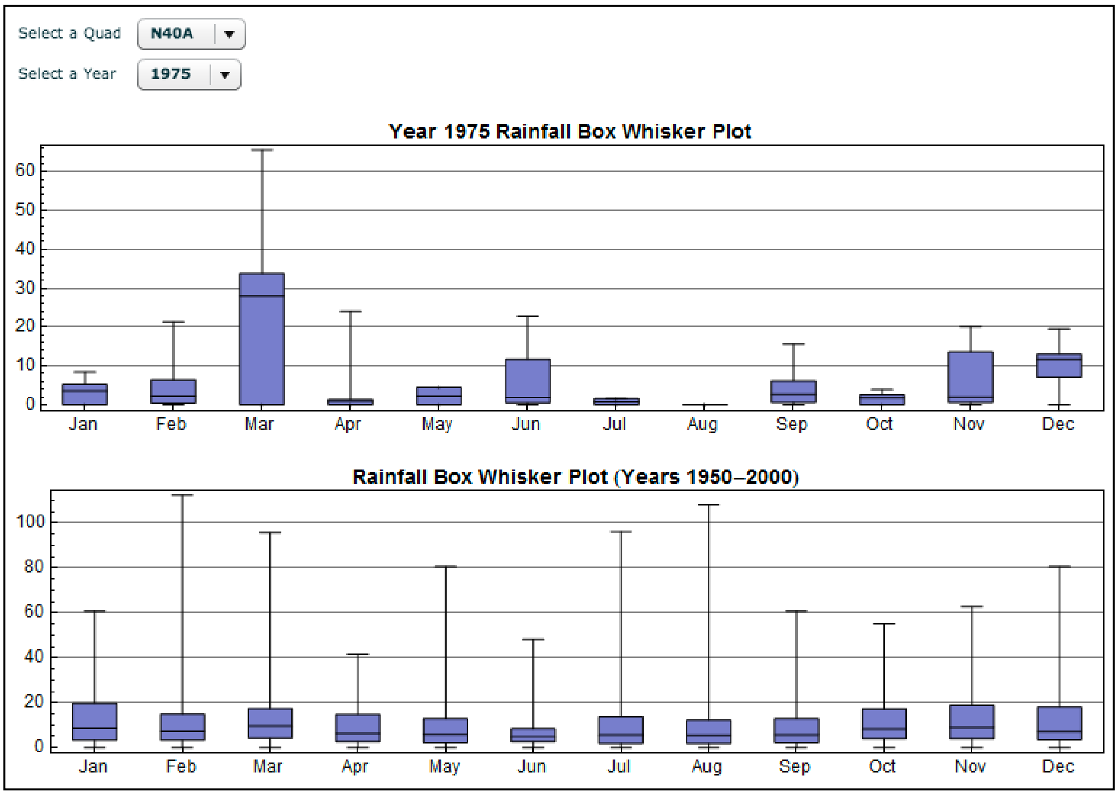


Fig. 4B.25: Examples of Box Whisker plots for a selected quaternary catchment and year

1.4.3 Temperature Menu

The Temperature Menu consists of two major sections, namely the:

- Annual sub-menu, and the
- Monthly sub-menu.

Table 4B.3: Temperature sub-menu content

Left Frame Menu Item	Description	Figure
- ANNUAL		
Linear Trend	Long term Max, Min and temperature difference Linear Trend	4B.26
Partial Trend	Long term Max, Min and temperature difference Partial Linear Trend	4B.27
Moving Average	Long term Max, Min Moving Average	4B.28
Around Mean	Min and Max temperature oscillation around Mean / Median	4B.29
- MONTHLY		
Per Month	Long term Max, Min and temperature difference Linear Trend for selected Month	4B.30
Moving Average	Long term Max, Min Moving Average for selected Month	4B.31
Box Plot	Temperature Box plot for selected Month	4B.32

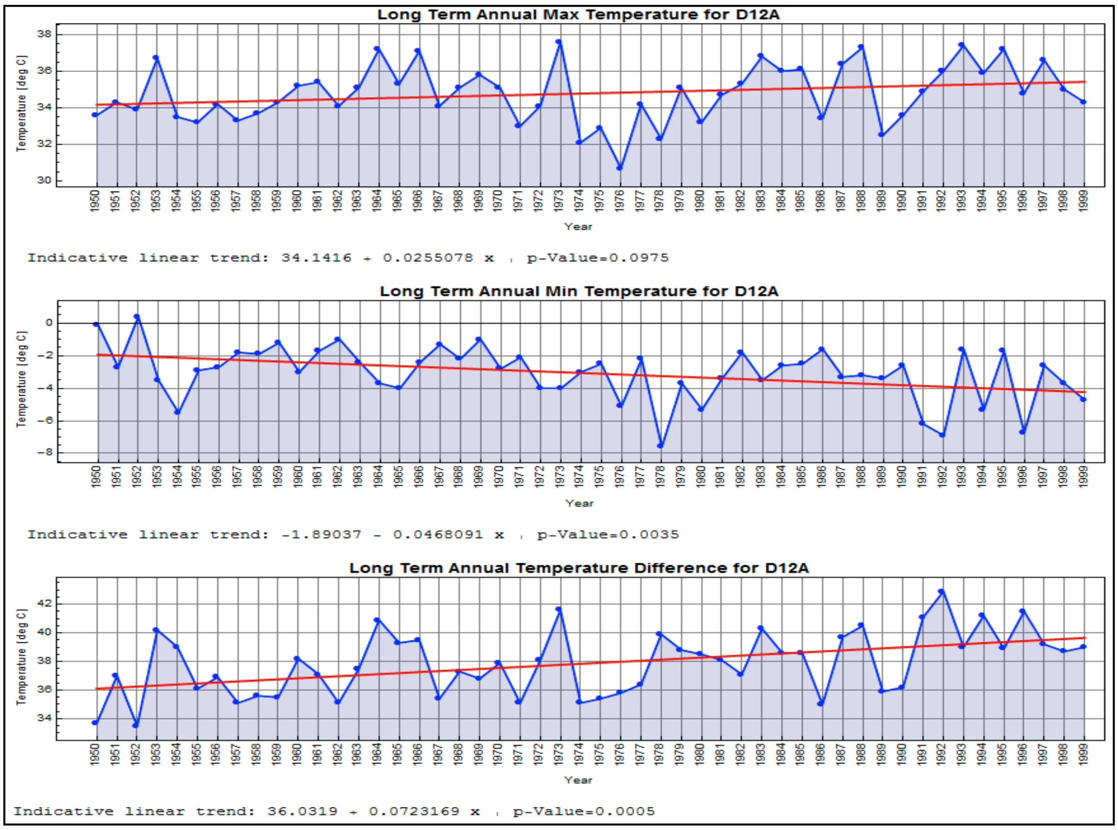


Fig. 4B.26: Examples of long term temperature linear trends

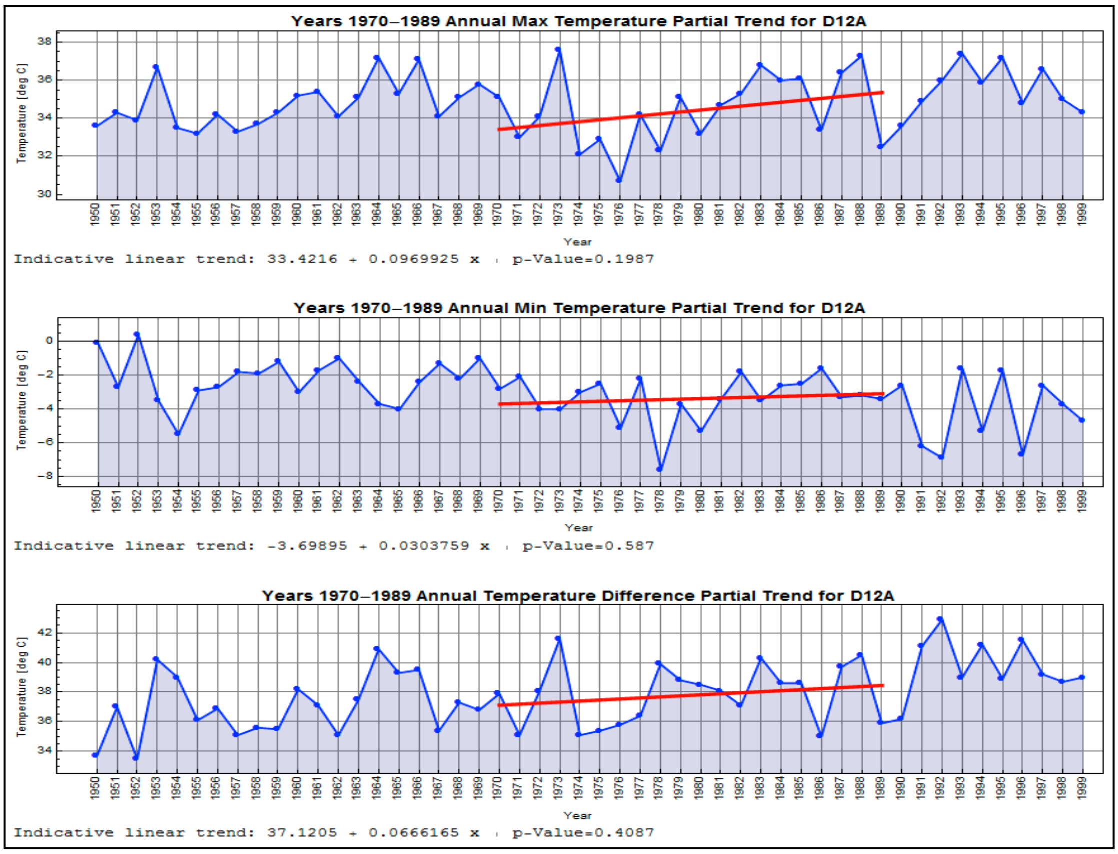


Fig. 4B.27: Examples of long term temperature partial trends

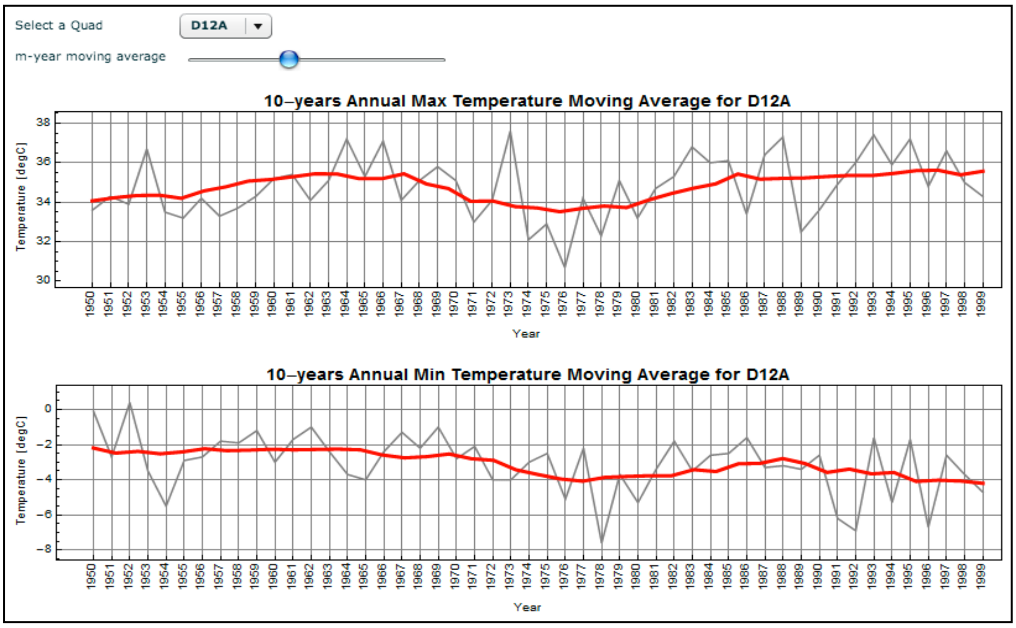


Fig. 4B.28: Examples of long term temperature moving averages

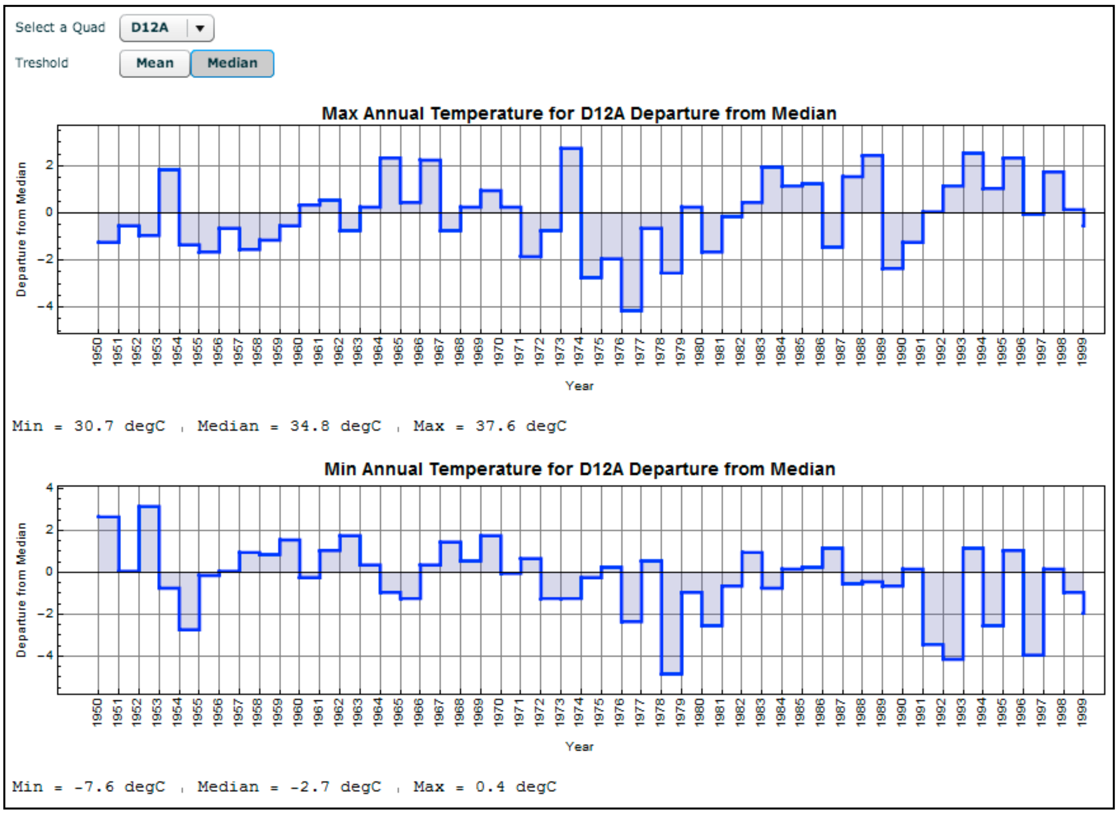


Fig. 4B.29: Examples of temperature departures around the median

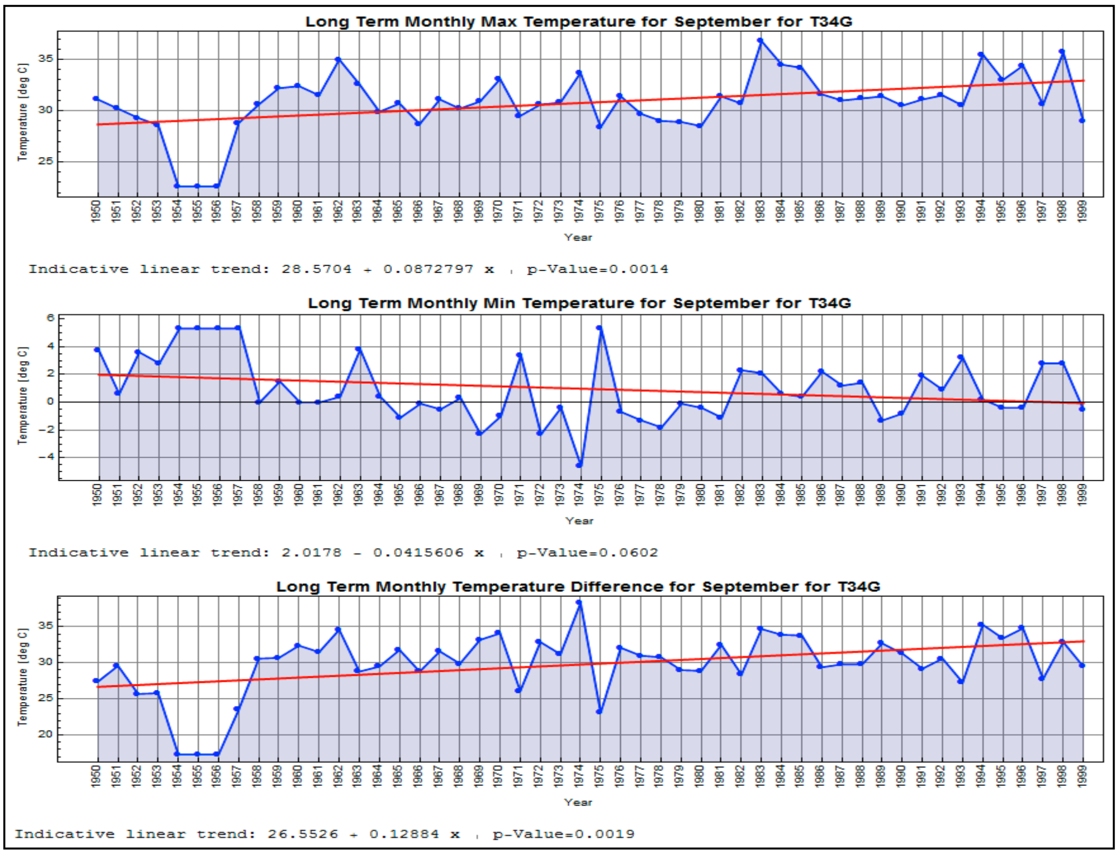


Fig. 4B.30: Examples of long term temperature linear trends for a selected month

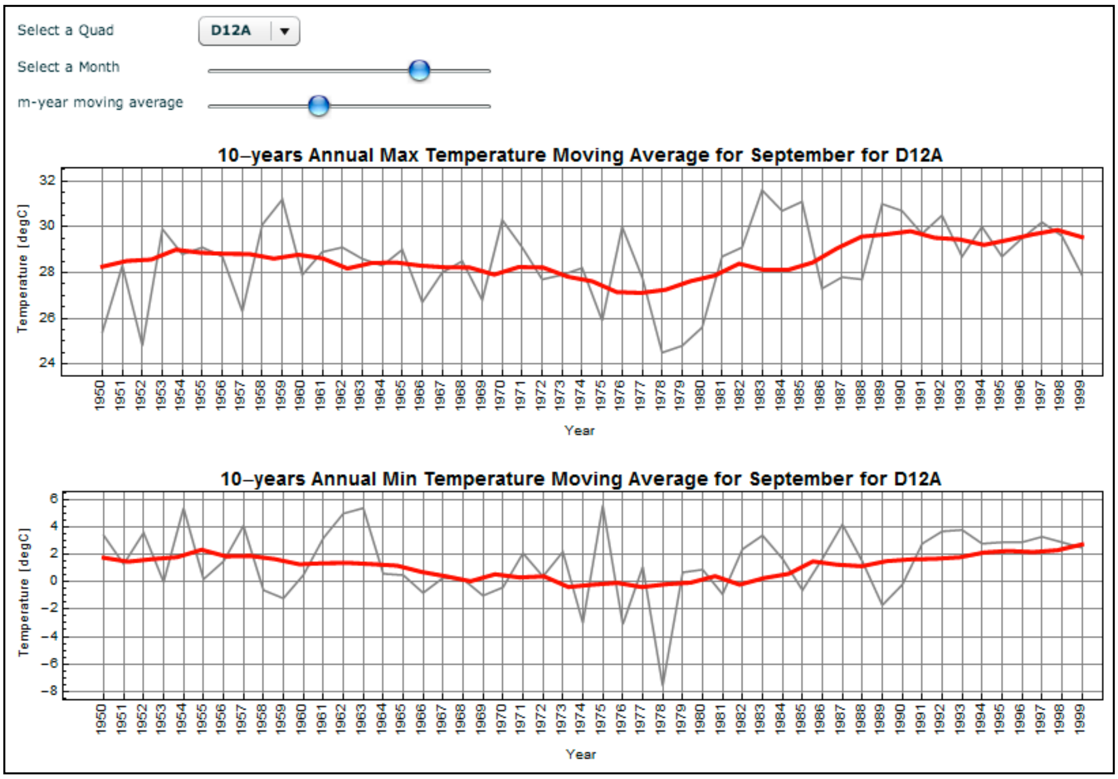


Fig. 4B.31: Examples of temperature moving averages

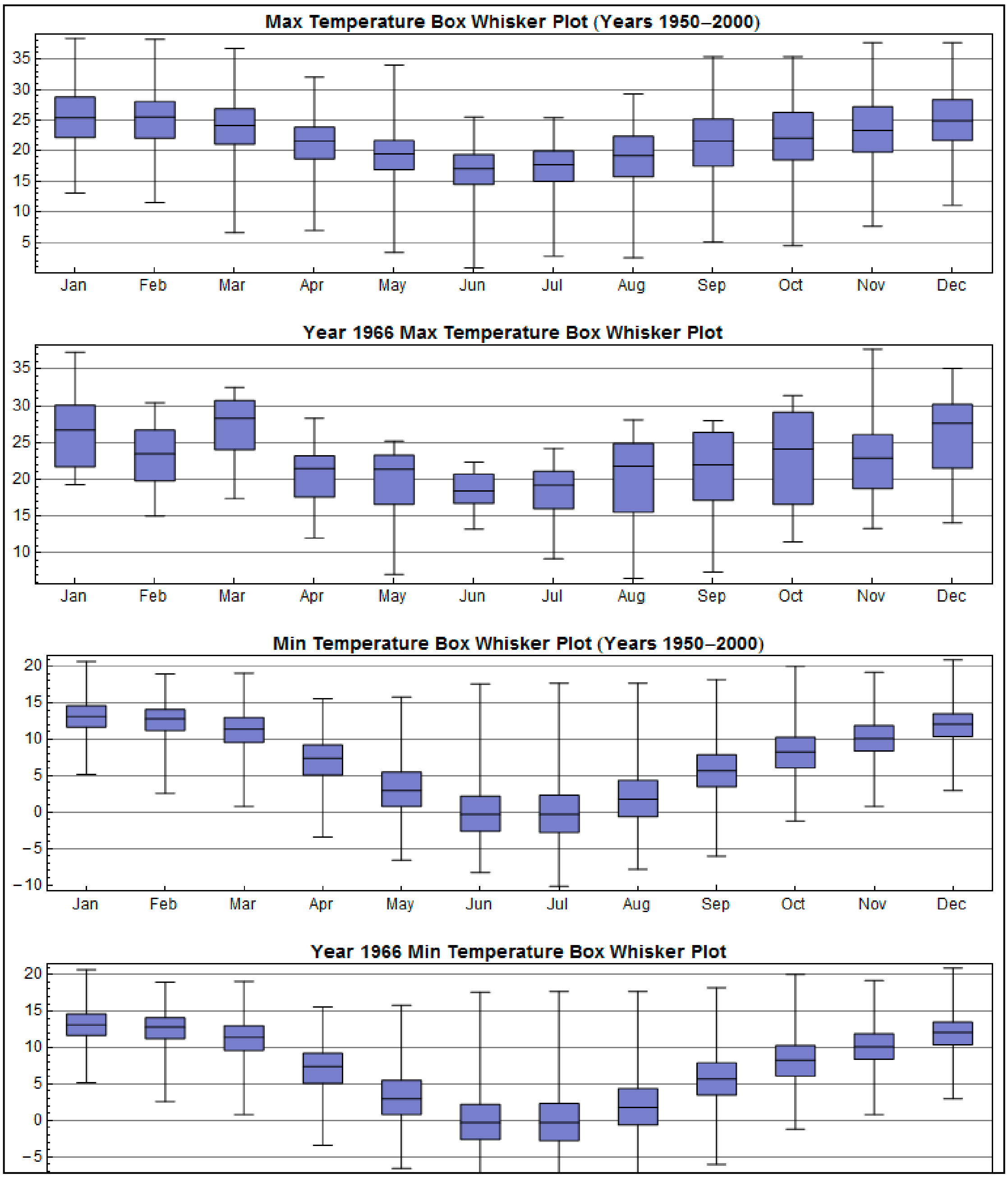


Fig. 4B.32: Examples of maximum and minimum temperature Box Whisker plots

1.4.4 Evaporation Menu

The Evaporation Menu consists of two major sections, namely the:

- Annual sub-menu, and the
- Monthly sub-menu.

Table 4B.4: The Evaporation sub-menu content

Left Frame Menu Item	Description	Figure
- ANNUAL		
Linear Trend	Long term evaporation Linear Trend	4B.33
Partial Trend	Long term evaporation Partial Linear Trend	4B.34
Moving Average	Long term evaporation Moving Average	4B.35
Around Mean	Evaporation oscillation around Mean / Median	4B.36
- MONTHLY		
Per Month	Long term evaporation Linear Trend for selected Month	4B.37
Moving Average	Long term evaporation Moving Average for selected Month	4B.38
Box Plot	Evaporation Box plot for selected Month	4B.39

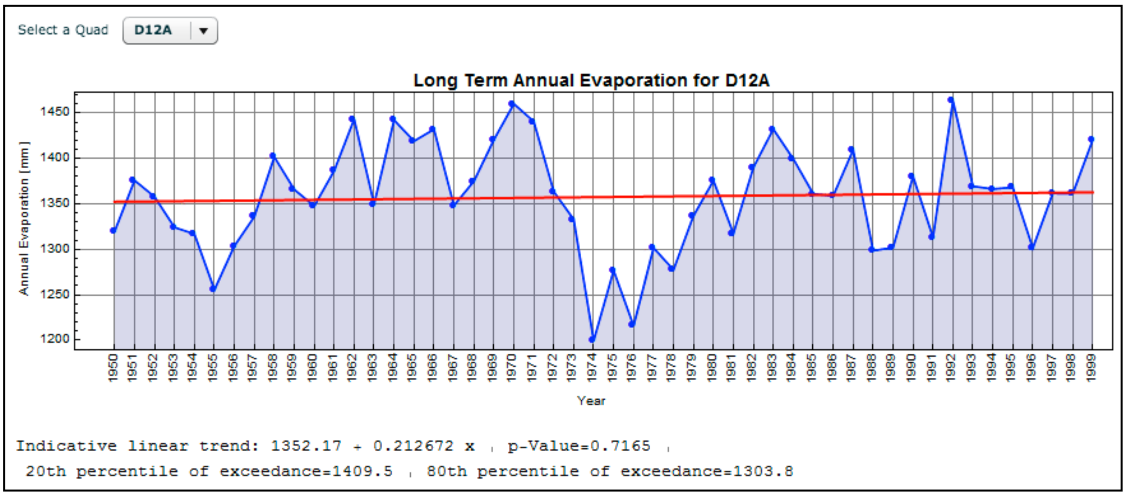


Fig. 4B.33: Example of a long term evaporation linear trend

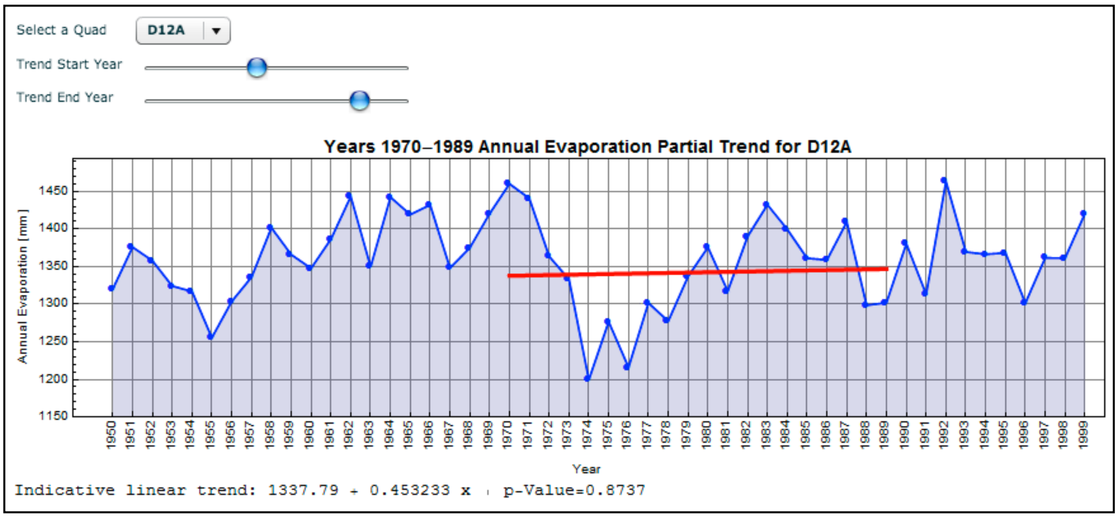


Fig. 4B.34: Example of a long term evaporation partial linear trend

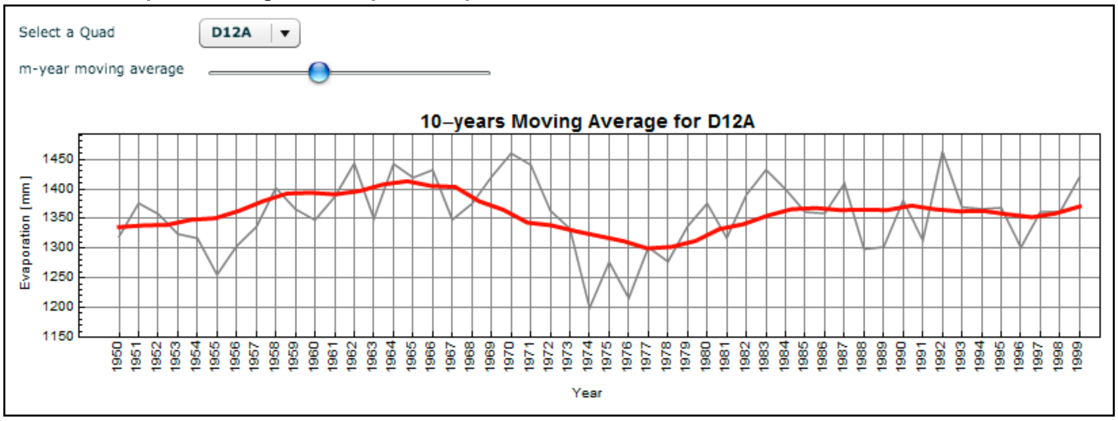


Fig. 4B.35: Example of a long term evaporation moving average

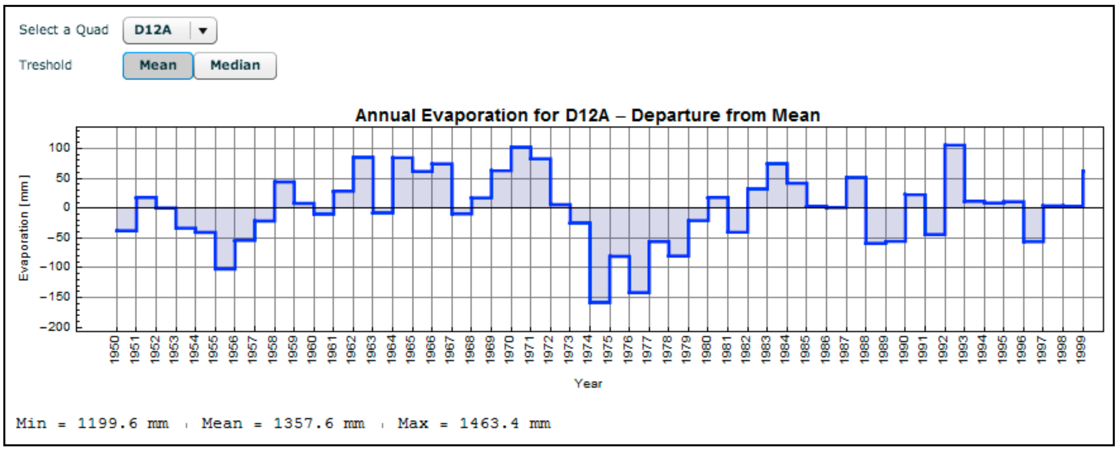


Fig. 4B.36: Example of evaporation departures around the mean

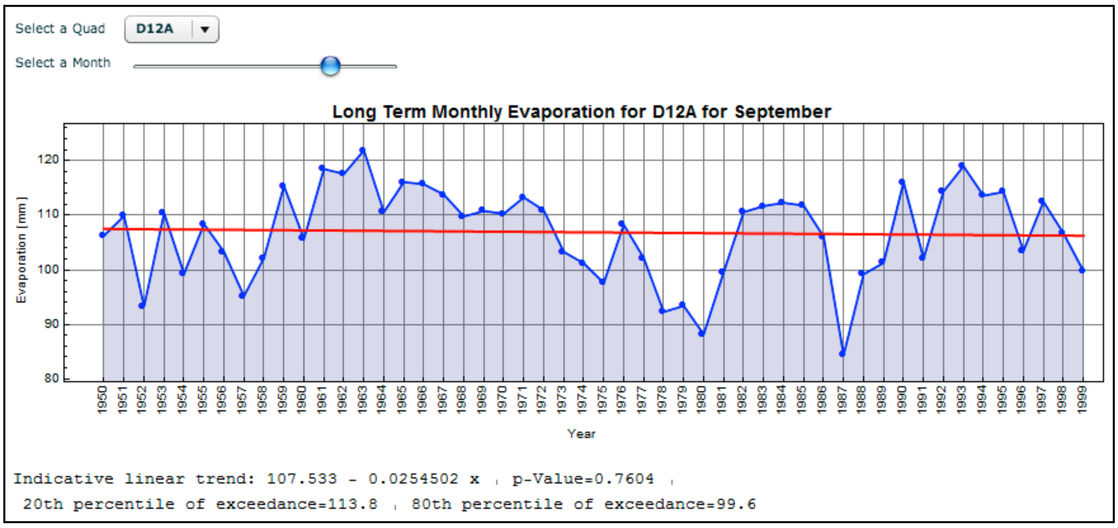


Fig. 4B.37: Example of a long term evaporation linear trend for a selected month

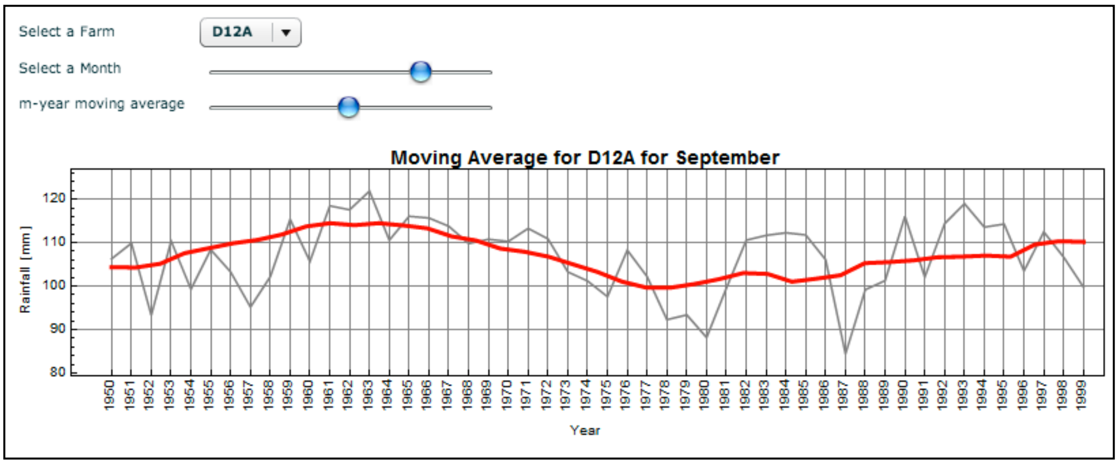


Fig. 4B.38: Example of a long term evaporation moving average for a selected month

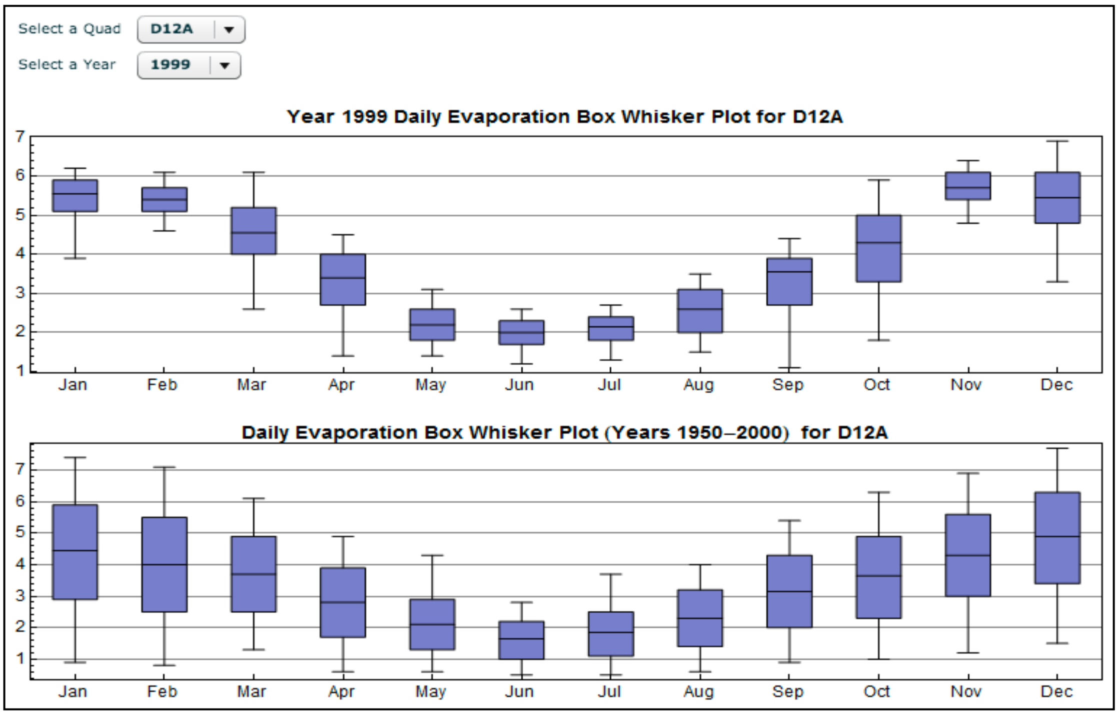


Fig. 4B.39: Examples of evaporation Box Whisker plots

Announcement

Developed by Dusan SAKULSKI Agro-economic expertise by Andries JORDAAN	POWERED BY Wolfram webMathematica

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