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 II

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by

Jordaan, A.J. (Editor)

with contributions by

DM Sakulski, F Muyambo, S Shwababa, N Mdungela, B Phatudi-Mphahlele, C Mashimbye, D Mlambo, O Fadeyi, T Miya, Y Bahta, E Owusu-Sekyere, RE Schulze
Disaster Management Training and Education Centre for Africa (DiMTEC), University of the Free State

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Gezina 0031
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orders@wrc.org.za or download from www.wrc.org.za

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Executive Summary

Introduction

Dry periods and droughts remain the major meteorological 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 have highlighted the critical role of vulnerability and resilience in drought risk management. One cannot assess drought risk by assessing solely precipitation, evaporation and transpiration alone. These are variables used for the hazard assessment and not 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 (i.e. ecological) and economic factors in watershed management already since the 1980s. Currently, much research focuses on climate change and future climate scenarios, yet relatively little work is undertaken on the vulnerability to climate change of the agricultural sector and 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 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 rest of the commercial farmers, yet this research clearly shows the difference in vulnerability and coping capacity between communal and commercial farmers within the same region.

This poses a challenge to institutions responsible for disaster management in 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 addressed a serious issue in agricultural risk and disaster management in South Africa. The results of the research provided the basis for a national drought management strategy and provided 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 was 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 resilience. In support of the main objective the following sub-objectives were formulated:

6 *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;*
7 *Determination of economic, social and environmental vulnerability to drought in the designated area;*
8 *Determination of current adaptation and coping capacities to drought risk and identification of factors that contribute to drought resilience;*
9 *Developing a drought risk profile for the study area;*
10 *Developing drought loss functions for the livestock sector and selected rain fed crops in the research area;*
11 *Proposing adaptation and coping mechanisms for the commercial livestock sector as well as to communal livestock farmers to future drought risks; and*
12 *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 4).*
- *Identification and measurement of vulnerability indicators to drought for the rain fed commercial and small-scale communal farming sectors. (Chapters 3. 6 and 7).*
- *Calculation of drought risk based on hazard, vulnerability, adaptation and coping mechanisms for each quaternary catchment in the designated area. (Chapter 8).*
- *Identification of adaptation strategies and coping mechanisms for drought in both commercial and small-scale sectors. (Chapter 11).*
- *Provision of a web-based information tool for drought risk management in the selected areas, which extension officers, farmers and other role players could use for drought risk planning (See dimtecrisk.ufs.ac.za/wrc_ec. (Annexure 4B)*

- *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. (Chapter 10).*

Reporting

The research report consists of two volumes: Volume I deal with the literature study and hazard assessment. Volume II consist of the risk assessment, vulnerability and coping capacity assessment for communal and commercial farmers, loss functions and proposed drought plans. Volume II concludes with the final conclusion and recommendations. Both volumes are structured in different chapters according to the project deliverables and research objectives. Chapters follow each other in a logical way according to the risk assessment methodology but each chapter can be read as a chapter on its own 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:* *Recommendations for Drought Risk Reduction*

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 Annexure 1A at end of Chapter 1.

Description of Study Area

Chapter 2 only deal with the Identification and description of the study area. The selection of a suitable study area was important in that the study area should allowed 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 Gqabi were good study areas since commercial farms and communal land are entwined, especially near in the Joe Gqabi district and the eastern part of Cacadu. OR Tambo consist mainly of communal farmers farming in a high rainfall region. The second chapter of this report elaborate on the demarcation of the study area and describe 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 cover the methodology applied to complete the research in the study area. The primary source of information was a literature study of available documentation on (i) the web as well as offices of (ii) the Eastern Cape Department of Agriculture and Rural Development in Bisho, East London and Port Elizabeth, (iii) National Department of Rural Development and Land Reform in East London and Pretoria, (iv) South African Weather Service (SAWS) in Port Elizabeth, (v) Statistics South Africa (StatsSA), and (vi) District Municipalities.

Individuals consulted during the research period included inter alia (i) the Director General of the Department of Agriculture and Rural Development in the EC, (ii) Assistant Directors 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, (vi) middle management officials working for Department of Agriculture and Rural Development, (vii) extension officers, (viii) scientists, (ix) communal farmers and (x) commercial farmers. GIS specialists provided the GIS data, including shape files from the (i) Department of Agriculture and Rural Development, (ii) National Department of Rural Development, and (iii) Department of Geography at the University of the Free State.

Transect drives were also undertaken through most of study area. Information reported in chapter one were 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 focus 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 identify 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 impact of drought or dry conditions. One of the main challenges in the drought risk assessment was 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 context of its 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 focus on theoretivcal models for vulnerability and resilience. The concept of resilience was especially highlighted in that the answer for drought risk reduction is embedded in a resilient system.

Hazard Assessment

The research described in Chapter four focused on the drought hazard (H) or the meteorological variables in the drought risk assessment equation. Historical meteorological data was 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 meteorological data remained one of the challenges. For the 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 gamma distribution, which were used to calculate the cumulative probabilities of precipitation events.

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

Drought Risk Assessment

The calculation of drought risk in the selected study areas is explained and illustrated in chapter five. The framework selected for indicator selection in this research was the Community Capitals Framework (CCF7). Indicators were grouped as part of each capital for both vulnerability and coping capacity. All indicators as well as the seven capitals were weighted according its contribution or importance to drought risk. Weighting of the seven capitals were (i) human = 0,12, (ii) social = 0,04, (iii) cultural = 0,1, (iv) financial = 0,27, (v) infrastructure = 0,08, (vi) environmental = 0,35, and (vii) political = 0,04. Weighting was done arbitrary after inputs from experts, experienced commercial farmers and communal farmers. The research team finally allocated weights arbitrary according to these expert inputs. For better accuracy the weighting process was repeated after two months and adjusted accordingly.

The results showed a higher than expected hazard risk for the higher rainfall OR Tambo district. Vulnerability was also the highest in OR Tambo due to mainly serious land degradation and human, social and cultural factors. Resiliency on the other hand was also lower in OR Tambo but not as dramatic as vulnerability due to the inherent potential of the natural resources such as soil, water availability and climate. Drought risk however was 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 of the research described in Chapter six (Volume II) was on the analysis of drought vulnerability amongst communal farmers. Understanding farmers' vulnerability to drought remain complicated yet very necessary for planning preparedness, mitigation and response policies and programmes. Vulnerability analysis highlighted the various burdens of drought losses that farmers experienced at different locations. The EC regularly experienced drought with government relief programmes mostly too late. Past drought analysis and drought relief programmes, however, did not consider actual vulnerability; it did not reduce risk or improve resiliency against drought. This chapter discuss and highlight the factors that rendered communal farmers vulnerable to drought.

Mixed methods of qualitative and quantitative approaches were used to analyse drought vulnerability. Transect trips were carried out through the study area and that provided valuable insight to the different agricultural systems. During these transect trips several vulnerability indicators were identified such as over grazing, 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 (CCF7), were 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 groundwater supply. In OR Tambo, it was observed that overgrazing, soil erosion and land degradation contributed mostly to drought vulnerability. Farmers from Joe Gqabi also reported moderate vulnerability to drought and high vulnerability in the Sterkspruit area. Economically, farmers from the three districts perceived lack of financial 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 perception, farmers viewed psychological stress, cultural values and practices and lack of preparedness strategies as contributing the most to social vulnerability to drought.

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

Drought Resilience; Commercial Farmers

Chapter seven contain 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 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 served as a good structure and framework for analysis and can be used for future planning of beneficiary selection for land reform as well as for the development of extension programmes in support to all new farmers. The communal farmers can also learn from the results discussed in this section 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 reticulation 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

Calculation of Mean Annual Loss (MAL) and the development of loss functions are particularly important to the insurance industry since it provides 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 is 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 couldn't be compared to other years because 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 determined global mohair prices. Wool prices on the other hand, were 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 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 were 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 robust drought loss functions for maize. In desperation the SAPWAT3 programme 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 should be based on certain indicator thresholds and should provide a framework for drought management. The drought classification, indicator selection and indicator thresholds discussed in this chapter was 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 in 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 is easy to monitor on a daily basis and secondary indicators, which focuses more on drought impacts. Primary indicators were categorized as (i) meteorological indicators, (ii) agricultural indicators, which is remotely sensed and (iii) 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 provide the guide that was developed for drought indicators for future drought management in South Africa. The proposed indicators are in line with current 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 were 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 Fisheries and Forestry (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 has a well-developed economy with a strong agricultural sector and the citizens in SA were 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 is expected to also suffer water shortages in future droughts if South Africa do not plan properly for the next drought.

The drought plan template proposed in this chapter was based on the National Disaster Management Framework and consist of the 4 Key Performance Areas (KPA's) 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. *Inventory resource 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 programmes*
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 identified during the research 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 continuously evaluate results and findings.

Hundred-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 were 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 5 national conferences. Two papers were already published in peer-reviewed journals, one paper was published as a chapter in a book and 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 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 that planned completion of his research in 2018. The remaining two students enrolled for studies at other Universities due to personal circumstances.

Capacity building was also targeted to extension officers and farmers. Hundred-thirty-nine 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 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 already provided the framework for drought classification in South Africa. The National Drought Task Team 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 already took note of the fact that dry periods are already droughts for communal farmers and therefore the requirement of different thresholds for drought declaration for different sectors.

The research also highlighted several areas for future research.

Table of Contents, Volume II

List of Tables

List of Figures

List of Pictures

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 Systems
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
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 are 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 risks 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, between 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 (UNISDR, 2004).
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).	**T**he 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 programme 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 socioeconomic 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 subterm; 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 timescales 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: (1) disaster risk knowledge based on the systematic collection of data and disaster risk assessments; (2) detection, monitoring, analysis and forecasting of the hazards and possible consequences; (3) dissemination and communication, by an official source, of authoritative, timely, accurate and actionable warnings and associated information on likelihood and impact; and (4) 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 happen 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 microeconomic impacts (e.g., revenue declines owing to business interruption), mesoeconomic 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).	**T**he 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, 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, 2006)	Definite statement or statistical estimate of the occurrence of a future event.
Geographic Information System (GIS) (UNISDR, 2004)	Analysis that combine 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 socionatural 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* ***socionatural****, 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 (1) the selection of multiple major hazards that the country faces, and (2) 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. Hydrometeorological 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.* ***Hydrometeorological 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. Hydrometeorological 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, 2006)	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. *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 (1) the selection of multiple major hazards that the country faces, and (2) 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. Hydrometeorological 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.* ***Hydrometeorological 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. Hydrometeorological 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*.
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.*

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 livelihood means 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 (Jordaan & Jooste, 2003).
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".*

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5 Drought Risk Assessment

Jordaan, A.J., Sakulski, D.M., Maybuye C., Mayumbe, F.

Executive Summary

This chapter builds on previous chapters and covers the calculation of drought risk in the selected study areas. Drought risk is a function of hazard, vulnerability and coping capacity. Indicators for vulnerability and coping capacity were discussed in Chapter 3 while drought hazard was discussed in detail in Chapter 4.

The framework for indicator selection in this research was the Community Capitals Framework, which identified the capitals as (i) human, (ii) social, (iii) cultural, (iv) financial, (v) infrastructure, (vi) environmental and (vii) political. Indicators 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 contributions, or importance, to drought risk. Weighting of the seven capitals were (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 were obtained from experts and experienced 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.

Data for hazard analysis were the WRC 2000 data and data provided by the SAWS in Port Elizabeth. Data per quaternary catchment for the seven capitals were in most cases not available from recognized sources such as StatsSA or the Department of Agriculture. Where possible, available data were used for the indexing of vulnerability and coping capacity indicators. The inputs of experts, extension officers and farmers residing in the study areas were assessed. This was then finalized with the arbitrary allocation of indexes for the different indicators by the research team.

The results showed a higher than expected hazard risk for the higher rainfall OR Tambo district. Vulnerability was also the highest in OR Tambo due mainly to serious land degradation and human, social and cultural factors. Resiliency on the other hand was also lower in OR Tambo, but not as dramatic as vulnerability, due to the potential of the natural resources, as well as soil and water availability. Drought risk, however, was the highest in OR Tambo. One would expect drought risk to be the highest in the arid Karoo region, but that was not the case due to low coping capacity and high

vulnerability of farmers in OR Tambo district. Drought risk was also the lowest in catchments with available water for irrigation, where farmers have the opportunity for diversification and stocking of fodder banks.

Drought Hazard Risk Assessment

Drought hazard indicators were discussed in detail in Chapter 4. Vulnerability and resilience indicators were discussed in Chapter 3. Drought risk assessment originates from the hazard, which is drought caused by too little precipitation and too much evaporation (Wilhite *et al.,* 2000; Wilhelmi & Wilhite, 2002). This chapter deals with the hazard (*H*) in the drought risk assessment equation:

$$R = \left(\frac{\boldsymbol{H}}{\boldsymbol{C_H}}\right) x \left[\frac{\sum(V_{econ}V_{env}V_{Soc})}{\sum(C_{econ}C_{env}C_{soc})}\right]$$

where: $H = f(H_P H_s)$

with: H_p = Probability for drought with a 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, within the context of this research, one cannot manage or control the rainfall and evaporation. In the case of irrigation agriculture C_H would probably have a number >1 since efficient water supply and water management can reduce the hazard risk, which is not the case with extensive livestock 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, it is 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 would be weather related, although scientists have also developed indicators based on the biological indicators affected by drought (Fouche *et al.*, 1985; 1992; Du Pisani, 1998).

The results for the hazard assessment, as discussed in detail in Chapter 4, are illustrated spatially in Figure 5.1. As already indicated previously in Chapter 4 precipitation, or the deviation of precipitation from the mean expressed as the SPEI value, was used as the preferred index for drought risk assessment in this study. The most influential factors contributing to the hazard rating in this study were exceedence probability, intensity and duration. The 12-month SPEI was used in this assessment as the index for drought hazard. McKee *et al.* (1993) found that for small time-scales such as the three- and six-months SPEI, each new month had a large impact on the period sum of precipitation, so it was easy to have the SPEI respond quickly and move from dry to wet periods. The discussion about the SPEI values in Chapter 4 clearly indicated that a SPEI of -1.5 should be used as a threshold for drought.

SPEI <-1.5 is an indication of severe drought whereas SPEI <-2 indicates extreme droughts. The assumption of drought based on a specific SPEI value, or any other meteorological indicator for that matter, must be challenged since vulnerabilities and drought impacts differ from region to region, from system to system and from community to community. Communal farmers farming on degraded land with no resources, for example, are much more vulnerable to dry periods of SPEI <-1.5 and might experience *man-made-droughts* already at SPEI <-1.2.

McKee *et al.* (1993) calculated drought magnitude (severity) as:

$$DM = -\left(\sum_{j=1}^{x} SPI_{ij}\right)$$

where *j* starts with the first month of the dry period and continues to increase until the end of the dry period (*x*) for any of the *i* time scales. The DM has units of months and will be numerically equivalent to the dry period duration if each month of the dry period has SPI = -1 (McKee *et al.,* 1993). The logic behind the use of magnitude or severity as a measure of drought is that the longer the dry period persists without a water recharge, the worse the magnitude is, as evapotranspiration continues to occur (McKee *et al.,* 1993).

McKee *et al.* (1993) calculated drought hazard by multiplying exceedence probability with drought severity to determine drought hazard as follows:

$$D^H = P^{SPI<-1.5} x D^S$$

where: D^H = Drought hazard

$P^{SPI<-1.5}$ = Exceedence probability for SPI <1.5[1]

D^S = Drought Severity

Drought severity is then calculated for each period with the 12-month SPEI by combining the duration or dry-month period with the intensity of the drought. For example, the area on the SPEI graph below SPEI -1.5 for a given period represents the drought severity. Therefore: Drought severity = Duration x Intensity

$$D^S = T^{SPI<1.5} I^{SPI<-1.5}$$

where: D^S = Drought Severity (magnitude)

$T^{SPI<-1.5}$ = Number of dry-months with SPI <-1.5

$I^{SPI<-1.5}$ = Intensity of dry period with SPI <-1,5

The above-mentioned methodology was applied to calculate drought severity for the total period of measurement for all catchments. Through these calculations the sum of severity could be calculated and used as an indicator for the drought hazard.

The sum of severity and the exceedence probability are correlated to determine the fit for the severity sum to be used as a drought indicator. Exceedence probability on its own only reflects the probability for a dry period of SPEI <-1.5 and does not reflect severity, whereas the sum of severity combines probability, duration and intensity. Severity sum was calculated for all quaternary catchments (Annexure 5A, Table 5A.1). The sum of severity was indexed on a scale of 1 to 5 and the drought hazard profile was developed for the three districts, Cacadu, Joe Gqabi and OR Tambo. See Figure 5.1.

[1] For purpose of this research SPI -1.5 is used

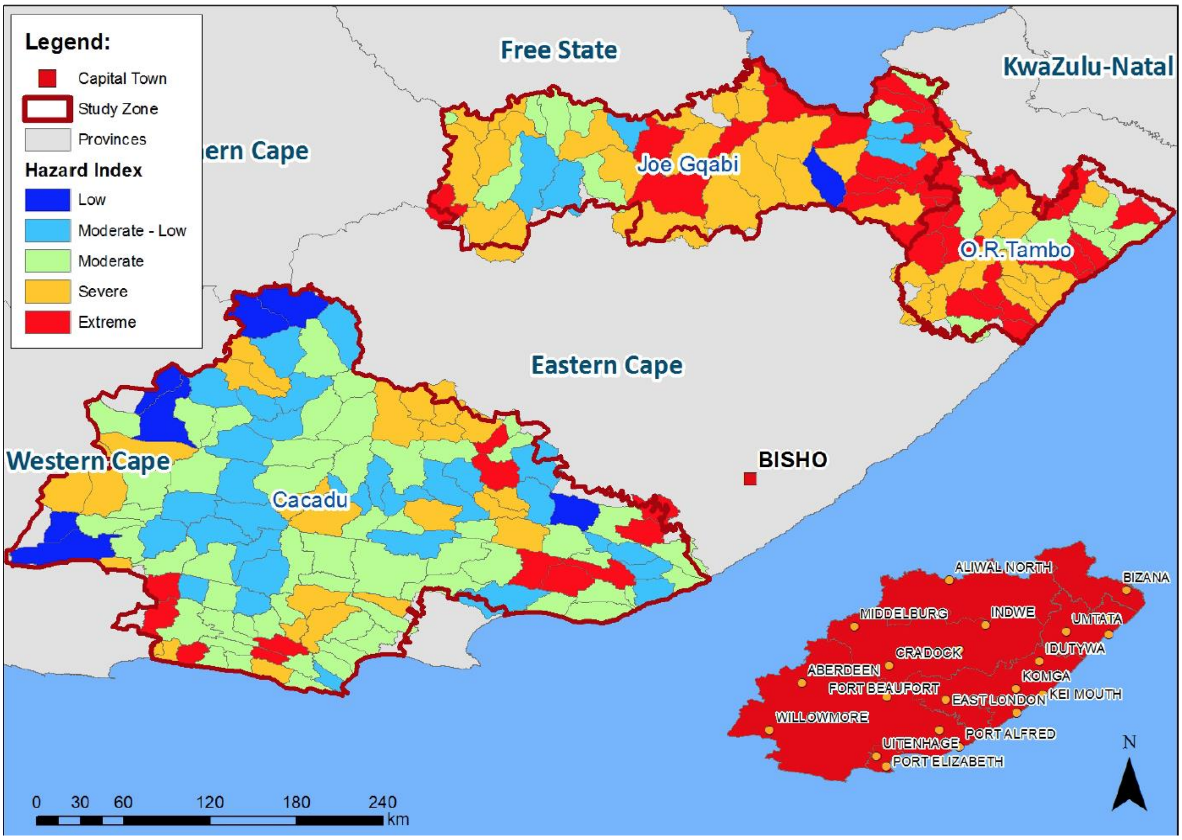

Fig. 5.1: Livestock sector drought hazard map for Northern Cape

It is interesting to note that the regions with the highest hazard severity are in fact the higher rainfall zones located in the OR Tambo district. High hazard risk zones, however, are also located in arid regions of Joe Gqabi. It is important to note that this map only shows the probability and intensity of drought based on historical meteorological data. It is not an indication of drought patterns for the next 100 years. More important for future forecasts for decision-making and policy adjustments is the assessment of the impact of droughts and the vulnerabilities and lack of coping capacity that causes dry spells to be droughts. The detailed hazard information for each quaternary catchment is shown Annexure 5A, Table 5A.1.

Vulnerability and Coping Capacity Indicators

Although rainfall, or rather the lack of rainfall, is regarded as the main indicator for drought and most of the known indices are related to rainfall, the *impact* of drought becomes the decisive factor when analysing drought risks. This chapter deals with the vulnerabilities, coping mechanisms or resilience to drought, as highlighted in the following equation.

$$R = \left(\frac{\boldsymbol{H}}{\boldsymbol{C_H}}\right) x \left[\frac{\sum(V_{hum}V_{soc}V_{cult}V_{fin}V_{inf}V_{env}V_{env})}{\sum(C_{hum}C_{soc}C_{cult}C_{fin}C_{inf}C_{env}C_{env})}\right]$$

As already discussed in a previous chapter, vulnerability, coping capacity and resilience are usually grouped as social, environment and economic, but this research proposes a more detailed classification according to the community capitals framework. Social, environmental and economic indicators are interrelated. For example, the deterioration of the environment has a direct impact on the productivity of animals on the veld, which then impacts economically on the farmer. Because of economic stress the farmer then experiences the social impacts of the disaster. If the farmer is not in a position to support the farm workers anymore the economic impact is then translated to the farm workers, and that has a social impact on them. The same impact is experienced in the village or town where the local economy to a large extent depends on the well-being of the farmers. In the context of this research the community capitals provides a more detailed framework and is used to calculate vulnerability and coping capacity, meaning that indicators are grouped under (i) human capital, (ii) social capital, (iii) cultural capital, (iv) financial capital, (v) infrastructure capital, (vi) environmental capital, and (vii) political capital.

Vulnerability is then calculated as follows:

$$V = \sum_{i=1}^{7} w_i V_i$$

$$V = f(w_1^{hum}\, V^{hum} w_1^{soc}, V^{soc}, w_1^{cult} V^{cult}, w_1^{fin} V^{fin}, w_1^{inf} V^{inf}, w_1^{env} V^{env}, w_1^{pol} V^{pol})$$

where: V^{hum} = Human capital vulnerability to drought hazard

V^{soc} = Social capital vulnerability to drought hazard

V^{cult} = Cultural capital vulnerability to drought hazard

V^{fin} = Financial capital vulnerability to drought hazard

V^{blt} = Infrastructure capital vulnerability to drought hazard

V^{env} = Environmental capital vulnerability to drought hazard

V^{pol} = Political capital vulnerability to drought hazard

w_i = Weight of vulnerability indicator *i.*

and, the weighted factor for V^{hum} = 0,12

weighted factor for V^{soc} = 0,04

weighted factor for V^{cult} = 0,10

weighted factor for V^{fin} = 0,27

weighted factor for V^{blt} = 0,08

weighted factor for V^{env} = 0,35

weighted factor for V^{pol} = 0,04

Coping capacity is calculated as follows:

$$C = \sum_{i=1}^{7} w_i C_i$$

$$C = f(w_1^{hum}C^{hum}, w_1^{soc}C^{soc}, w_1^{cult}C^{cult}, w_1^{fin}C^{fin}, w_1^{inf}C^{inf}, w_1^{env}C^{env}, w_1^{pol}C^{pol})$$

where: C^{hum} = Human capital vulnerability to drought hazard

C^{soc} = Social capital vulnerability to drought hazard

C^{cult} = Cultural capital vulnerability to drought hazard

C^{fin} = Financial capital vulnerability to drought hazard

C^{blt} = Infrastructure capital vulnerability to drought hazard

C^{env} = Environmental capital vulnerability to drought hazard

C^{pol} = Political capital vulnerability to drought hazard

w_i = Weight of vulnerability indicator *i.*

And, weighted factor for C^{hum} = 0,12

weighted factor for C^{soc} = 0,04

weighted factor for C^{cult} = 0,10

weighted factor for C^{fin} = 0,27

weighted factor for C^{blt} = 0,08

weighted factor for C^{env} = 0,35

weighted factor for C^{pol} = 0,04

The weighting of indicators are discussed in the next section.

5.1.1 Weighting of Indicators

In most cases the different indicators are not weighted owing to lack of data, hence they are considered as independent and equally important variables. That means that the effects of a certain combination of indicator values are not tested. The vulnerability of a farmer without tertiary education and with no other means of income, for example, is much higher than the vulnerability of a farmer with no tertiary education, but who diversifies with farms in other areas or other businesses. Similarly, the vulnerability of uneducated subsistence farmers with large families is much higher than those uneducated farmers with small families.

Weighting of indicators was important in the context of this research since composite indicators in most cases should bear a higher weight than individual indicators. Dwyer *et al.* (2004) reported that weight indicator values are in most cases determined according to subjective perceptions of the importance of some indicators. Davidson (1997) comes to the conclusion that *"no amount of clever mathematical manipulation will uncover the correct weights for social vulnerability indicators, because no single correct set of weights exists a priori"*. Some weighting techniques are derived from participatory methods such as analytical hierarchy processes (AHP) and budget locations; other methods include statistical models; a combination of statistical models and expert judgements; others from correlation analyses and problem tree analyses. Weighting can be very subjective in the absence of adequate data and proper modelling, but previous studies found have that weights based on experience of the researcher as well as inputs from experts in most cases were better than applying no weights at all (Dwyer, 2004; Damm, 2010; Jordaan, 2011). In the context of this research weights were allocated arbitrarily after consultations and inputs from experts, and they was also based on the following considerations:

1 Relevance of the indicator
2 Impact and importance of the indicator to vulnerability or resilience
3 Composite of single indicators (composite indicators have higher weights)
4 Data accuracy
5 The ability of an indicator to predict impacts that can be averted by management practices
6 Variability in response
7 The importance of the indicator to provide a basis for policy changes and action plans
8 The influence of the indicator to provide a basis for comparison across time and space

As a confirmation of Dwyer *et al.* (2004) and Jordaan's (2011) findings, the researchers' experience and first-hand knowledge of the topic attributed to the assurance of allocating weights. Dwyer *et al.* (2004) mentioned the importance of experience and expert knowledge as pre-requisites for weight allocation. The allocation of weights reflected the relative importance of each indicator, and that was discussed with, and tested with, farmers and other experts. Allocation of weights to the same indicators were repeated after 3 months and each new allocation was compared with the previous allocation; this method provided consistency and accuracy. The method of repeated weighting ratified the correctness of the arbitrary allocation and prevented impulsive decisions (Jordaan, 2011).

As indicated already, the final allocation of weights to the seven capitals were as follows:

- Human capital vulnerability or resilience 0,12
- Social capital vulnerability or resilience 0,04
- Cultural capital vulnerability or resilience 0,10
- Financial capital vulnerability or resilience 0,27
- Infrastructure capital vulnerability or resilience 0,08
- Environmental capital vulnerability or resilience 0,35
- Political capital vulnerability or resilience 0,04

Indicators were also weighted according the same methodology. It was interesting to note that the natural scientists interviewed allocated the highest weighting to natural resources, stating that "…you *cannot make a success on a bad farm".* Commercial farmers, on the other hand, allocated a higher rating to human capital, stating that *".a good manager through initiative and hard work can make a success on any farm as long as you farm according the potential of the farm".* Communal farmers as a group, however, rate financial capital as the most important, stating *".without money you cannot do anything".* The highest rating of 0,35 was allocated to environmental capital followed by financial capital. One of the main contributing factors to the importance of environmental capital was the inclusion of predators under environmental capital. Livestock farmers reported much higher losses as a result of predators than drought losses. This concurs with what was found by Jordaan (2011) in the Northern Cape.

5.1.2 Community Capitals Framework

Data were the major challenge for the development of vulnerability and coping capacity assessments. Except for environmental data, which was available per catchment, all other data were captured per district or per municipality. The availability of meta data was also a challenge. The calculation of vulnerability and coping capacity in this report was therefore based on data generated as follows:

- Where available, the use of meta data and actual data from previous reports,
- GIS data from previous studies,

- Expert inputs from scientists, extension officers and farmers,
- Individual observations and inputs from the research team, and
- Combining census data with individual observations.

The large number of indicators used limited potential errors with individual indicators. Calculating human capital, social capital, cultural capital and political capital is mostly qualitative. Follow-up research might be required to test the results.

5.1.1.1 Human capital vulnerability and coping capacity (weight; 0,12)

The following equations were used to calculate the index for human capital vulnerability and coping capacity for each quaternary catchment:

$$V^{hum} = \sum_{i=1}^{3} w_i^{hum} V_i^{hum}$$

$$V^{hum} = f(w_1^{edu} V_1^{edu} w_2^{age} V_2^{age} w_3^{hea} V_3^{hea})$$

where: V_1^{edu} = Highest education level index

V_2^{age} = Age index

V_3^{hea} = Health status index

and w_1^{edu} = weighting factor for education level index = 0,50

w_1^{age} = weighting factor for age index = 0,20

w_1^{soc} = weighting factor for health status index = 0,30

Indexing for each vulnerability indicator was undertaken as shown in the following tables.

Table 5.1: Index guidelines for vulnerability – education

Index	Guideline
1	> 50% of farmers with tertiary education
2	> 70% of farmers with secondary education
3	> 50% of farmers with secondary education
4	< 50% of farmers with secondary education
5	< 25% of farmers with secondary education

Table 5.2: Index guidelines for vulnerability – age

Index	Guideline
1	> 80% of farmers between 20 - 50
2	> 60% of farmers between 20 - 50
3	> 50% of farmers with secondary education
4	26% - 40% of farmers between 20 - 50
5	< 25% of farmers between 20 - 50

Table 5.3: Index guidelines for vulnerability – health status

Index	Guideline
1	Most farmers are very healthy
2	Some farmers of farmers suffer from stress and other health related symptoms
3	Large number of farmers suffer from stress and other health related symptoms
4	Majority of farmers suffer from stress and other health related symptoms
5	Vast majority of farmers are under-nourished and suffer from a disease

The detailed results for human capitals vulnerability is shown in Attachment 5-A, Table 5A.1.

Coping capacity calculation for human capitals was done as follows:

$$C^{hum} = \sum_{i=1}^{2} w_i^{hum} C_i^{hum}$$

$$C^{hum} = f(w_1^{pers} C_1^{pers}, w_2^{exp} C_2^{exp}, w_3^{ment} C_3^{ment}, w_3^{mng} C_3^{mng}) ,$$

where: C_1^{pers} = perseverance index

C_2^{exp} = Experience index

C_4^{ment} = Exposure to mentorship nets

C_4^{exp} = Management skills index

Indexing for each vulnerability indicator was done as shown in the following tables.

Table 5.4: Index guidelines for coping capacity - perseverance

Index	Guideline
1	No perseverance. No effort to try and survive dry spells
2	Little perseverance. Farmers dependent
3	Farmers show signs of perseverance
4	Majority of farmers show perseverance
5	Vast majority of farmers show very strong perseverance

Table 5.5: Index guidelines for coping capacity - experience

Index	Guideline
1	Farmers with no experience of dry spells or droughts
2	Some farmers survived at least one dry spell
3	Some farmers survived a few dry spells
4	Majority of farmers survived more than three droughts
5	Vast majority of farmers well educated and survived many dry spells

Table 5.6: Index guidelines for coping capacity – exposure to mentorship

Index	Guideline
1	No proper mentorship for farmers when young
2	Some farmers recalled some mentorship, but with little impact
3	Some farmers reported assistance from a mentor when young
4	Majority of farmers received support from mentors when young
5	Vast majority of farmers was supported by mentors when starting

Table 5.7: Index guidelines for coping capacity – management

Index	Guideline
1	No indication of good management
2	Minority of farmers with good management practices
3	In general, indications of acceptable management practices
4	Majority of farmers with good management practices
5	Excellent management skills by vast majority of farmers

The index for human capital coping capacity was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

5.1.1.2 Social capital vulnerability and resilience (weight; 0,04)

The following equations were used to calculate the index for social capital vulnerability and resilience for each quaternary catchment.

$$V^{soc} = \sum_{i=1}^{3} w_i^{soc} V_i^{soc}$$

$$V^{soc} = f(w_1^{net} V_1^{net}, w_3^{sup} V_3^{sup}, w_2^{safe} V_2^{safe},)$$

where: V_1^{net} = Formal network index (farmers associations, etc)

V_2^{sup} = Informal support structures index

V_3^{safe} = Safety and security index

and, w_1^{soc} = f(w_1^{net}, w_1^{sup}, w_1^{safe})

w_1^{net} = weighting factor for formal networks level index = 1

w_1^{sup} = weighting factor for informal support structures index = 1

w_1^{safe} = weighting factor for safety and security index = 1

The index for social capital vulnerability was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

Indexing for each vulnerability indicator was done as shown in the following tables.

Table 5.8: Index guidelines for vulnerability – formal networks

Index	Guideline
1	Well established and actively support farmers
2	Well established, but not all farmers are supported
3	Some formal networks with medium to low impact
4	Some formal networks but totally inefficient
5	No formal networks

Table 5.9: Index guidelines for vulnerability – informal support structures

Index	Guideline
1	Well established and very active
2	Well established, but in support to selected farmers
3	Established and sometimes support farmers
4	Established but do not really support farmers
5	No informal networks

Table 5.10: Index guidelines for vulnerability – safety and security

Index	Guideline
1	Absolutely secure. No incidence of stock theft
2	Slightly insecure. Few incidences of stock theft with small impact on management
3	Slightly insecure. Stock theft impact on management planning
4	Insecure. Stock theft is a big problem with impact on drought risk
5	Highly insecure. High incidence of crime and stock theft

The detailed results for social capitals vulnerability are shown in Annexure 5A, Table 5A.1.

Coping capacity calculation for financial capitals was done as follows:

$$C^{soc} = \sum_{i=1}^{2} w_i^{soc} C_i^{soc}$$

$$C^{soc} = f(w_1^{inst} C_1^{inst}, w_2^{sup} C_2^{sup}, w_3^{pvt} C_3^{pvt}, w_3^{inf} C_3^{inf}),$$

where: C_1^{inst} = Formal farming institutions index

C_2^{sup} = Informal farming support structures index

C_4^{pvt} = Private extension support index

C_4^{inf} = Exposure to information index

and w_1^{inst} = weighting factor for formal farming institutions index = 0,30

w_2^{sup} = weighting factor for informal farming support structures index = 0,40

w_2^{pvt} = weighting factor for private extension support index = 0,30

w_2^{inf} = weighting factor for access to information index = 0,30

Table 5.11: Index guidelines for coping capacity – formal farming institutions

Index	Guideline
1	No formal farming institutions
2	Some formal farming institutions, but with little impact
3	Farming institutions exist and represent some farmers successfully
4	Well established and actively assist majority of farmers
5	Well established and actively represent all farmers

Table 5.12: Index guidelines for coping capacity – informal farming support structures

Index	Guideline
1	No informal farming structures
2	Some indications of informal institutions with impact
3	Informal institutions sometimes active
4	Developed and actively supported by some farmers
5	Well developed and actively supported by majority of farmers

Table 5.13: Index guidelines for coping capacity – private extension support

Index	Guideline
1	No support from private sector
2	Little interaction with private sector
3	Irregular interaction
4	Active and regular interaction
5	Very active and regular (weekly) interaction

Table 5.14: Index guidelines for coping capacity – access to information

Index	Guideline
1	No access
2	Some farmers with access to radio
3	Access to TV, radio. No internet.
4	Good access. TV, radio, internet
5	Extremely good access. Majority of farmers have internet

The index for social capital coping capacity was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

5.1.1.3 Cultural capital vulnerability and resilience (weight; 0,10)

The following equation was used to calculate the index for cultural capital vulnerability and resilience for each quaternary catchment.

$$V^{cul} = \sum_{i=1}^{2} w_i^{cul} V_i^{cul}$$

$$V^{cul} = f(w_1^{dep} V_1^{dep}, w_2^{inn} V_2^{inn}, w_3^{pers} V_3^{pers}, w_4^{ind} V_4^{ind})$$

where: V_1^{dep} = Dependency index (dependency syndrome; depending on government)

V_2^{gen} = gender equality and beliefs

V_3^{pers} = Cultural beliefs

and w_1^{dep} = weighting factor for dependency level index = 0,6

w_2^{gen} = weighting factor for gender equality index = 0,1

w_3^{pers} = weighting factor cultural beliefs index = 0,3

The index for cultural capital vulnerability was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

Indexing for each vulnerability indicator was done as shown in the following tables.

Table 5.15: Index guidelines for vulnerability – dependency planning

Index	Guideline
1	No dependency on government support
2	Little dependency
3	Some farmers depend on government for support
4	High dependency
5	Extremely high dependency on government support

Table 5.16: Index guidelines for vulnerability – gender equality

Index	Guideline
1	Absolutely no discrimination. Women fully integrated in all agriculture activities
2	Women integrated, but not in all activities
3	Some discrimination against women
4	Discrimination against women

5	High discrimination against women

Table 5.17: Index guidelines for vulnerability – cultural beliefs

Index	Guideline
1	Culture play absolute no role in decision making
2	Culture has a small impact on management decisions
3	Some management decisions influenced by culture
4	Most management decisions influenced by culture
5	Cultural beliefs highly influenced management decisions

The detailed results for social capitals vulnerability are shown in Table A1, Attachment 6-A

Coping capacity calculation for financial capitals was done as follows:

$$C^{fin} = \sum_{i=1}^{2} w_i^{cul} C_i^{cul}$$

$$C^{cul} = f(w_1^{inn} C_1^{inn}, w_2^{pers} C_2^{pers}, w_3^{exp} C_3^{exp}) ,$$

where: C_1^{inn} = innovative planning index

C_2^{pers} = work ethic index

C_4^{exp} = experience safety nets

and w_1^{inc} = weighting factor for innovative planning index = 0,3

w_2^{sens} = weighting factor for perseverance index = 0,4

w_2^{mark} = weighting factor for experience index = 0,3

Indexing for each coping capacity indicator was done as shown in the following tables.

Table 5.18: Index guidelines for coping capacity – innovative planning

Index	Guideline
1	No innovative planning at all
2	Very few innovative ideas for drought coping
3	Some farmers have innovative ideas for drought coping
4	Majority of farmers show innovative ideas for drought survival
5	Vast majority of farmers show innovative use of plans to survive droughts

Table 5.19: Index guidelines for coping capacity – work ethics

Index	Guideline
1	No work ethic. Farmers have no interest in coping with drought
2	Some work ethic and farmers not always involved in farming
3	Good work ethic amongst most farmers. Most stay on farm
4	High work ethic. Farmers stay on farm

5	Extremely high work ethic. Farmers stay on farm

Table 5.20: Index guidelines for coping capacity – experience

Index	Guideline
1	No farming experience at all
2	Farming experience, but no experience of dry spells
3	Most farmers have farming experience, but little experience in coping with drought
4	Majority of farmers with experience and have coped with a drought and dry spells
5	Vast majority highly experienced and have coped with numerous extreme droughts

The Index for social capital coping capacity was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

5.1.1.4 Financial capital vulnerability and resilience (weight; 0,27)

The following equation was used to calculate the index for financial capital vulnerability and resilience for each quaternary catchment.

$$V^{fin} = \sum_{i=1}^{2} w_i^{fin} V_i^{fin}$$

$$V^{fin} = f(V_3^{sens}, w_4^{mark} V_4^{mark}, w_4^{unem} V_4^{unem},) \text{ ,}$$

where: V_3^{sens} = Price sensitivity of products index

V_4^{mark} = Market access index

V_4^{unem} = Unemployment rate index

and w_1^{sens} = weighting factor for product price sensitivity index = 0,3

w_1^{mark} = weighting factor for market access index = 0,4

w_1^{unem} = weighting factor for unemployment rate index = 0,3

Indexing for each vulnerability indicator was done as shown in the following tables.

Table 5.21: Index guidelines for vulnerability – product price sensitivity

Index	Guideline
1	No price sensitivity as result of drought
2	Little price sensitivity
3	Price sensitivity to some products
4	High price sensitivity
5	Extremely high price sensitivity

Table 5.22: Index guidelines for vulnerability – market access

Index	Guideline
1	Excellent market access at all times with high demand
2	Good market access
3	Good market access but far from market
4	Limited market access. Only one buyer
5	No market access

Table 5.23: Index guidelines for vulnerability – unemployment

Index	Guideline
1	No unemployment
2	Some unemployment
3	Significant unemployment
4	More than 50% unemployment
5	> 70% unemployment

The Index for financial capital vulnerability was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

Coping capacity calculation for financial capitals was done as follows:

$$C^{fin} = \sum_{i=1}^{2} w_i^{fin} C_i^{fin}$$

$$V^{fin} = f(w_1^{alt} C_1^{alt}, w_2^{inc} C_2^{inc}, w_3^{fin} C_3^{fin}, w_3^{fod} C_3^{fod})\ ,$$

where: C_1^{alt} = Alternative on-farm income index

C_2^{inc} = Alternative off-farm income index

C_4^{fin} = Financial safety nets index

C_4^{fod} = Fodder banks

and w_1^{alt} = weighting factor for alternative on-farm income index = 0,3

w_1^{inc} = weighting factor for alternative off-farm income index = 0,1

w_1^{fin} = weighting factor for financial safety net index = 0,3

w_1^{fod} = weighting factor for fodder banks index = 0,3

Indexing for each coping capacity indicator was done as shown in the following tables.

Table 5.24: Index guidelines for coping capacity – alternative on-farm income

Index	Guideline
1	No alternative income. Only 1 product, e.g. mutton
2	Potential income from maximum of 2 products e.g. wool/mutton
3	Income from livestock and dry land crops
4	Potential income from 4 products with limited irrigation
5	Potential income from at least 4 products including irrigation, e.g. dairy

Table 5.25: Index guidelines for coping capacity – alternative off-farm income

Index	Guideline
1	No potential for additional income
2	Limited potential for income outside agriculture
3	Additional income potential
4	Additional income through agri-tourism and others
5	Much potential for additional income e.g. tourism, processing, etc.

Table 5.26: Index guidelines for coping capacity – financial safety nets

Index	Guideline
1	No financial safety net
2	Limited financial safety nets
3	Some farmers have adequate financial safety nets
4	Access to safety nets, but low uptake
5	Access to financial safety nets

Table 5.27: Index guidelines for coping capacity – fodder banks

Index	Guideline
1	No fodder banks at all
2	Very few farmers with limited fodder banks
3	Many farmers with fodder banks
4	Majority of farmers with fodder banks
5	All farmers have own fodder banks from irrigation

The Index for financial capital coping capacity was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

5.1.1.5 Infrastructure capital vulnerability and resilience (weight; 0,08)

The following equations were used to calculate the index for infrastructure capitals vulnerability and resilience for each quaternary catchment.

$$V^{inf} = \sum_{i=1}^{2} w_i^{inf} V_i^{inf}$$

$$V^{inf} = f(w_1^{irr} V_1^{irr}, w_2^{com} V_2^{com}, w_3^{pln} V_3^{pln}) ,$$

where: V_1^{irr} = Irrigation infrastructure index

V_2^{inc} = Communication access index

V_3^{pln} = Land planning index (Fencing, water reticulation)

and w_1^{irr} = weighting factor for irrigation infrastructure index = 0,3

w_1^{com} = weighting factor for communication access index = 0,1

w_1^{pln} = weighting factor for farm infrastructure planning index = 0,6

Coping capacity calculation for infrastructure capitals was done as follows:

$$C^{inf} = \sum_{i=1}^{2} w_i^{inf} C_i^{inf}$$

$$C^{inf} = f(w_1^{irr} C_1^{irr}, w_2^{fenc} C_2^{fenc}, w_3^{art} C_3 \ ) \ ,$$

where: C_1^{irr} = Irrigation infrastructure index

C_2^{fenc} = Fencing index

C_4^{art} = Water reticulation index

and w_1^{irr} = weighting factor for irrigation index = 0,3

w_1^{fenc} = weighting factor for fencing index = 0,4

w_1^{art} = weighting factor for water reticulation index = 0,3

Indexing for each vulnerability indicator was done as shown in the following tables.

Table 5.28: Index guidelines for coping capacity – irrigation

Index	Guideline
1	No irrigation
2	Only small irrigation potential from groundwater only
3	Irrigation systems on number of farms from groundwater only
4	Irrigation from groundwater, rivers and streams
5	Full irrigation potential and well developed

Table 5.29: Index guidelines for coping capacity – fencing

Index	Guideline
1	No fencing and camp system
2	Some fencing, but poorly maintained
3	Fenced and signs of poor maintenance
4	Most of the area fenced
5	All farms fully planned with good fences

Table 5.30: Index guidelines for coping capacity – water reticulation

Index	Guideline
1	No water reticulation. Animals have to walk long distances for water
2	Some water reticulation on some farms
3	Water reticulation in most camps but some camps without water during dry spells
4	Most farms well planned with drinking water in most camps
5	All farms well planned with clean drinking water in all camps

The index for infrastructure capital coping capacity was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

5.1.1.6 Environmental capital vulnerability and coping capacity (weight; 0,35)

The following equations were used to calculate the index for environmental capital vulnerability and coping capacity for each quaternary catchment.

$$V^{env} = \sum_{i=1}^{2} w_i^{env} V_i^{env}$$

$$V^{env} = f(w_1^{deg} V_1^{deg}, w_2^{land} V_2^{land}, w_3^{mount} V_3^{mount}, w_4^{pred} V_4^{pred}) \ ,$$

where:

V_1^{deg} = Land degradation index (land degradation is a composite indicator that includes overgrazing and encroachment of unwanted species)

V_2^{deg} = Land degradation index

V_3^{land} = Land use index

V_4^{mount} = Mountainous index

V_4^{pred} = Predator threat index

and w_1^{deg} = weighting factor for land degradation index = 0,6

w_1^{land} = weighting factor for land use index = 0,2

w_1^{mount} = weighting factor for mountainous index = 0.1

w_1^{pred} = weighting factor for predator threat index = 0,1

Indexing for each vulnerability indicator was done as shown in the following tables.

Table 5.31: Index guidelines for vulnerability – land degradation

Index	Guideline
1	No signs of degradation at all
2	Limited degradation
3	Degraded
4	Highly degraded
5	Extremely degraded

Table 5.32: Index guidelines for vulnerability – land use

Index	Guideline
1	100% secure property rights with agriculture use
2	Secure property rights, but leased out
3	Open access. Good control by land owners and or Chiefs
4	Totally open access. Some and regulated somewhat by chiefs/land owners
5	Totally open access. No regulation

Table 5.33: Index guidelines for vulnerability – mountainous

Index	Guideline
1	No mountains
2	Low mountains
3	Medium sized mountains
4	High mountains. Limited navigation by small roads. 4X4 only.
5	High mountains. Navigation only on foot

Table 5.34: Index guidelines for vulnerability – predator threat

Index	Guideline
1	No threat at all
2	Small predator threat
3	Significant predator threat
4	High predator threat. Have to kraal livestock during lambing season. 20% progeny loss
5	High predator threat. Have to kraal livestock always. >50% progeny loss

Coping capacity calculation for environmental capitals was done as follows:

$$C^{env} = \sum_{i=1}^{2} w_i^{env} C_i^{env}$$

$$V^{env} = f(w_1^{soil} C_1^{soil}, w_2^{grnd}\, C_2^{grnd}, w_3^{surf}\, C_3^{surf})\ ,$$

where: C_1^{soil} = Soil quality index

C_2^{grnd} = Groundwater supply index

C_4^{surf} = Surface water supply index

and w_1^{soil} = weighting factor for soil quality index = 0,3

w_1^{grnd} = weighting factor for groundwater supply index = 0,2

w_1^{surf} = weighting factor for surface water supply index = 0,5

Indexing for each coping capacity indicator was done as shown in the following tables.

Table 5.35: Index guidelines for coping capacity – soil quality

Index	Guideline
1	Extremely low soil quality
2	Low quality soil. Good for grazing
3	Medium quality soil. Good for pastures
4	Good quality soil. Good for crops and irrigation
5	High quality soil. Good for high potential crops

Table 5.36: Index guidelines for coping capacity – groundwater supply

Index	Guideline
1	No groundwater
2	Groundwater available in normal years, but not during dry spells
3	Relatively good groundwater supply
4	Good groundwater supply with boreholes
5	Extremely good groundwater supply

Table 5.37: Index guidelines for coping capacity – surface water supply

Index	Guideline
1	No surface water available
2	Limited supply of surface water during rainy season
3	Surface water only during rainy season
4	Adequate surface water during all seasons
5	Abundance surface water during all seasons

The Index for environmental capital coping capacity was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

5.1.1.7 Political capital vulnerability (weight; 0,04)

The following equation was used to calculate the index for political capital vulnerability for each quaternary catchment.

$$V^{pol} = \sum_{i=1}^{2} w_i^{pol} V_i^{pol}$$

$$V^{pol} = f(w_1^{plns} V_1^{plns}, w_2^{gov} V_2^{gov} w_2^{own} V_2^{own}) ,$$

where: V_1^{plns} = Drought relief plans index

V_2^{gov} = Government efficiency index

V_2^{gov} = Ownership of land index

And, w_1^{plns} = Drought relief plans index = 4

w_1^{gov} = Government efficiency index = 1

w_1^{own} = Ownership of land index = 1

Indexing for each vulnerability indicator was done as shown in the following tables.

Table 5.38: Index guidelines for vulnerability – drought relief plans

Index	Guideline
1	Well documented drought contingency plan
2	Drought contingency handled successfully by officials
3	Drought contingency sometimes activated by officials
4	Plans handled on ad hoc basis by extension officers
5	No plans at all

Table 5.39: Index guidelines for vulnerability – government efficiency

Index	Guideline
1	100% efficiency from government officials
2	Most official operate efficiently
3	Inefficiency by some officials
4	Inefficient
5	Totally inefficient

Table 5.40: Index guidelines for vulnerability – ownership of land

Index	Guideline
1	100% secure and private ownership
2	Private ownership
3	Some private ownership, but good control
4	Open access, tragedy of commons
5	No control over land. Total open access

Coping capacity calculation for environmental capitals was done as follows:

$$C^{pol} = \sum_{i=1}^{2} w_i^{pol} C_i^{pol}$$

$$C^{pol} = f(w_1^{rel} C_1^{rel}, w_2^{ext} C_2^{ext},) \ ,$$

where: C_1^{rel} = drought relief to farmers index

C_2^{ext} = Government extension to farmers index

and w_1^{rel} = weighting factor for drought relief index = 0,4

w_1^{ext} = weighting factor for Government extension = 0,6

Indexing for each coping capacity indicator was done as shown in the following tables.

Table 5.41: Index guidelines for coping capacity – drought relief

Index	Guideline
1	No drought relief
2	Some drought relief during extreme droughts
3	Drought relief during most droughts
4	Good drought relief during most dry spells
5	Regular and good support from Government

Table 5.42: Index guidelines for coping capacity – government extension

Index	Guideline
1	No extension
2	Inadequate extension support
3	Some extension support
4	Good extension support
5	Extremely high quality extension support

The index for environmental capital coping capacity was calculated for each quaternary catchment and results are shown in Annexure 5A, Table 5A.1.

Results of the Vulnerability and Coping Capacity Assessment

A summary of the results for vulnerability for each of the capitals per district is shown in Table 5.43 and illustrated in Figure 5.2. According to these results, OR Tambo was extremely vulnerable with an average vulnerability index of more than 4[2]. Cacadu as a district was the least vulnerable to drought even though it was the most arid district. This is again proof that aridity and drought are two separate concepts and one cannot simply classify high drought vulnerability to arid regions.

[2] One is low vulnerability and 5 is high vulnerability.

Table 5.43: Mean vulnerability indices per capital per district

	Human	Social	Culture	Financial	Environm.	Political
Cacadu	2,03	1,95	1,05	1,83	1,70	2,68
Joe Gqabi	2,48	2,84	1,83	2,16	2,69	3,42
OR Tambo	3,98	3,68	4,42	4,61	3,83	4,67

Figure 5.3 is a radar graph illustrating results for vulnerability to drought according to the CCF7 analysis.

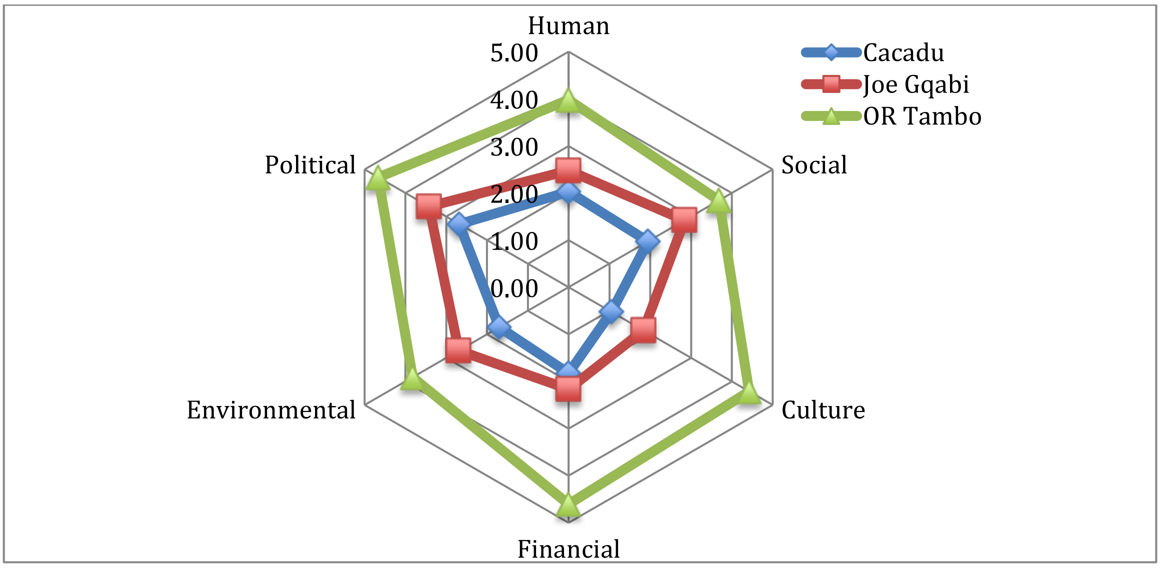

Fig 5.2: Vulnerability indices per capital per district

The detailed results per quaternary catchment are shown in Annexure 5A, Table 5A.1 and illustrated in the map in Figure 5.3.

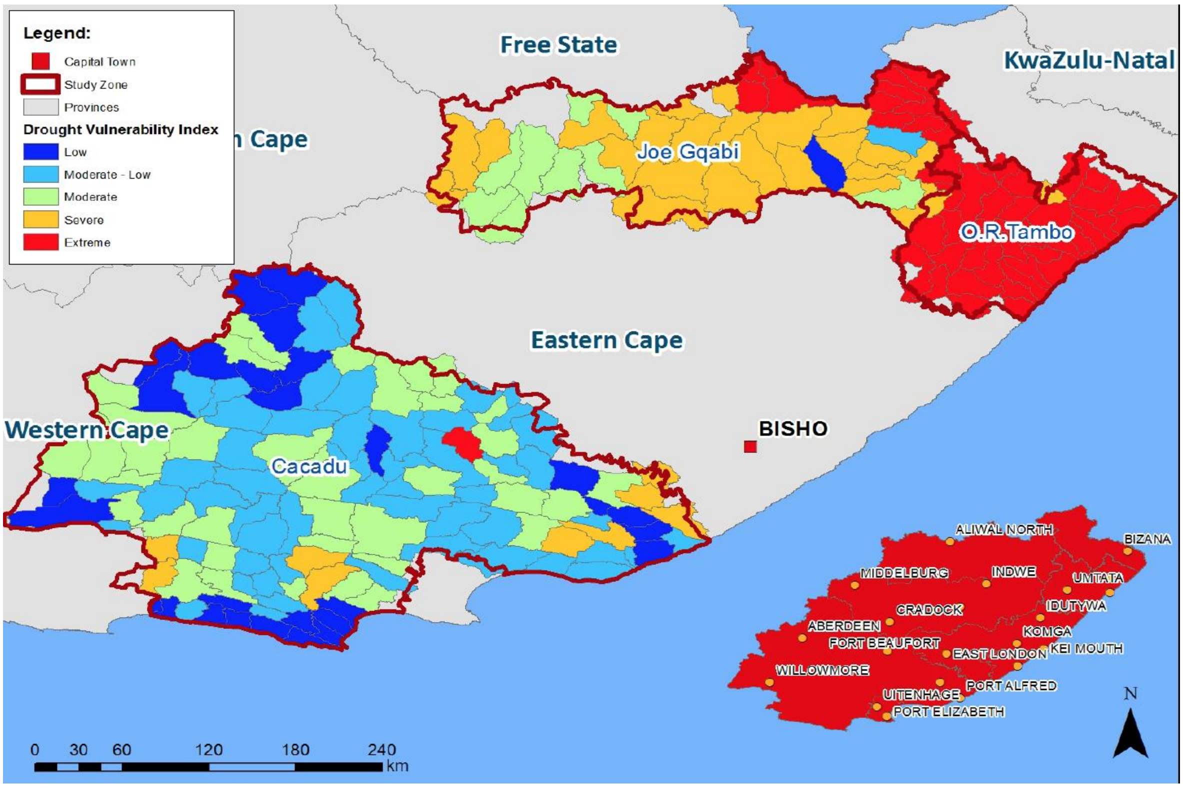

Fig 5.3: Drought vulnerability map for Cacadu, Joe Gqabi and OR Tambo District Municipalities

Vulnerability and coping capacity are key elements in drought risk in that these represent man-made factors that one can address in order to reduce drought risk. Drought hazard based on precipitation and evapotranspiration is a given within which farmers have to plan. Drought risk was the highest in OR Tambo district, which might be a surprise to most as this is the district with the highest average annual precipitation. High vulnerability and low coping capacity combined with hazard risk was responsible for the high drought risk in the OR Tambo district. Drought vulnerability was the highest in OR Tambo as illustrated in Figure 5.3.

In spite of the relatively high precipitation in OR Tambo, vulnerability to drought was the highest due mainly to high land degradation, which in turn was partly the result of the communal land use system. Other factors that also contributed to high vulnerability were the land ownership system with open access to land, and social factors such as low levels of education, a dependency syndrome, and cultural beliefs. This was also true for the Sterkspruit region within the Joe Gqabi district. The value of this assessment, however, is not only in the spatial illustration of drought risk, but rather in the identification of vulnerability and resilience factors. Coping capacity results for each of the capitals were also calculated for each district. It was clear from the results shown in Table 5.44 and illustrated in Figure 5.5 that coping capacity was the highest in Cacadu and the lowest in OR Tambo[3]. The relatively high index for the environmental capital was mainly the result of the high quality soil and high rainfall. The fact that the land was degraded and overgrazed was over-shadowed by the natural potential of the region.

Table 5.44: Mean Coping capacity indices per capital per district

	Human	Social	Culture	Finance	Infrastr	Environ.	Political
Cacadu	2,74	3,63	4,22	3,21	3,83	3,00	1,41
Joe Gqabi	2,55	2,59	3,65	2,47	3,31	3,04	1,80
OR Tambo	1,85	1,79	2,79	1,05	1,94	4,30	2,40

The results for the capitals for each district are illustrated in the radar graph in Figure 5.4.

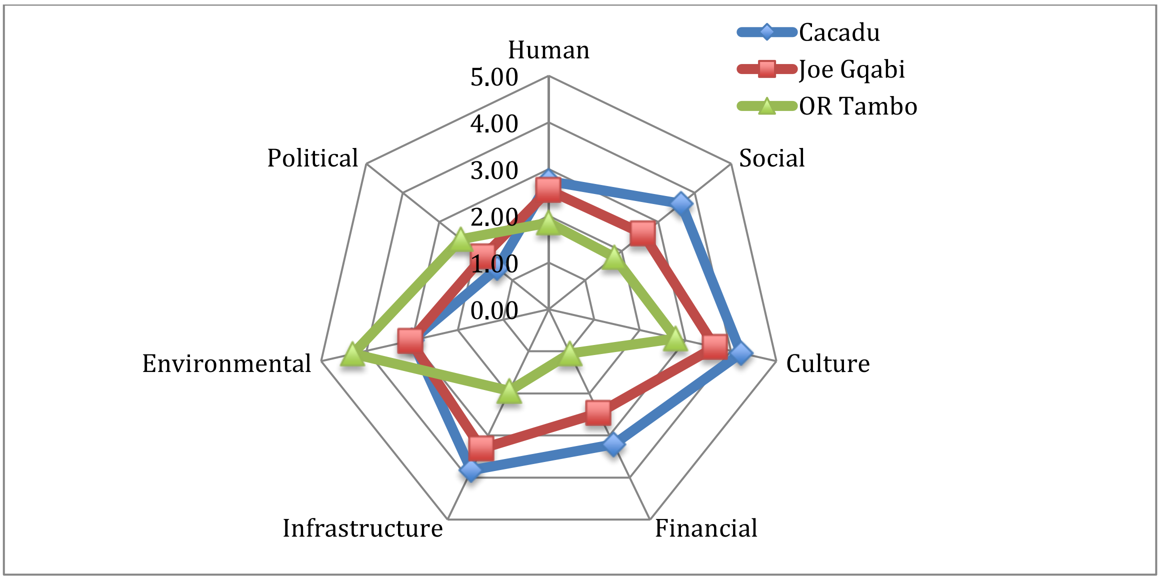

Fig 5.4: Coping capacity indices per capital per district

Coping capacity was also relatively low in OR Tambo, due mainly to human, social, financial and political factors. Soil quality and the availability of surface water due to the relatively high precipitation, on the other hand, increased the values for coping capacity. Catchments with high coping capacity were those with access to irrigation, since farmers then had alternative income sources and they could provide own feed and fodder during dry spells.

The map for coping capacity for each of the catchments is illustrated in Figure 5.5. Communal lands belonging to municipalities are not clearly illustrated on the maps due to the small scale in relation to

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[3] Low coping capacity is 1 and high coping capacity is 5.

catchment size, but all communal land had the same characteristics and were even worse than the communal land in the OR Tambo district. The Sterkspruit area within the Joe Gqabi district is a typical example of communal land that was extremely vulnerable with little coping capacity.

The net index scores for each of the capitals were also calculated and they are shown in Annexure 5A, Table 5A.2. The negative values were an indication of vulnerable catchments while catchments with positive values indicated resilience. The higher the values the more resilient those catchments were against dry periods and drought. The method of calculating the net index score for each of the capitals has not been done before. No evidence was found in the literature of others using a similar methodology and we therefore recommend further research on the use of the net index score for the capitals as an indication of vulnerability or resilience.

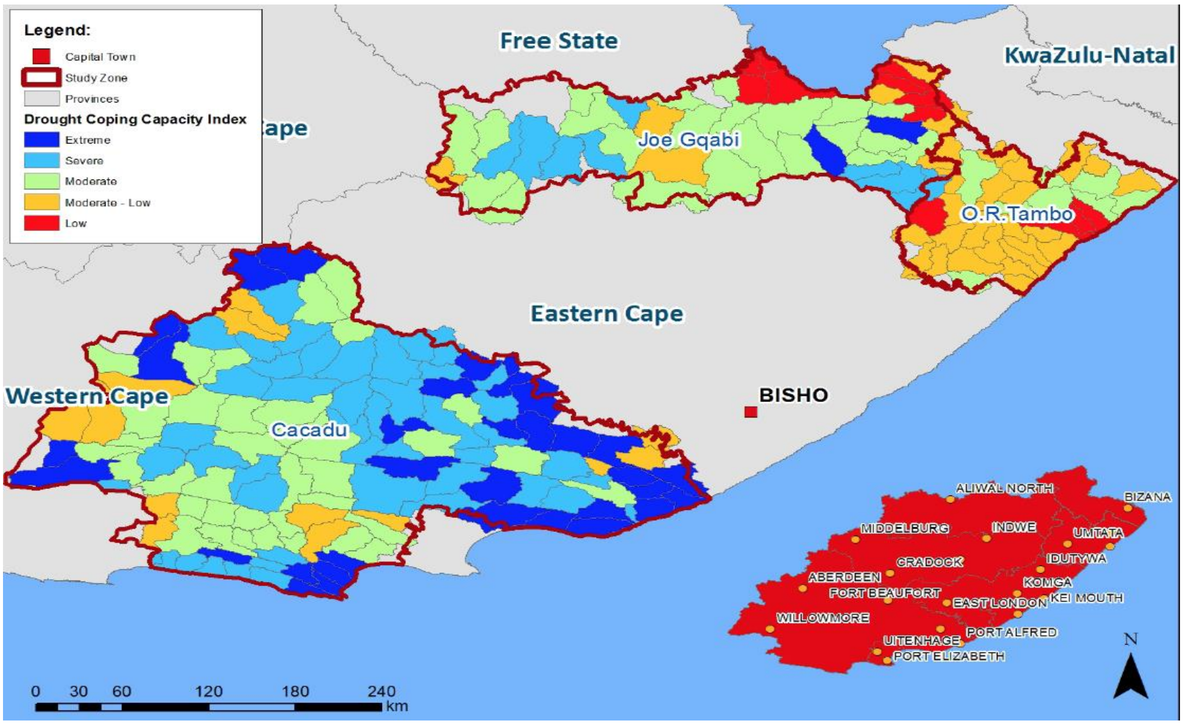

Fig 5.5: Drought coping capacity map for the Cacadu, Joe Gqabi and OR Tambo District Municipalities

The final results for the drought risk assessment are shown in Figure 5.6. The OR Tambo district was the district with the highest drought risk in spite of the fact that it is the district with the highest annual precipitation. Communal farmers in the district experienced normal dry periods as droughts simply because they did not have capacity to withstand dry periods, and they were extremely vulnerable to any exogenous shock. Cacadu district seems to be more resilient against dry periods and droughts because farming systems were well adapted to arid conditions. Most commercial farmers farm with wool sheep and goats, which are well adapted to dry climatic conditions. Irrigation water also played an important role in making farming systems more resilient. The irrigation areas of the Orange-Fish irrigation system, the coastal areas of Alexandria and west of Humansdorp are clearly illustrated on Figure 5.6. Other catchments with higher resilience within Cacadu were areas where farmers applied a conservative grazing capacity and they had access to groundwater for irrigation.

The Sterkspruit area, the communal land in the Mount Fletcher area and municipal land were the most vulnerable areas in the Joe Gqabi district. The Sterkspruit area is probably the most vulnerable area to drought in all the districts and requires serious interventions. Soil erosion as a result of extreme overgrazing was evident in the whole Sterkspruit area. The region is home to a large population with extreme poverty and, combined with high unemployment, this renders that area extremely vulnerable.

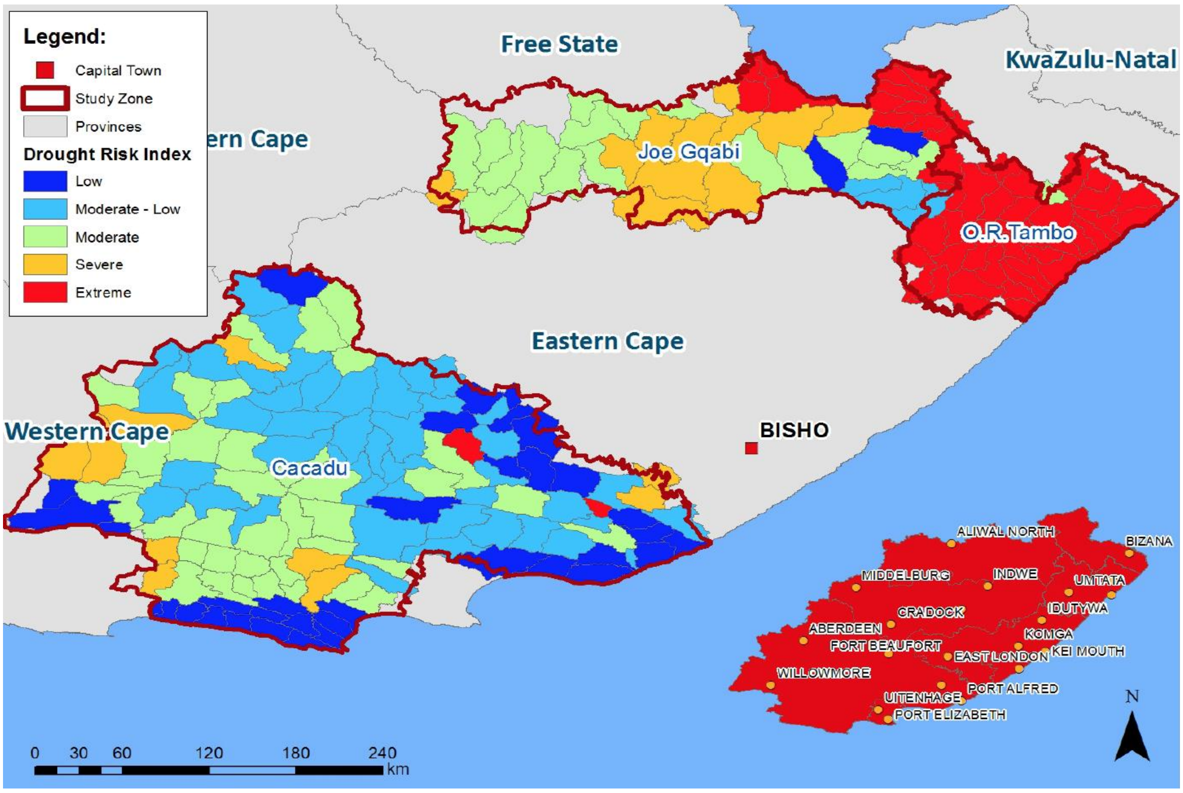

Fig 5.6: Drought risk map for the Cacadu, Joe Gqabi and OR Tambo District Municipalities

Conclusion

The results for drought risk assessment clearly highlighted the importance of vulnerability and coping capacity as essential elements in drought risk. The importance of the drought risk assessment was not in the final result illustrated in the maps, but rather in the identification of indicators that resulted in drought vulnerability or contributed to drought resilience. It is important for extension services and development agencies to identify and understand these indicators and address the gaps through extension programmes and development plans.

The Department of Agriculture and Rural Development should take note of the factors which increase drought vulnerability, since that also impacts on sustainable land reform. Extension managers should identify these factors and build them into extension programmes. The low level of drought-related knowledge amongst extension officers was of concern since they were primarily responsible for training farmers and supporting farmers to activate measures for drought risk reduction. The high dependency on government support amongst communal farmers was one of the key contributors to drought risk. As a result of government dependency, communal farmers did not plan properly and they applied poor agricultural practices in anticipation that "*government will assist when drought comes".*

A detailed analysis for the communal farming and commercial farming sectors is provided in Chapters 6 and 7.

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Annexure 5-A: Risk Assessment

Table 5A.1: Hazard and vulnerability indices per quaternary catchment

		H	Vulnerability																									
			Human			V H	Social			V S	Culture			V C	Financial			V F	Environmental			VE	Political			V P		Vuln I.
Weight			0,12				0,04				0,1				0,27				0,35				0,04			0,9		
Municipality	Quaternary Catchment		education	age	health status		formal networks	informal support	safety/security		dependency	gender	cultural beliefs		price sensitivity	market access	unemployment		land degradation	land use	predators		Drought plans	Gov; efficiency	land ownership		Total Vulnerability	Vuln Index
Weight			,4	0,2	0,3		0,3	0,4	0,3		0,6	0,1	0,3		0,3	0,4	0,3		0,6	0,2	0,1		0,2	0,3	0,5			
ORT	T11G	3,88	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	5	5	4	4,4	5	4	5	4,7	4,08	15,81
ORT	T13A	3,8	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	5	5	4	4,4	5	4	5	4,7	4,08	15,49
ORT	T13B	3,8	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	14,69
ORT	T20A	4,68	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	18,09
ORT	T20B	4,3	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	16,62
ORT	T20C	3,92	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	15,15
ORT	T20D	3,92	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	15,15
ORT	T20E	4,08	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	15,77
ORT	T20F	4,15	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	16,04
ORT	T20G	4,22	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	16,31
ORT	T32H	4,31	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	5	5	4	4,4	5	4	5	4,7	4,08	17,56
ORT	T33K	4,17	4	2	4	3,2	2	4	3	3,1	2	2	1	1,7	1	1	2	1,3	1	3	5	1,7	4	4	3	3,5	1,76	7,36

ORT	T34J	4,24	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	5	5	4	4,4	5	4	5	4,7	4,08	17,28
ORT	T34K	3,69	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	5	5	4	4,4	5	4	5	4,7	4,08	15,04
ORT	T35E	4,08	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	15,77
ORT	T35J	4,08	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	15,77
ORT	T35K	3,57	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	13,80
ORT	T35L	3,67	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	14,18
ORT	T35M	3,68	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	14,22
ORT	T36A	3,61	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	13,95
ORT	T36B	4,56	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	17,62
ORT	T60E	3,93	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	15,19
ORT	T60F	3,52	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	13,60
ORT	T60G	4,13	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	15,96
ORT	T60H	3,55	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	13,72
ORT	T60J	3,42	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	13,22
ORT	T60K	4,6	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	17,78
ORT	T70A	3,6	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	13,91
ORT	T70B	4,57	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	17,66
ORT	T70C	3,8	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	14,69
ORT	T70D	3,8	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	14,69
ORT	T70E	3,71	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	14,34
ORT	T70F	3,81	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	14,73
ORT	T70G	3,79	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	14,65
ORT	T80A	4,3	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	16,62
ORT	T80C	3,44	5	4	4	4,0	4	4	3	3,7	5	3	4	4,5	4	5	5	4,7	4	5	4	3,8	5	4	5	4,7	3,87	13,30
JG	D12A	3,9	5	4	5	4,3	4	4	4	4,0	5	3	4	4,5	3	3	5	3,6	5	5	5	4,5	5	4	5	4,7	3,86	15,06
JG	D12B	4,04	5	4	5	4,3	4	4	4	4,0	5	3	4	4,5	3	3	5	3,6	5	5	5	4,5	5	4	5	4,7	3,86	15,60
JG	D12C	3,95	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	2	3	2,3	3	2	4	2,6	5	4	5	4,7	2,17	8,56
JG	D12F	3,94	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,20

JG	D13A	3,85	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,04
JG	D13B	4,15	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,59
JG	D13C	2,44	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	4,46
JG	D13D	3,87	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,07
JG	D13E	3,98	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,28
JG	D13F	3,84	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,02
JG	D13G	4	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,31
JG	D13H	3,92	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,17
JG	D13J	4,22	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,71
JG	D13K	4,12	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,53
JG	D13L	3,95	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,22
JG	D13M	4,23	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,73
JG	D14A	3,24	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	5,92
JG	D14E	3,24	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	5,92
JG	D14F	3,38	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	6,18
JG	D14G	3,97	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,26
JG	D14H	3,85	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,04
JG	D14J	3,6	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	6,58
JG	D14K	3,38	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	3	1	2	1,9	3	1	4	2,4	5	4	1	2,7	1,91	6,45
JG	D18K	4,22	5	4	4	4,0	1	3	5	3,0	5	4	4	4,6	3	4	3	3,4	4	4	5	3,7	5	4	3	3,7	3,42	14,44
JG	D18L	4,15	2	3	2	2,0	3	3	5	3,6	3	2	2	2,6	2	2	3	2,3	5	5	5	4,5	5	4	5	4,7	3,03	12,57
JG	D34A	3,63	2	3	2	2,0	3	3	5	3,6	3	2	2	2,6	2	2	3	2,3	5	5	5	4,5	5	4	5	4,7	3,03	10,99
JG	D35B	3,63	2	3	2	2,0	3	3	5	3,6	3	2	2	2,6	2	2	3	2,3	5	5	5	4,5	5	4	5	4,7	3,03	10,99
JG	D35C	3,27	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	5,98
JG	D35D	3,45	2	3	3	2,3	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,86	6,43
JG	D35E	3,9	2	3	3	2,3	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,86	7,27
JG	D35G	3,84	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,02
JG	D35H	3,84	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,02

JG	D35J	3,85	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,04
JG	D35K	3,85	2	3	2	2,0	1	3	4	2,7	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	5	4	1	2,7	1,83	7,04
JG	Q11A	4,12	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	2	2	2,0	2	2	3	1,9	5	3	1	2,4	1,74	7,16
JG	Q12A	3,83	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	2	2	2,0	2	2	3	1,9	5	3	1	2,4	1,74	6,65
JG	Q12B	3,82	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	2	2	2,0	2	2	3	1,9	5	3	1	2,4	1,74	6,64
JG	T33C	3,63	5	5	4	4,2	4	3	3	3,3	5	3	4	4,5	3	4	5	4,0	4	4	4	3,6	5	3	5	4,4	3,60	13,08
JG	T34A	3,42	5	5	4	4,2	4	3	3	3,3	5	3	4	4,5	3	4	5	4,0	4	4	4	3,6	5	3	5	4,4	3,60	12,32
JG	T34B	4,33	5	5	4	4,2	4	3	3	3,3	5	3	4	4,5	3	4	5	4,0	4	4	4	3,6	5	3	5	4,4	3,60	15,60
JG	T34C	4,35	5	5	4	4,2	4	3	3	3,3	5	3	4	4,5	3	4	5	4,0	4	4	4	3,6	5	3	5	4,4	3,60	15,67
JG	T34D	4,39	5	5	4	4,2	4	3	3	3,3	5	3	4	4,5	3	4	5	4,0	4	4	4	3,6	5	3	5	4,4	3,60	15,81
JG	T34E	3,21	5	5	4	4,2	4	3	3	3,3	5	3	4	4,5	3	4	5	4,0	4	4	4	3,6	5	3	5	4,4	3,60	11,56
JG	T34F	4,35	5	5	4	4,2	4	3	3	3,3	5	3	4	4,5	3	4	5	4,0	4	4	4	3,6	5	3	5	4,4	3,60	15,67
JG	T34G	3,78	5	5	4	4,2	4	3	3	3,3	5	3	4	4,5	3	4	5	4,0	4	4	4	3,6	5	3	5	4,4	3,60	13,62
JG	T35A	3,13	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	1	2	1,6	2	1	3	1,7	5	3	5	4,4	1,64	5,13
JG	T35B	4,32	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	1	2	1,6	2	1	3	1,7	5	3	5	4,4	1,64	7,08
JG	T35C	4,36	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	1	2	1,6	2	1	3	1,7	5	3	5	4,4	1,64	7,15
JG	T35D	4,35	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	1	2	1,6	2	1	3	1,7	5	3	5	4,4	1,64	7,13
JG	T35F	4,16	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	1	2	1,6	2	1	3	1,7	5	3	5	4,4	1,64	6,82
JG	T35G	3,68	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	1	2	1,6	2	1	3	1,7	5	3	5	4,4	1,64	6,03
JG	T35H	4,12	2	3	2	2,0	1	3	3	2,4	1	1	1	1,0	2	1	2	1,6	2	1	3	1,7	5	3	5	4,4	1,64	6,75
Cac	J31C	3,87	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	1	1,3	2	1	3	1,7	4	4	1	2,5	1,45	5,63
Cac	J32D	2,72	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	1	1,3	2	1	3	1,7	4	4	1	2,5	1,45	3,95
Cac	J32E	2,71	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	1	1,3	2	1	3	1,7	4	4	1	2,5	1,45	3,94
Cac	K70B	3,8	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,79
Cac	K80A	3,79	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,78
Cac	K80B	4,13	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	5,20
Cac	K80C	3,62	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,56
Cac	K80D	3,65	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,60

Cac	K80E	3,77	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,75
Cac	K80F	3,47	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,37
Cac	K90A	3,51	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,42
Cac	K90B	4,15	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	5,23
Cac	K90C	4,15	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	5,23
Cac	K90D	3,53	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,45
Cac	K90E	3,28	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,13
Cac	K90F	3,5	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,41
Cac	K90G	3,46	2	3	2	2,0	1	3	2	2,1	1	1	1	1,0	2	1	1	1,3	1	1	3	1,1	4	4	1	2,5	1,26	4,36
Cac	L12C	3,75	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	6,06
Cac	L12D	3,74	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	6,04
Cac	L22D	2,47	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	3,99
Cac	L23A	3,47	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,61
Cac	L23B	2,47	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	3,99
Cac	L23C	3,87	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	6,25
Cac	L23D	3,53	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,70
Cac	L30A	3,41	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,51
Cac	L30B	3,36	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,43
Cac	L30C	3,53	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,70
Cac	L30D	3,06	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	4,94
Cac	L40A	3,65	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,90
Cac	L40B	2,92	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	4,72
Cac	L50A	3,55	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,74
Cac	L50B	3	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	4,85
Cac	L60A	3,2	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,17
Cac	L60B	3,19	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,16
Cac	L70A	3,6	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,82
Cac	L70B	3,07	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	4,96

Cac	L70C	3,14	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,07
Cac	L70D	3,3	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,33
Cac	L70E	3,51	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,67
Cac	L70F	3,42	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,53
Cac	L70G	4,02	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	6,50
Cac	L81A	4,15	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	6,71
Cac	L81B	3,27	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,28
Cac	L81C	3,4	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,49
Cac	L81D	3,25	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,25
Cac	L82C	4,09	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	6,61
Cac	L82D	3,44	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,56
Cac	L82E	3,47	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,61
Cac	L82F	3,3	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,33
Cac	L82G	3,38	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,46
Cac	L82H	3,38	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,46
Cac	L82J	3,69	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,96
Cac	L90A	3,96	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	6,40
Cac	L90B	3,44	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,56
Cac	L90C	3,55	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	3	1,9	2	1	3	1,7	4	4	1	2,5	1,62	5,74
Cac	M10A	3,95	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	2	1,6	2	1	3	1,7	4	4	1	2,5	1,54	6,06
Cac	M10B	3,38	2	3	2	2,0	1	2	2	1,7	1	1	1	1,0	2	1	2	1,6	2	1	3	1,7	4	4	1	2,5	1,54	5,19
Cac	N11A	3,19	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	4	1	2,5	1,66	5,28
Cac	N11B	3,31	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,52
Cac	N12A	2,35	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	3,92
Cac	N12B	2,41	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	4,02
Cac	N12C	2,96	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	4,93
Cac	N13A	3,7	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	6,17
Cac	N13B	3,75	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	6,25

Cac	N13C	2,93	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	4,88
Cac	N14A	3,29	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,48
Cac	N14B	3,51	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,85
Cac	N14C	2,86	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	4,77
Cac	N14D	2,94	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	4,90
Cac	N21A	2,97	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	4,95
Cac	N21B	3,59	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,98
Cac	N21C	3,36	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,60
Cac	N21D	3,39	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,65
Cac	N22A	3,48	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,80
Cac	N22B	3,89	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	6,48
Cac	N22C	3,14	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,23
Cac	N22D	2,95	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	4,92
Cac	N22E	3,45	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,75
Cac	N23A	3,69	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	6,15
Cac	N23B	3,47	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,78
Cac	N24A	3,27	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,45
Cac	N24B	3,42	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,70
Cac	N24C	3,53	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,88
Cac	N24D	3,84	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	6,40
Cac	N30A	3,77	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	6,28
Cac	N30B	3,36	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,60
Cac	N30C	3,07	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,12
Cac	N40A	3,16	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,27
Cac	N40B	3,56	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,93
Cac	N40C	3,5	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,83
Cac	N40D	3,39	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,65
Cac	N40E	3,4	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,67

Cac	N40F	3,15	3	3	3	2,7	2	2	4	2,6	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,78	5,59
Cac	P10A	2,9	4	3	3	3,1	4	2	4	3,2	4	3	3	3,6	3	2	3	2,6	5	4	3	4,1	4	5	1	2,8	3,11	9,02
Cac	P10B	3,57	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,95
Cac	P10C	3,44	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,73
Cac	P10D	3,96	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	6,60
Cac	P10E	4,05	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	6,75
Cac	P10F	4,35	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	7,25
Cac	P10G	3,39	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	2	2	2,0	2	1	3	1,7	4	5	1	2,8	1,67	5,65
Cac	P20A	3,58	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,46
Cac	P20B	3,47	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,29
Cac	P30A	3,36	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	3	1	2	1,9	2	1	3	1,7	4	5	1	2,8	1,64	5,51
Cac	P30B	4,29	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	3	1	2	1,9	2	1	3	1,7	4	5	1	2,8	1,64	7,04
Cac	P30C	3,47	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	3	1	2	1,9	2	1	3	1,7	4	5	1	2,8	1,64	5,69
Cac	P40A	2,82	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	4,30
Cac	P40B	3,15	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	4,80
Cac	P40C	3,07	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	4,68
Cac	P40D	3,5	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,33
Cac	Q50B	3,69	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,62
Cac	Q50C	4,25	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	6,48
Cac	Q60C	3,36	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,12
Cac	Q70A	3,39	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,17
Cac	Q70B	4,18	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	6,37
Cac	Q70C	3,68	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,61
Cac	Q80A	3,89	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,93
Cac	Q80B	3,86	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,88
Cac	Q80C	3,78	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,76
Cac	Q80D	3,52	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	1	2,8	1,52	5,36
Cac	Q80E	3,05	4	4	4	3,6	4	3	4	3,6	5	3	4	4,5	4	3	5	3,9	5	4	3	4,1	4	5	3	3,8	3,67	11,18

Cac	Q80F	3,08	2	3	2	2,0	4	2	3	2,9	1	1	1	1,0	2	1	2	1,6	3	1	4	2,4	4	5	1	2,8	1,84	5,67
Cac	Q80G	3,71	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	2	1	2	1,6	4	5	3	3,8	1,56	5,80
Cac	Q91A	2,98	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	3	1	3	2,3	4	5	1	2,8	1,77	5,27
Cac	Q91B	2,28	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	3	1	3	2,3	4	5	1	2,8	1,77	4,03
Cac	Q91C	3,53	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	3	1	3	2,3	4	5	1	2,8	1,77	6,24
Cac	Q92F	2,98	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	2	1	2	1,6	3	1	3	2,3	4	5	1	2,8	1,77	5,27
Cac	Q93A	4,28	2	3	2	2,0	1	2	4	2,3	1	1	1	1,0	3	1	3	2,2	3	1	5	2,5	4	5	1	2,8	2,01	8,62
Cac	Q93B	4,28	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	3	1	3	2,2	3	1	5	2,5	4	5	1	2,8	2,00	8,56
Cac	Q93D	3,55	2	3	2	2,0	1	2	3	2,0	1	1	1	1,0	3	1	3	2,2	3	1	4	2,4	4	5	1	2,8	1,97	6,98

Table 5A.2: Coping capacity indices per quaternary catchment

		Coping capacity																																
		Human					Social					Cultural				Financial					Infrastructure				Environment.				Political					
Weight		0,12					0,04					0,1				0,27				0,1	0,08				0,35				0,04					
Municipality	Quart. Catchment	Perseverance	Experience	Exp to mentorship	Management		formal institutions	support structures	prvt ext support	information access		innovative plan	work ethic	experience		alt farm income	alt non-farm	fin safety net	fodder banks		irrigation	fencing	water reticulation		soil	groundwater	surface water		relief	extension support		Total Coping Capacity	Coping index	R=V/C
Weight		0,20	0,30	0,15	0,35		0,20	0,20	0,50	0,10		0,20	0,20	0,60		0,30	0,10	0,30	0,30		0,50	0,20	0,30		0,30	0,20	0,50		0,40	0,60				
ORT	T11G	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,49	6,09
ORT	T13A	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,46	5,96
ORT	T13B	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,46	5,66
ORT	T20A	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,80	6,97
ORT	T20B	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,66	6,40
ORT	T20C	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,51	5,83
ORT	T20D	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,51	5,83

ORT	T20E	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,57	6,07
ORT	T20F	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,60	6,18
ORT	T20G	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,62	6,28
ORT	T32H	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,66	6,76
ORT	T33K	4	3	2	3	2,0	4	4	5	3	4,1	3	4	2	2,6	4	4	3	1	2,8	3	3	4	3,3	4	3	5	4,3	3	2	2,4	3,29	1,27	2,24
ORT	T34J	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,63	6,65
ORT	T34K	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,42	5,79
ORT	T35E	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,57	6,07
ORT	T35J	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,57	6,07
ORT	T35K	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,37	5,31
ORT	T35L	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,41	5,46
ORT	T35M	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,42	5,48
ORT	T36A	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,39	5,37
ORT	T36B	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,76	6,79
ORT	T60E	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,51	5,85
ORT	T60F	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,36	5,24
ORT	T60G	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,59	6,15
ORT	T60H	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,37	5,28
ORT	T60J	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,32	5,09
ORT	T60K	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,77	6,85
ORT	T70A	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,39	5,36
ORT	T70B	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,76	6,80
ORT	T70C	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,46	5,66
ORT	T70D	4	3	1	1	1,9	1	3	2	1	1,8	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,60	1,46	5,66
ORT	T70E	4	3	1	1	1,9	1	3	1	1	1,3	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,58	1,44	5,56
ORT	T70F	4	3	1	1	1,9	1	3	1	1	1,3	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,58	1,48	5,71
ORT	T70G	4	3	1	1	1,9	1	3	1	1	1,3	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,58	1,47	5,68
ORT	T80A	4	3	1	1	1,9	1	3	1	1	1,3	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,58	1,67	6,45

ORT	T80C	4	3	1	1	1,9	1	3	1	1	1,3	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	4	3	5	4,3	3	2	2,4	2,58	1,33	5,16
JG	D12A	3	3	1	1	1,7	2	3	1	1	1,5	1	2	3	2,4	1	2	1	1	1,1	1	1	2	1,3	2	2	2	2,0	3	3	3,0	1,72	2,27	8,76
JG	D12B	3	3	1	1	1,7	2	2	1	1	1,3	1	2	3	2,4	1	2	1	1	1,1	1	1	2	1,3	2	2	1	1,5	3	3	3,0	1,54	2,63	10,16
JG	D12C	4	4	4	4	2,6	4	3	3	3	2,9	4	4	4	4,0	2	2	3	4	2,9	3	4	4	3,5	3	4	3	3,2	2	1	1,4	3,07	1,29	2,79
JG	D12F	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	3	4	3	3,2	2	1	1,4	3,11	1,27	2,32
JG	D13A	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,28	2,34
JG	D13B	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,38	2,53
JG	D13C	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	0,81	1,49
JG	D13D	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,29	2,36
JG	D13E	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,33	2,42
JG	D13F	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,28	2,34
JG	D13G	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,33	2,44
JG	D13H	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,31	2,39
JG	D13J	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,41	2,57
JG	D13K	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,37	2,51
JG	D13L	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,32	2,41
JG	D13M	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,41	2,58
JG	D14A	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,08	1,97
JG	D14E	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,08	1,97
JG	D14F	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,13	2,06
JG	D14G	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,32	2,42
JG	D14H	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,28	2,34
JG	D14J	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,20	2,19
JG	D14K	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,13	2,15
JG	D18K	4	4	3	4	2,5	3	3	1	2	1,7	3	3	3	3,0	1	1	1	1	1,0	1	2	2	1,5	1	3	3	2,4	2	3	2,6	2,00	2,11	7,23
JG	D18L	5	5	2	4	2,8	1	3	1	2	1,3	1	3	3	2,6	1	1	1	1	1,0	1	1	1	1,0	1	3	3	2,4	2	3	2,6	1,94	2,14	6,47
JG	D34A	5	5	2	4	2,8	1	3	1	2	1,3	1	3	3	2,6	1	1	1	1	1,0	1	1	1	1,0	1	3	3	2,4	2	3	2,6	1,94	1,87	5,66
JG	D35B	5	5	2	4	2,8	1	3	1	2	1,3	1	3	3	2,6	1	1	1	1	1,0	1	1	1	1,0	1	3	3	2,4	2	3	2,6	1,94	1,87	5,66

JG	D35C	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,09	1,99
JG	D35D	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,15	2,14
JG	D35E	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,30	2,42
JG	D35G	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,7	4	4	4	4,0	2	4	3	2,9	2	1	1,4	2,95	1,30	2,38
JG	D35H	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,28	2,34
JG	D35J	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,7	4	4	4	4,0	2	4	3	2,9	2	1	1,4	2,95	1,31	2,39
JG	D35K	4	4	4	4	2,6	4	3	3	4	2,9	4	4	4	4,0	2	2	3	4	2,9	4	4	4	4,0	2	4	3	2,9	2	1	1,4	3,00	1,28	2,34
JG	Q11A	4	4	4	4	2,6	5	3	2	4	2,6	4	4	4	4,0	2	2	3	4	2,9	2	5	5	3,5	2	4	2	2,4	2	1	1,4	2,78	1,48	2,58
JG	Q12A	4	4	4	4	2,6	5	3	2	4	2,6	4	4	4	4,0	2	2	3	4	2,9	2	5	5	3,5	2	4	2	2,4	2	1	1,4	2,78	1,38	2,40
JG	Q12B	4	4	4	4	2,6	5	3	2	4	2,6	4	4	4	4,0	2	2	3	4	2,9	2	5	5	3,5	2	4	2	2,4	2	1	1,4	2,78	1,38	2,39
JG	T33C	4	4	3	2	2,5	2	3	1	2	1,5	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	3	3	4	3,5	3	3	3,0	2,40	1,51	5,45
JG	T34A	4	4	3	2	2,5	2	3	1	2	1,5	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	3	3	4	3,5	3	3	3,0	2,40	1,42	5,13
JG	T34B	4	4	3	2	2,5	2	3	1	2	1,5	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	3	3	4	3,5	3	3	3,0	2,40	1,80	6,50
JG	T34C	4	4	3	2	2,5	2	3	1	2	1,5	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	3	3	4	3,5	3	3	3,0	2,40	1,81	6,53
JG	T34D	4	4	3	2	2,5	2	3	1	2	1,5	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	3	3	4	3,5	3	3	3,0	2,40	1,83	6,59
JG	T34E	4	4	3	2	2,5	2	3	1	2	1,5	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	3	3	4	3,5	3	3	3,0	2,40	1,34	4,82
JG	T34F	4	4	3	2	2,5	2	3	1	2	1,5	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	3	3	4	3,5	3	3	3,0	2,40	1,81	6,53
JG	T34G	4	4	3	2	2,5	2	3	1	2	1,5	1	4	3	2,8	1	1	1	1	1,0	1	1	4	1,9	3	3	4	3,5	3	3	3,0	2,40	1,57	5,67
JG	T35A	4	4	4	5	2,6	5	3	4	4	3,6	4	4	4	4,0	3	2	3	5	3,5	3	5	5	4,0	4	4	4	4,0	2	1	1,4	3,58	0,88	1,43
JG	T35B	4	4	4	5	2,6	5	3	4	4	3,6	4	4	4	4,0	3	2	3	5	3,5	3	5	5	4,0	4	4	4	4,0	2	1	1,4	3,58	1,21	1,98
JG	T35C	4	4	4	5	2,6	5	3	4	4	3,6	4	4	4	4,0	3	2	3	5	3,5	3	5	5	4,0	4	4	4	4,0	2	1	1,4	3,58	1,22	2,00
JG	T35D	4	4	4	5	2,6	5	3	4	4	3,6	4	4	4	4,0	3	2	3	5	3,5	3	5	5	4,0	4	4	4	4,0	2	1	1,4	3,58	1,22	1,99
JG	T35F	4	4	4	5	2,6	5	3	4	4	3,6	4	4	4	4,0	3	2	3	5	3,5	3	5	5	4,0	4	4	4	4,0	2	1	1,4	3,58	1,16	1,91
JG	T35G	4	4	4	5	2,6	5	3	4	4	3,6	4	4	4	4,0	3	2	3	5	3,5	3	5	5	4,0	4	4	4	4,0	2	1	1,4	3,58	1,03	1,69
JG	T35H	4	4	4	5	2,6	5	3	4	4	3,6	4	4	4	4,0	3	2	3	5	3,5	3	5	5	4,0	4	4	4	4,0	2	1	1,4	3,58	1,15	1,89
Cac	J31C	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	1,06	1,54
Cac	J32D	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	0,74	1,08
Cac	J32E	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	0,74	1,08

Cac	K70B	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	1,04	1,31
Cac	K80A	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	1,04	1,31
Cac	K80B	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	1,13	1,42
Cac	K80C	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	0,99	1,25
Cac	K80D	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	1,00	1,26
Cac	K80E	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	1,03	1,30
Cac	K80F	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	0,95	1,20
Cac	K90A	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	0,96	1,21
Cac	K90B	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	1,14	1,43
Cac	K90C	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	1,14	1,43
Cac	K90D	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	0,97	1,22
Cac	K90E	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	0,90	1,13
Cac	K90F	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	0,96	1,21
Cac	K90G	5	4	4	5	2,8	5	3	5	5	4,1	4	5	4	4,2	4	3	3	5	3,9	5	5	5	5,0	3	3	4	3,5	2	1	1,4	3,65	0,95	1,19
Cac	L12C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,37	2,21
Cac	L12D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,37	2,21
Cac	L22D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	0,90	1,46
Cac	L23A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,27	2,05
Cac	L23B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	0,90	1,46
Cac	L23C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,41	2,28
Cac	L23D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,29	2,08
Cac	L30A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,25	2,01
Cac	L30B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,23	1,98
Cac	L30C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,29	2,08
Cac	L30D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,12	1,81
Cac	L40A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,33	2,15
Cac	L40B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,07	1,72
Cac	L50A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,30	2,10

Cac	L50B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,10	1,77
Cac	L60A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,17	1,89
Cac	L60B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,17	1,88
Cac	L70A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,31	2,12
Cac	L70B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,12	1,81
Cac	L70C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,15	1,85
Cac	L70D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,21	1,95
Cac	L70E	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,28	2,07
Cac	L70F	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,25	2,02
Cac	L70G	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,47	2,37
Cac	L81A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,52	2,45
Cac	L81B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,19	1,93
Cac	L81C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,24	2,01
Cac	L81D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,19	1,92
Cac	L82C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,49	2,41
Cac	L82D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,26	2,03
Cac	L82E	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,27	2,05
Cac	L82F	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,21	1,95
Cac	L82G	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,23	1,99
Cac	L82H	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,23	1,99
Cac	L82J	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	3	4	1	2,2	2	1	1,4	2,74	1,35	2,18
Cac	L90A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	5	3,5	3	4	1	2,2	2	1	1,4	2,76	1,43	2,32
Cac	L90B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	5	3,5	3	4	1	2,2	2	1	1,4	2,76	1,25	2,01
Cac	L90C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	5	3,5	3	4	1	2,2	2	1	1,4	2,76	1,29	2,08
Cac	M10A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	5	3,5	3	4	1	2,2	2	1	1,4	2,76	1,43	2,20
Cac	M10B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	5	3,5	3	4	1	2,2	2	1	1,4	2,76	1,22	1,88
Cac	N11A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,21	2,01
Cac	N11B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,26	2,10

Cac	N12A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	0,89	1,49
Cac	N12B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	0,92	1,53
Cac	N12C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,12	1,87
Cac	N13A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,41	2,34
Cac	N13B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,42	2,37
Cac	N13C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,11	1,86
Cac	N14A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,25	2,08
Cac	N14B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,33	2,22
Cac	N14C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,09	1,81
Cac	N14D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	5	4	3,2	2	4	1	1,9	2	1	1,4	2,63	1,12	1,86
Cac	N21A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	1	1,9	2	1	1,4	2,67	1,11	1,85
Cac	N21B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,19	1,98
Cac	N21C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,11	1,85
Cac	N21D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,12	1,87
Cac	N22A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,15	1,92
Cac	N22B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,29	2,15
Cac	N22C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,04	1,73
Cac	N22D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	0,98	1,63
Cac	N22E	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,14	1,90
Cac	N23A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,22	2,03
Cac	N23B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,15	1,91
Cac	N24A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,08	1,80
Cac	N24B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,13	1,89
Cac	N24C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,17	1,95
Cac	N24D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	5	4	3,7	2	4	3	2,9	2	1	1,4	3,02	1,27	2,12
Cac	N30A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	4	1	3	5	3,7	3	5	5	4,0	2	4	3	2,9	2	1	1,4	3,29	1,15	1,91
Cac	N30B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	4	1	3	5	3,7	3	5	5	4,0	2	4	3	2,9	2	1	1,4	3,29	1,02	1,70
Cac	N30C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	4	1	3	5	3,7	3	5	5	4,0	2	4	3	2,9	2	1	1,4	3,29	0,93	1,56

Cac	N40A	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	5	3,1	5	5	4	4,7	3	5	4	3,9	2	1	1,4	3,53	0,89	1,49
Cac	N40B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	5	3,1	5	5	4	4,7	3	5	4	3,9	2	1	1,4	3,53	1,01	1,68
Cac	N40C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	5	3,1	5	5	4	4,7	3	5	4	3,9	2	1	1,4	3,53	0,99	1,65
Cac	N40D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	5	3,1	5	5	4	4,7	3	5	4	3,9	2	1	1,4	3,53	0,96	1,60
Cac	N40E	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	5	3,1	3	5	4	3,7	3	4	3	3,2	2	1	1,4	3,21	1,06	1,77
Cac	N40F	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	4	3	3	5	3,9	3	5	4	3,7	4	4	4	4,0	2	1	1,4	3,71	0,85	1,51
Cac	P10A	4	4	2	1	2,3	2	3	1	3	1,5	1	3	3	2,6	1	1	1	1	1,0	1	2	2	1,5	2	3	3	2,7	3	2	2,4	2,03	1,43	4,45
Cac	P10B	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	3	4	4	3,5	2	3	4	3,2	2	1	1,4	3,11	1,15	1,91
Cac	P10C	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	4	4	3,0	2	3	4	3,2	2	1	1,4	3,07	1,12	1,87
Cac	P10D	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	2	1	3	4	2,8	2	4	4	3,0	2	3	4	3,2	2	1	1,4	3,07	1,29	2,15
Cac	P10E	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	3	2	3	5	3,5	4	5	4	4,2	4	4	5	4,5	2	1	1,4	3,81	1,06	1,77
Cac	P10F	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	3	2	3	5	3,5	4	5	4	4,2	4	4	5	4,5	2	1	1,4	3,81	1,14	1,90
Cac	P10G	5	4	4	4	2,8	5	3	4	3	3,6	4	5	4	4,2	3	2	3	5	3,5	4	5	4	4,2	4	4	5	4,5	2	1	1,4	3,81	0,89	1,48
Cac	P20A	4	4	4	5	2,6	4	3	5	5	3,9	5	5	5	5,0	5	4	4	5	4,6	5	5	5	5,0	4	4	5	4,5	2	1	1,4	4,24	0,84	1,29
Cac	P20B	4	4	4	5	2,6	4	3	5	5	3,9	5	5	5	5,0	5	4	4	5	4,6	5	5	5	5,0	4	4	5	4,5	2	1	1,4	4,24	0,82	1,25
Cac	P30A	5	4	4	4	2,8	5	3	4	4	3,6	4	5	4	4,2	2	3	3	3	2,7	2	4	4	3,0	3	4	4	3,7	2	1	1,4	3,22	1,04	1,71
Cac	P30B	5	4	4	4	2,8	5	3	4	4	3,6	4	5	4	4,2	2	3	3	3	2,7	2	4	4	3,0	3	4	4	3,7	2	1	1,4	3,22	1,33	2,18
Cac	P30C	5	4	4	4	2,8	5	3	4	4	3,6	4	5	4	4,2	2	3	3	3	2,7	2	4	4	3,0	3	4	4	3,7	2	1	1,4	3,22	1,08	1,77
Cac	P40A	4	4	4	5	2,6	4	3	5	5	3,9	5	5	5	5,0	4	4	4	5	4,3	5	5	5	5,0	4	4	5	4,5	2	1	1,4	4,16	0,68	1,03
Cac	P40B	4	4	4	5	2,6	4	3	5	5	3,9	5	5	5	5,0	4	4	4	5	4,3	5	5	5	5,0	4	4	5	4,5	2	1	1,4	4,16	0,76	1,15
Cac	P40C	4	4	4	5	2,6	4	3	5	5	3,9	5	5	5	5,0	4	4	4	5	4,3	5	5	5	5,0	4	4	5	4,5	2	1	1,4	4,16	0,74	1,12
Cac	P40D	4	4	4	5	2,6	4	3	5	5	3,9	5	5	5	5,0	4	4	4	5	4,3	5	5	5	5,0	4	4	5	4,5	2	1	1,4	4,16	0,84	1,28
Cac	Q50B	4	4	4	5	2,6	4	3	5	5	3,9	5	5	5	5,0	4	4	4	5	4,3	5	5	5	5,0	3	4	5	4,2	2	1	1,4	4,06	0,91	1,39
Cac	Q50C	4	4	4	5	2,6	4	3	5	5	3,9	5	5	5	5,0	4	4	4	5	4,3	5	5	5	5,0	3	4	5	4,2	2	1	1,4	4,06	1,05	1,60
Cac	Q60C	4	4	4	4	2,6	4	3	5	5	3,9	4	5	4	4,2	4	4	4	4	4,0	5	5	5	5,0	3	4	5	4,2	2	1	1,4	3,89	0,86	1,32
Cac	Q70A	4	4	4	4	2,6	4	3	5	5	3,9	4	5	4	4,2	4	4	4	4	4,0	5	5	5	5,0	3	4	5	4,2	2	1	1,4	3,89	0,87	1,33
Cac	Q70B	4	4	4	4	2,6	4	3	5	5	3,9	4	5	4	4,2	4	4	4	4	4,0	5	5	5	5,0	3	4	5	4,2	2	1	1,4	3,89	1,07	1,64
Cac	Q70C	4	4	4	4	2,6	4	3	5	5	3,9	4	5	4	4,2	4	4	4	4	4,0	5	5	5	5,0	3	4	5	4,2	2	1	1,4	3,89	0,95	1,44

Cac	Q80A	4	4	4	4	2,6	4	3	5	5	3,9	4	5	4	4,2	4	4	4	4	4,0	3	4	5	3,8	3	4	5	4,2	2	1	1,4	3,80	1,02	1,56
Cac	Q80B	4	4	4	4	2,6	4	3	5	5	3,9	4	5	4	4,2	4	4	4	4	4,0	3	4	5	3,8	3	4	5	4,2	2	1	1,4	3,80	1,02	1,55
Cac	Q80C	4	4	4	4	2,6	4	3	5	5	3,9	4	5	4	4,2	4	4	4	4	4,0	3	4	5	3,8	3	4	5	4,2	2	1	1,4	3,80	1,00	1,52
Cac	Q80D	4	4	4	4	2,6	4	3	5	5	3,9	4	5	4	4,2	4	4	4	4	4,0	3	4	5	3,8	3	4	5	4,2	2	1	1,4	3,80	0,93	1,41
Cac	Q80E	2	2	1	1	1,2	2	2	1	3	1,3	1	2	2	1,8	4	2	3		2,3	3	3	4	3,3	3	4	3	3,2	2	1	1,4	2,43	1,25	4,60
Cac	Q80F	4	4	4	4	2,6	4	2	3	4	2,7	4	4	4	4,0	2	2	2	3	2,3	2	3	4	2,8	2	3	3	2,7	2	1	1,4	2,67	1,16	2,13
Cac	Q80G	4	4	4	5	2,6	4	3	4	3	3,4	4	5	4	4,2	4	2	3	5	3,8	3	4	5	3,8	4	4	4	4,0	2	1	1,4	3,65	1,02	1,59
Cac	Q91A	4	4	4	5	2,6	4	3	4	4	3,4	5	5	4	4,4	4	2	4	5	4,1	4	4	5	4,3	4	4	5	4,5	2	1	1,4	3,97	0,75	1,33
Cac	Q91B	4	4	4	5	2,6	4	3	4	4	3,4	5	5	4	4,4	4	2	4	5	4,1	4	4	5	4,3	4	4	5	4,5	2	1	1,4	3,97	0,57	1,02
Cac	Q91C	4	4	4	5	2,6	4	3	4	4	3,4	5	5	4	4,4	4	2	4	5	4,1	4	4	5	4,3	4	4	5	4,5	2	1	1,4	3,97	0,89	1,57
Cac	Q92F	4	4	4	5	2,6	4	3	4	4	3,4	5	5	4	4,4	4	2	4	5	4,1	4	4	5	4,3	4	4	5	4,5	2	1	1,4	3,97	0,75	1,33
Cac	Q93A	4	4	4	4	2,6	4	2	2	3	2,2	4	5	4	4,2	3	2	2	4	2,9	4	3	4	3,8	1	3	3	2,4	2	1	1,4	2,80	1,53	3,07
Cac	Q93B	4	4	4	4	2,6	4	2	2	3	2,2	4	5	4	4,2	3	2	2	4	2,9	3	3	4	3,3	1	3	3	2,4	2	1	1,4	2,76	1,55	3,10
Cac	Q93D	4	4	4	4	2,6	4	3	4	4	3,4	4	5	4	4,2	4	4	4	4	4,0	5	5	5	5,0	4	4	5	4,5	2	1	1,4	3,98	0,89	1,75

Table 5A.3: Net capital scores per quad catchment

Q Catchment	Human	Social	Cultural	Financial	Infrastructural	Environmental	Political	Nett
T11G	-2,15	-1,90	-1,70	-3,90	1,90	-0,10	-2,30	**-10,15**
T13A	-2,15	-1,90	-1,70	-3,90	1,90	-0,10	-2,30	**-10,15**
T13B	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T20A	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T20B	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T20C	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T20D	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T20E	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T20F	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**

Q Catchment	Human	Social	Cultural	Financial	Infrastructural	Environmental	Political	Nett
T20G	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T32H	-2,15	-1,90	-1,70	-3,90	1,90	-0,10	-2,30	**-10,15**
T33K	-1,20	1,00	0,90	1,15	3,30	2,60	-1,10	**6,65**
T34J	-2,15	-1,90	-1,70	-3,90	1,90	-0,10	-2,30	**-10,15**
T34K	-2,15	-1,90	-1,70	-3,90	1,90	-0,10	-2,30	**-10,15**
T35E	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T35J	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T35K	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T35L	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T35M	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T36A	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T36B	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T60E	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T60F	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T60G	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T60H	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T60J	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T60K	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T70A	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T70B	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T70C	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T70D	-2,15	-1,90	-1,70	-3,90	1,90	0,50	-2,30	**-9,55**
T70E	-2,15	-2,40	-1,70	-3,90	1,90	0,50	-2,30	**-10,05**
T70F	-2,15	-2,40	-1,70	-3,90	1,90	0,50	-2,30	**-10,05**
T70G	-2,15	-2,40	-1,70	-3,90	1,90	0,50	-2,30	**-10,05**
T80A	-2,15	-2,40	-1,70	-3,90	1,90	0,50	-2,30	**-10,05**
T80C	-2,15	-2,40	-1,70	-3,90	1,90	0,50	-2,30	**-10,05**

Q Catchment	Human	Social	Cultural	Financial	Infrastructural	Environmental	Political	Nett
D12A	-2,65	-2,50	-2,10	-3,15	1,30	-2,50	-1,70	**-13,30**
D12B	-2,65	-2,70	-2,10	-3,15	1,30	-3,00	-1,70	**-14,00**
D12C	0,60	0,20	3,00	0,10	3,50	0,60	-3,30	**4,70**
D12F	0,60	0,20	3,00	0,95	4,00	0,80	-1,30	**8,25**
D13A	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13B	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13C	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13D	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13E	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13F	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13G	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13H	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13J	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13K	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13L	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D13M	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D14A	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D14E	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D14F	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D14G	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D14H	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D14J	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D14K	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**0,00**
D18K	-1,55	-1,30	-1,60	-2,30	1,50	-1,30	-1,10	**-7,65**
D18L	0,80	-2,30	0,00	-1,65	1,00	-2,10	-2,10	**-6,35**
D34A	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**0,00**
D35B	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**0,00**

Q Catchment	Human	Social	Cultural	Financial	Infrastructural	Environmental	Political	Nett
D35C	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D35D	0,30	0,20	3,00	0,95	4,00	0,50	-1,30	**7,65**
D35E	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**0,00**
D35G	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D35H	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**0,00**
D35J	0,60	0,20	3,00	0,95	4,00	0,50	-1,30	**7,95**
D35K	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**0,00**
Q11A	0,60	0,20	3,00	0,70	3,50	0,50	-1,00	**7,50**
Q12A	0,60	0,20	3,00	0,70	3,50	0,50	-1,00	**7,50**
Q12B	0,60	0,20	3,00	0,70	3,50	0,50	-1,00	**7,50**
T33C	-1,75	-1,80	-1,70	-3,50	1,90	-0,10	-1,40	**-8,35**
T34A	-1,75	-1,80	-1,70	-3,50	1,90	-0,10	-1,40	**-8,35**
T34B	-1,75	-1,80	-1,70	-3,50	1,90	-0,10	-1,40	**-8,35**
T34C	-1,75	-1,80	-1,70	-3,50	1,90	-0,10	-1,40	**-8,35**
T34D	-1,75	-1,80	-1,70	-3,50	1,90	-0,10	-1,40	**-8,35**
T34E	-1,75	-1,80	-1,70	-3,50	1,90	-0,10	-1,40	**-8,35**
T34F	-1,75	-1,80	-1,70	-3,50	1,90	-0,10	-1,40	**-8,35**
T34G	-1,75	-1,80	-1,70	-3,50	1,90	-0,10	-1,40	**-8,35**
T35A	0,60	1,20	3,00	1,50	4,00	2,30	-3,00	**9,60**
T35B	0,60	1,20	3,00	1,50	4,00	2,30	-3,00	**9,60**
T35C	0,60	1,20	3,00	1,50	4,00	2,30	-3,00	**9,60**
T35D	0,60	1,20	3,00	1,50	4,00	2,30	-3,00	**9,60**
T35F	0,60	1,20	3,00	1,50	4,00	2,30	-3,00	**9,60**
T35G	0,60	1,20	3,00	1,50	4,00	2,30	-3,00	**9,60**
T35H	0,60	1,20	3,00	1,50	4,00	2,30	-3,00	**9,60**
J31C	0,80	2,40	3,20	2,50	5,00	1,80	-1,10	**14,60**
J32D	0,80	2,40	3,20	2,50	5,00	1,80	-1,10	**14,60**

Q Catchment	Human	Social	Cultural	Financial	Infrastructural	Environmental	Political	Nett
J32E	0,80	2,40	3,20	2,50	5,00	1,80	-1,10	**14,60**
K70B	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K80A	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K80B	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K80C	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K80D	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K80E	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K80F	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K90A	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K90B	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K90C	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K90D	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K90E	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K90F	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
K90G	0,80	2,00	3,20	2,50	5,00	2,40	-1,10	**14,80**
L12C	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L12D	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L22D	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L23A	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L23B	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L23C	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L23D	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L30A	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L30B	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L30C	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L30D	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L40A	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**

Q Catchment	Human	Social	Cultural	Financial	Infrastructural	Environmental	Political	Nett
L40B	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L50A	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L50B	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L60A	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L60B	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L70A	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L70B	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L70C	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L70D	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L70E	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L70F	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L70G	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L81A	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L81B	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L81C	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L81D	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L82C	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L82D	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L82E	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L82F	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L82G	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L82H	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L82J	0,80	1,90	3,20	0,25	3,20	0,50	-1,10	**8,75**
L90A	0,80	1,90	3,20	0,25	3,50	0,50	-1,10	**9,05**
L90B	0,80	1,90	3,20	0,25	3,50	0,50	-1,10	**9,05**
L90C	0,80	1,90	3,20	0,25	3,50	0,50	-1,10	**9,05**
M10A	0,80	1,90	3,20	0,85	3,50	0,50	-1,10	**9,65**

Q Catchment	Human	Social	Cultural	Financial	Infrastructural	Environmental	Political	Nett
M10B	0,80	1,90	3,20	0,85	3,50	0,50	-1,10	**9,65**
N11A	0,80	1,60	3,20	0,60	3,20	0,20	-1,10	**8,50**
N11B	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N12A	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N12B	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N12C	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N13A	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N13B	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N13C	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N14A	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N14B	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N14C	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N14D	0,80	1,60	3,20	0,60	3,20	0,20	-1,40	**8,20**
N21A	0,80	1,60	3,20	0,60	3,70	0,20	-1,40	**8,70**
N21B	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N21C	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N21D	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N22A	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N22B	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N22C	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N22D	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N22E	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N23A	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N23B	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N24A	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N24B	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N24C	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**

Q Catchment	Human	Social	Cultural	Financial	Infrastructural	Environmental	Political	Nett
N24D	0,80	1,60	3,20	0,60	3,70	1,20	-1,40	**9,70**
N30A	0,80	1,60	3,20	1,45	4,00	1,20	-1,40	**10,85**
N30B	0,80	1,60	3,20	1,45	4,00	1,20	-1,40	**10,85**
N30C	0,80	1,60	3,20	1,45	4,00	1,20	-1,40	**10,85**
N40A	0,80	1,60	3,20	0,85	4,70	2,20	-1,40	**11,95**
N40B	0,80	1,60	3,20	0,85	4,70	2,20	-1,40	**11,95**
N40C	0,80	1,60	3,20	0,85	4,70	2,20	-1,40	**11,95**
N40D	0,80	1,60	3,20	0,85	4,70	2,20	-1,40	**11,95**
N40E	0,80	1,60	3,20	0,85	3,70	1,50	-1,40	**10,25**
N40F	0,10	1,00	3,20	1,65	3,70	2,30	-1,40	**10,55**
P10A	-0,80	-1,70	-1,00	-1,80	1,50	-1,40	-0,40	**-5,60**
P10B	0,80	1,60	3,20	0,60	3,50	1,50	-1,40	**9,80**
P10C	0,80	1,60	3,20	0,60	3,00	1,50	-1,40	**9,30**
P10D	0,80	1,60	3,20	0,60	3,00	1,50	-1,40	**9,30**
P10E	0,80	1,60	3,20	1,25	4,20	2,80	-1,40	**12,45**
P10F	0,80	1,60	3,20	1,25	4,20	2,80	-1,40	**12,45**
P10G	0,80	1,60	3,20	1,25	4,20	2,80	-1,40	**12,45**
P20A	0,60	1,90	4,00	2,60	5,00	2,90	-1,40	**15,60**
P20B	0,60	1,90	4,00	2,60	5,00	2,90	-1,40	**15,60**
P30A	0,80	1,60	3,20	0,65	3,00	2,00	-1,40	**9,85**
P30B	0,80	1,60	3,20	0,65	3,00	2,00	-1,40	**9,85**
P30C	0,80	1,60	3,20	0,65	3,00	2,00	-1,40	**9,85**
P40A	0,60	1,90	4,00	2,30	5,00	2,90	-1,40	**15,30**
P40B	0,60	1,90	4,00	2,30	5,00	2,90	-1,40	**15,30**
P40C	0,60	1,90	4,00	2,30	5,00	2,90	-1,40	**15,30**
P40D	0,60	1,90	4,00	2,30	5,00	2,90	-1,40	**15,30**
Q50B	0,60	1,90	4,00	2,30	5,00	2,60	-1,40	**15,00**

Q Catchment	Human	Social	Cultural	Financial	Infrastructural	Environmental	Political	Nett
Q50C	0,60	1,90	4,00	2,30	5,00	2,60	-1,40	**15,00**
Q60C	0,60	1,90	3,20	2,05	5,00	2,60	-1,40	**13,95**
Q70A	0,60	1,90	3,20	2,05	5,00	2,60	-1,40	**13,95**
Q70B	0,60	1,90	3,20	2,05	5,00	2,60	-1,40	**13,95**
Q70C	0,60	1,90	3,20	2,05	5,00	2,60	-1,40	**13,95**
Q80A	0,60	1,90	3,20	2,05	3,80	2,60	-1,40	**12,75**
Q80B	0,60	1,90	3,20	2,05	3,80	2,60	-1,40	**12,75**
Q80C	0,60	1,90	3,20	2,05	3,80	2,60	-1,40	**12,75**
Q80D	0,60	1,90	3,20	2,05	3,80	2,60	-1,40	**12,75**
Q80E	-2,45	-2,30	-2,70	-2,05	3,30	-0,90	-2,40	**-9,50**
Q80F	0,60	-0,20	3,00	0,40	2,80	0,30	-1,40	**5,50**
Q80G	0,60	1,40	3,20	1,80	3,80	2,40	-2,40	**10,80**
Q91A	0,60	1,40	3,40	2,10	4,30	2,20	-1,40	**12,60**
Q91B	0,60	1,40	3,40	2,10	4,30	2,20	-1,40	**12,60**
Q91C	0,60	1,40	3,40	2,10	4,30	2,20	-1,40	**12,60**
Q92F	0,60	1,40	3,40	2,10	4,30	2,20	-1,40	**12,60**
Q93A	0,60	-0,10	3,20	0,20	3,80	-0,10	-1,40	**6,20**
Q93B	0,60	0,20	3,20	0,20	3,30	-0,10	-1,40	**6,00**
Q93D	0,60	1,40	3,20	1,30	5,00	2,10	-1,40	**12,20**

6 Drought Vulnerability: Communal Farmers

Jordaan, A.J., Muyambu, F., Mdungela, N., Phatudi-Mphahlele, B., Bahta, Y., Mashimbye, C., Fadeyi, O. & Shwavaba, S.

Executive Summary

This chapter focuses 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 programmes. Vulnerability highlights the various burdens of drought losses that farmers experience in different locations. The Eastern Cape Province regularly experiences drought. The drought relief seems to be too little too late. However, without an insight into peoples' vulnerability, it does not reduce risk or improve resiliency against drought. Therefore the objective of this study was to assess farmers' vulnerability to drought in Cacadu, Joe Gqabi and OR Tambo districts.

An 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. Farmers in Cacadu district highlighted problems with surface and groundwater 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 a lack of safety nets, dependency on agriculture (lack of diversification) and level of debt as contributing more to vulnerability than most 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 that social vulnerability was extremely high for farmers in OR Tambo district, high for farmers from Joe Gqabi and moderate for farmers in Cacadu. According to their perception, farmers viewed psychological stress, cultural factors and practices and the lack of preparedness strategies as contributing the most to social vulnerability to drought.

In total, vulnerability to drought was estimated very high for farmers in OR Tambo district, followed by farmers in Joe Gqabi with Cacadu farmers experiencing the lowest vulnerability to drought, in spite of the fact that Cacadu is the most arid of the three districts. However, the results also indicated that farmers from these three districts were not completely vulnerable to drought. They have some coping mechanisms that that contribute to drought resilience. For example, they reported that they have indigenous farming knowledge, which they use in place of the formal knowledge that most of them

did not acquire. The study concluded that whilst dry periods are frequent in the three districts, there are social, economic and environmental factors that contribute to vulnerability to drought.

Selecting Drought Vulnerability Indicators

Drought hazard indicators are based on meteorological and hydrological variables such as precipitation, streamflow, soil moisture, reservoir storage, and groundwater levels. 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 recognized as useful 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) highlighted 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. 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 some of the drought indicators and triggers may lack scientific justification. Nevertheless, sound indicators and triggers are important in order to detect the onset of drought conditions, to monitor and measure drought events, and to reduce drought impacts (Steinemann, 2003).

Policy-makers and decision-makers make life-changing decisions based on information presented as indicators and therefore there is a need for indicators to be (i) transparent; (ii) robust; (iii) representative; (iv) replicable; (v) comparable; and (vi) easy to understand (Cannon, 2003; IADB 2005; Dercon, 2007). Moldan & Dahl (2007), on the other hand, state that the quality of indicators is measured by the (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

    - *Validity/accuracy* provides a true reflection of the issue under assessment and must be developed in a consistent analytical framework. Data have to be verified, be scientifically robust and be 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 them.
- Participatory-relevant criteria imply that indicators be
    - *Understandable* in order for users to grasp the indicators;
    - *Easy to interpret* since users are in most cases not subject matter experts and indicators should communicate the message to the common user.
- Practitioner-relevant criteria imply the following:
    - *Data availability* is probably the first criterion to be evaluated by the practitioner, since without data no indicator can be developed;
    - *Cost effective* indicators are more accepted when data are simple and easy to collect; and
    - *Policy relevance* indicates the usefulness of an indicator. Policy relevant indicators monitor key outcomes, progress, and processes and provide relevant information.

It was not practically possible to include all aspects of social, economic and environmental (ecological) indicators related to the study, hence the selection of indicators that contributed to a practical solution. The BBC framework formed the basis for identifying locally developed social, economic and environmental indicators, which were appropriate for this study (Adger *et al.,* 2004; Birkmann, 2006; Wongbusarakum & Loper, 2011; Jordaan, 2011). The indicators selected were directional and linked to drought in the research area and allow for comparisons between the two farming systems. Indicators selected also assisted in identifying where and how to intervene in order to increase drought resilience (Alwang *et al*., 2001; Wongbusarakum & Loper, 2011). Thus, the indicators selected included the three main components of vulnerability, namely exposure, susceptibility and coping capacity of the target population.

Adger *et al*. (2004) proposed a selection procedure for indicators that involves two general approaches, namely the deductive and inductive approaches. The deductive approach is based on the selection of indicators on a theoretical understanding of relationships and follows the identification of the processes under study and how they are related. The most suitable indicators were selected and values and weights assigned thereto according to the method proposed by 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 made use of both methods. 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, the literature and preliminary study tour observations. Jordaan (2011) also emphasized the importance of indicator relevance to drought and the outcome of the final result.

Socio-Economic Characteristics

The distribution of respondents according to various socio-economic characteristics is summarized in Table 6.1. Most respondents were mature adults with 73% males and 27% females; an indication that communal agriculture in the study area was dominated by males. This can be attributed to the fact that males in the study area have access to land as a productive resource, which was not the case with females. Quisumbing (1994) reported that there has been a great disparity between women and men in the size of landholdings and that the mode of women participation in agricultural production varies with the land ownership status of households.

Thirty five per cent of respondents were above 55 years of age, with a mean age 51.7 years. Age is an important determinant of socio-economic status of a population. It is shown in Table 6.1 that 30% of the respondents had more than 15 years farming experience, while on average the farming experience was 12.7 years. Although experience is gained with age, farming needs not be dominated with aged populations in any region as this could have negative implications on the future of food production in such region. The average household size was seven. Small- and medium-scale farmers were characterized by having larger households.

A significant number of respondents (22%) did not have any formal education, with 4% with tertiary education and 17% with secondary level education. These demographic and socio-economic characteristics are of significant importance, as they can influence households' economic behaviour (Randela, 2005). Land is an important asset for farmers and there was a significant difference between the three district municipalities in terms of land size. Results show that the majority of the farmers cultivated land ranging from 1 to 2.5 hectares in OR Tambo. These farmers farmed with food crops, horticultural crops and livestock. Farmers closer to the mountains in the western part of OR Tambo had access to much larger tracts of land. In Cacadu district land size was 100 ha to 200 ha as a result of the arid climate in the region. These farmers were mainly livestock farmers. Farmers in Joe Gcabi farmed on smaller land ranging from 10 ha to 100 ha.

Table 6.1: Socio-economic characteristics of survey respondents (*N* = 121)

Characteristics	Sub-characteristics	OR Tambo (*n* = 87)		Joe Gqabi (*n* = 19)		Cacadu (*n* = 15)		% (*N* = 121)			Total
		N	%	*N*	%	*N*	%	ORT	JG	CD	%
Age group (years)	25-34	7	8	3	16	2	13	6	2	2	10
	35-44	20	23	3	16	2	13	17	2	2	21
	45-54	25	29	4	21	4	27	21	3	3	27
	> 55	35	40	9	47	7	47	29	7	6	42
Gender	Male	62	71	16	84	11	73	51	13	9	73
	Female	25	29	3	16	4	27	21	2	3	27
Education	None	23	26	1	5	3	20	19	1	2	22
	Primary	44	51	13	68	12	80	36	11	10	57
	Secondary	18	21	2	11	-	-	15	2	-	17
	Graduate	2	2	3	16	-	-	2	2	-	4
Household size	0- 4	29	33	5	26	8	54	24	4	7	35
	5- 8	32	37	11	58	5	33	26	9	4	39
	9-12	14	16	3	16	2	13	12	2	2	16
	> 13	12	14	-	-	-	-	10	-	-	10
Access to resources	Land	69	79	17	89	14	93	57	14	12	83
	Water	35	40	10	53	6	40	29	8	5	42
Experience (years)	0- 4	10	12	4	21	7	47	8	3	6	17
	5- 9	20	23	6	32	4	27	17	5	3	25
	10- 14	28	32	4	21	2	13	23	3	2	28
	> 15	29	33	5	26	2	13	24	4	2	30

ORT - OR Tambo; JG - Joe Gqabi; CD - Cacadu district municipality; N- number

6.1.1 Livestock Production

The majority of farmers in the Cacadu district farm with livestock. All farmers farming with goats and cattle in the Cacadu district reported animal losses as a result of drought, while 50% sheep farmers also reported losses. All farmers in Joe Gqabi district reported livestock losses. OR Tambo seems to be more resilient to drought when based on livestock number losses alone. Eighty-five per cent of sheep farmers reported animal losses, while 78% of goat farmers and 72% of cattle farmers also reported losses (See Figure 6.1).

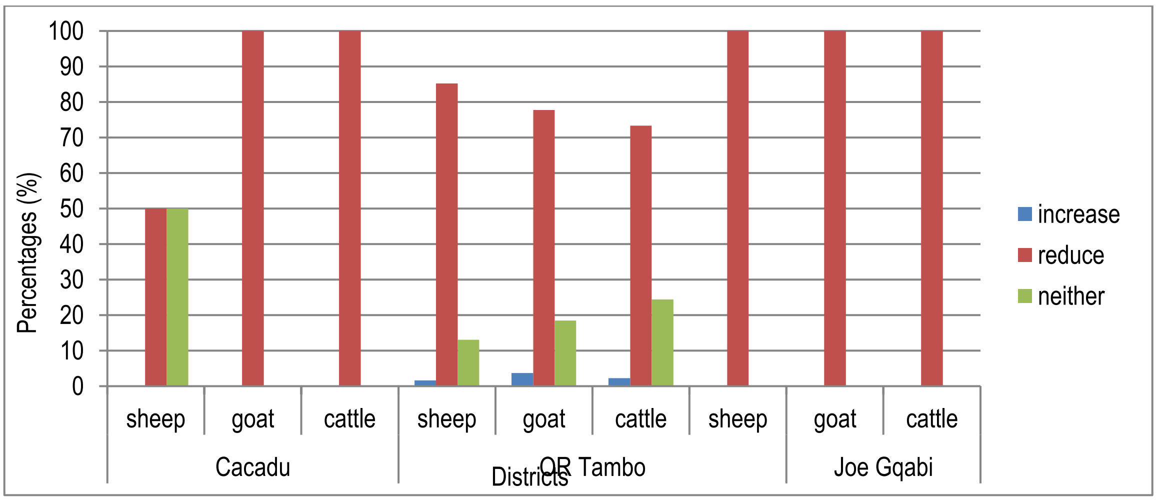

Fig 6.1: Percentage of farmers with livestock

Farmers in Joe Gqabi reported a decrease in sheep numbers of 45% as a result of previous droughts. Goat and cattle losses were 29% and 24% respectively. OR Tambo farmers reported losses of 36% for sheep and 24% for goats. Cattle numbers also decreased during droughts, but not as drastic as with small stock. Cacadu farmers also reported losses ranging from 20% to 28%. One farmer in OR Tambo indicated that he increased his livestock numbers during previous droughts because he manages to buy in at reduced prices due to increased supply.

Farmers in all three districts reported that they reduced stock numbers according Department. of Agriculture guidelines as a coping strategy, but extension officers mentioned that it happened too late when the condition of livestock were already very poor Prices were also very low as a result of over-supply and poor conditioned of animals.

6.1.2 Crop Production

Crop production in all the three districts was practised on dry land, but few communal farmers depended on crop production. Results for crop production are shown in Table 6.2. The results show that maize was the most popular crop among communal farmers in all three districts. The popularity of maize production is not surprising because it remains the staple food of the South African population (National Department of Agriculture, 2014). Other crops such as lucerne, beans and wheat were are not widely produced by communal farmers.

Table 6.2: Farmers with crops on dry land and under irrigation

	Lucerne		Grazing grass		Maize		Wheat		Vegetables	
	Dry	Irrigated	Dry	Irrigated	Dry	Irrigated	Dry	Irrigated	Dry	Irrigated
Cacadu										
Mean	-	0.4	-	-	4	2	-	-	-	0.5
Maximum	-	1	-	-	4	2	-	-	-	1
% of farmers	-	26.7	-	-	13.3	6.7	-	-	-	13.3
Joe Gqabi										
Mean	6	-	-	-	5	4	-	-	-	1
Maximum	15	-	-	-	109	4	-	-	-	10
% of farmers	10.5	-	-	-	15.8	5.3	-	-	-	5.3
ORT										
Mean	-	1.3	10	1	0.25	1	0.5	1	0.1	1
Maximum	-	1.3	170	6	58	8	3	1	15	20
% of farmers	-	1.15	5.7	2.3	65.5	3.4	3.4	1.15	27.6	9.2

6.1.3 Drought Risk Perception

Most respondents perceived their farming operation's level of drought risk to be high. Figure 6.2 shows that 37% of farmers from Joe Gqabi perceived their risk to drought to be high and another 37% perceived it to be very high. Farmers from OR Tambo also indicated that their risk to drought is mostly in the high to very high categories. Cacadu district, however, had more respondents who perceived their risk to drought to be in the moderate category, which is interesting since Cacadu is the most arid of the three districts. The research team came to the conclusion that farmers in Cacadu had already adapted to the arid conditions in the district.

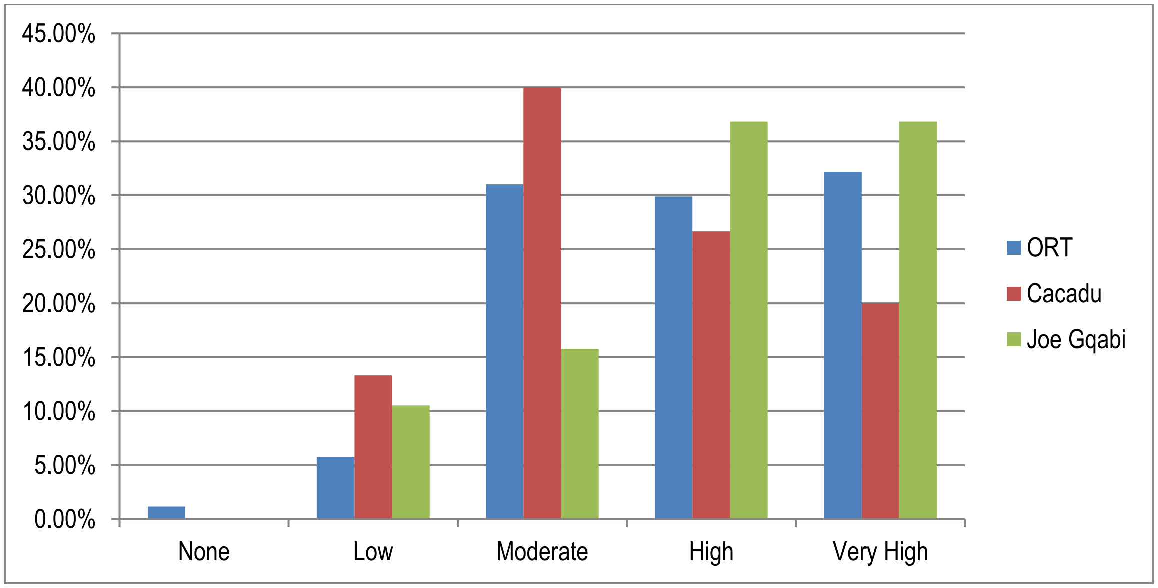

Fig 6.2: Respondents' perceptions of risk level

In relation to the farmers' perception of drought risk was their experience of severe drought years. Table 6.3 shows that the average years of drought were more for Joe Gqabi district than for the other two districts. However, OR Tambo has the highest maximum years of drought. The most frequent response for years of drought was 2 years for OR Tambo and Cacadu districts and 3 years for Joe Gqabi. Cacadu and OR Tambo districts had some respondents who indicated that they had never experienced any severe drought, whilst the minimum for Joe Gqabi district was 2 years.

Table 6.3: Number of severe droughts experienced by respondents

	Mean	Mode	Minimum	Maximum
Cacadu	2.13	2	0	6
Joe Gqabi	3	3	2	5
OR Tambo	2.62	2	0	10

The most extreme drought years prioritised by respondents were 1982/83, followed by 2009/10, 2012/13 and 1992/93 for OR Tambo and Joe Gqabi districts. Farmers from Cacadu district prioritized 2009/10, followed by 2007/2008 and 2012/13.

Social Vulnerability Analysis

The assessment of vulnerability provided an understanding of how social conditions and processes directly or indirectly impacted on vulnerability to drought. The following indicators were identified as possible social factors that play a substantial role in vulnerability of communal farmers towards drought. These were (i) age, (ii) security and safety, (iii) gender participation, (iv) education level, (v) social networks, (vi) psychological stress, (vii) external support, (viii) social dependence, (ix) indigenous knowledge, (x) preparedness strategies, (xi) cultural values, and (xii) beliefs and practices.

6.1.4 Age

Forty seven per cent of respondents from Cacadu, 47% from Joe Gqabi and 40% from OR Tambo were at least 55 years old. Table 6.2 shows that it was mostly older people who were engaged in agriculture. The average age for respondents from the three districts was 51.7 years, with the maximum age being 85 years. Authors such as Cutter *et al*. (2003); Wisner *et al*., (2004); Rygel *et al.* (2006) and Wongbasarakum & Loper, (2011) argued that extremities in age, i.e. the old and very young of age, is an important social vulnerability indicator to natural hazards. An example is the assessment of the Bhuj earthquake of Gujarat where it was revealed that people above 60 years were most affected (ADPC, 2000).

Older communal farmers reported difficulty in accessing agricultural resources due to physical ailments which hinder their farm activity, and reduced mobility. When the respondents were asked why the younger generation were not actively involved in farming their responses were as follows:

- *Farming is for the old and uneducated folk*
- *My children are in the big cities, they do not want to be involved in farming…I have no one to help me*

The comments above showed a possible negative attitude towards farming amongst the younger generation. One farmer, 75 years old, desperately lamented his childrens' lack of interest in his farming activities.

6.1.5 Gender Participation

In relation to gender participation the study focused particularly on the balance of decision-making between men and women and its effect on vulnerability to drought. Communal farmers from Cacadu district perceived gender as not affecting decision-making related to farming, as shown in Figure 6.3. They argued that women and men make decisions about farming together. Women, according to the respondents, were treated equally and made equal contributions to agricultural activities. Respondents made comments such as:

- *Women and men can work well together*

- *Leadership consists of men and women, women dominate*
- *Women are actively involved in decision making*

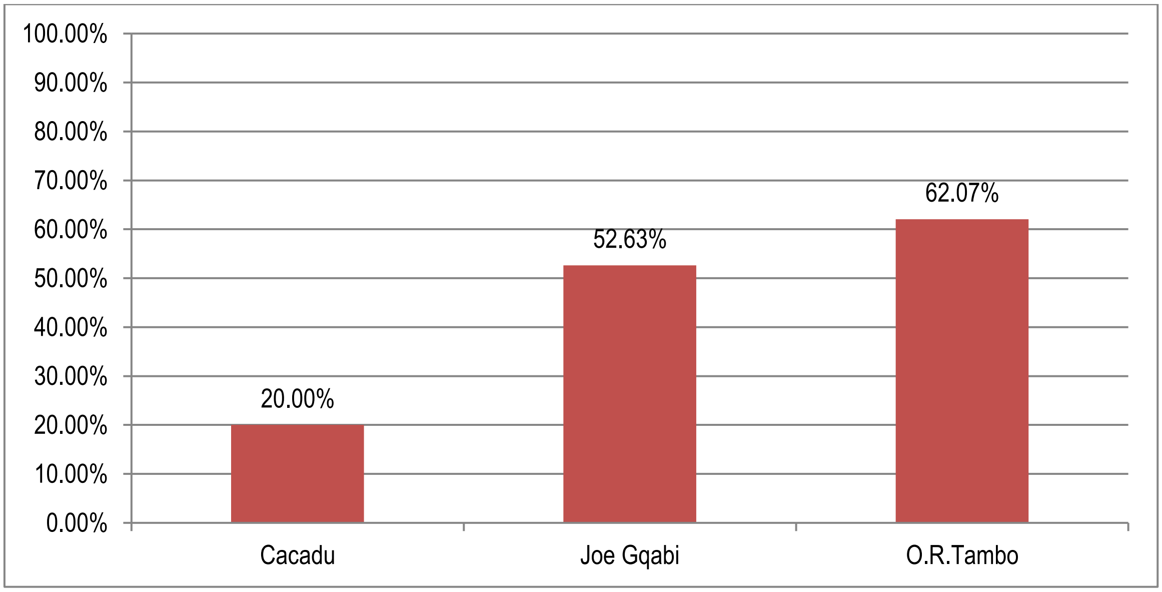

Fig 6.3: Perception of the effect of gender on decision-making

However, farmers from Joe Gqabi and OR Tambo districts had a different perception of the influence of gender in decision-making and consequently vulnerability to drought. From Joe Gqabi district, the responses were almost balanced between those who viewed gender as a critical factor in vulnerability towards drought and those who did not (See Figure 6.3). Some respondents reported that that they made decisions and worked together. Farmers from OR Tambo district mostly viewed women as being undermined in decision-making. Women (especially the married ones), generally, could not made decisions relating to livestock without the husband's approval. Some of the comments made by farmers from both Joe Gqabi and OR Tambo districts were:

- *We don't talk to women when it comes to farming business…women belong in the kitchen*
- *Men are the decision-makers in the household and that restricts women to certain activities related to stock*
- *In our culture females are expected to respect their men, so the man is the head of the household; he is the one who decides*

On the other hand, a smaller proportion of the respondents perceived women as being more resilient as men during droughts. They said the following:

- *Women survive drought better than men. They fight for their children's survival*
- *Women are not more vulnerable, they are fighters*
- *Women are strong…they know how to search for food for the family in times of drought*

Moreover, some male respondents made the following comments, which show that there was a slight shift in the idea of gender and agricultural development:

- *In the democratic South Africa we respect gender equality*
- *Everybody in South Africa has a right to speak out his/her views or to contribute what he/she thinks is right*

The balance of decision-making between men and women concerning farming was generally in favour of men, making women more vulnerable to drought. This confirms the findings of Jordaan & Adoko (2014) in Karamoja, Uganda, where men dominated decision-making

6.1.6 Psychological Stress

All respondents from Joe Gqabi and most respondents from OR Tambo perceived psychological stress as contributing to vulnerability to drought (Figure 6.4). Stress resulted in several other health problems such as fatigue, insomnia, stroke, sexual problems, hypertension and migraines. This, in turn, made it more difficult for farmers to plan and work efficiently during dry periods. Their coping capacity was eroded by a stressful condition. Most respondents from Cacadu district, however, indicated that stress did not affect their vulnerability or resilience to drought. Contrary to this, in a different question, 67% of the respondents in Cacadu indicated stress as the main social consequence of previous droughts (Figure 6.5). The farmers indicated that drought worsened their psychological health conditions that were already being stressed by other problems such as family issues and financial or health challenges before the onset of droughts.

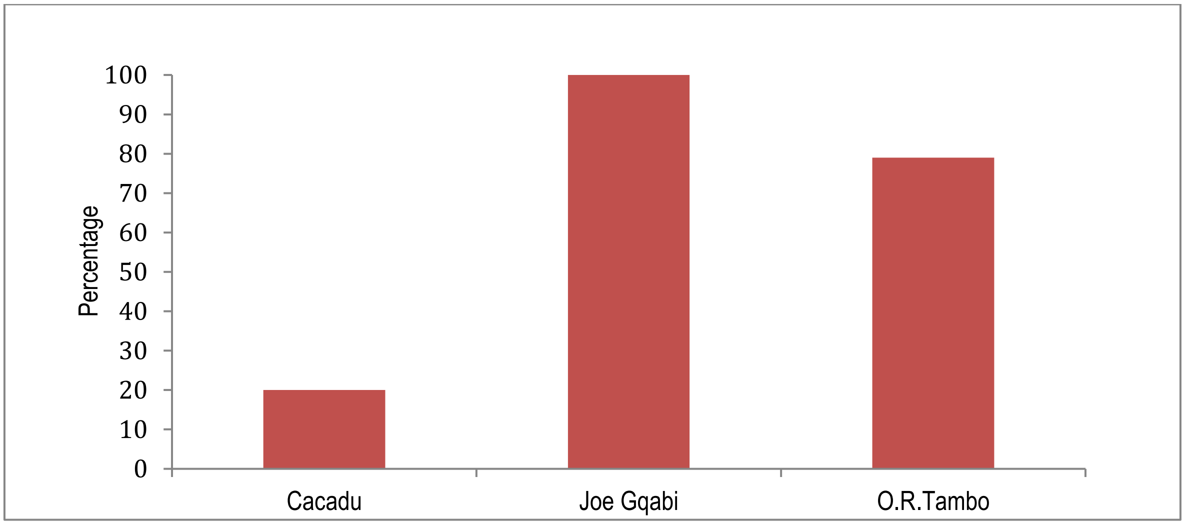

Fig 6.4: Farmers' perception about how stress affects farm activities

Two different respondents gave the following comments during workshops:

- *Life is full of stress. I am always stressed by family and financial problems…drought just worsens it all…I feel like running away*
- *From the moment I realize that the rains are delayed or may not be normal, I get stressed.*

When asked about the drought impacts that cause psychological stress the respondents gave the following responses:

- *Watching my children going to school without eating anything*
- *I wake up in the morning and see my sheep dying… and I cannot do anything to help them… I have no feed, no water.*
- *As a man I have to provide for my family. I don't like it when I cannot simply do that.*

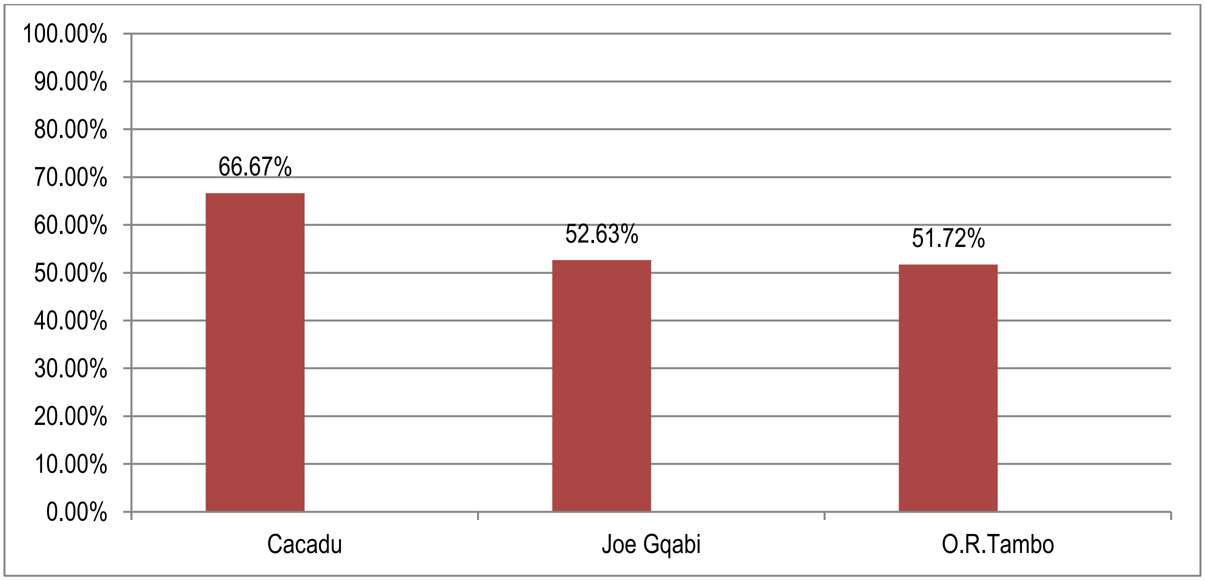

Fig 6.5: Percentage of respondents who perceived stress as a major social effect of drought

The experience of these farmers is similar to what has already been revealed in other studies elsewhere; for example by Aslin & Russell (2008) in Australia, and Zarafshani *et al*. (2012) in Western Iran. The onset of drought causes considerable stress to the farmers, yet those farmers who were already desperate or despondent prior to drought have less capacity to cope with drought impacts. It can be established that psychological stress makes farmers more vulnerable to drought.

6.1.7 Social Dependence

Based on the 2011 census results, the social dependency ratios were 81%, 71% and 52% for OR Tambo, Joe Gqabi and Cacadu districts, respectively. Extension officers raised the issue of social grant dependency as an issue of concern. Social grants created a syndrome of dependency where people expected government to do everything for them. The South Africa Social Security Agency (SASSA) pays child support for children up to 18 years. It also pays older persons' grants to adults over 60 years old to relieve poverty and allow people to buy food.

Some of the concerns raised by extension officers were:

- *Farmers depend too much on the government… they don't want to do anything for themselves*
- *Communal farmers should find ways to help themselves and not expect government to do everything all the time*

The general sentiments from extension officers were that social grants create a dependent society that cannot do anything for themselves. Instead people wait for *"government"* to do everything for them. As a result of this dependency syndrome, communal farmers did nothing to plan, prepare for or mitigate drought impacts because they waited for government intervention. This increased their vulnerability to drought. The extension officers' views of the negative effects of dependency on social grants echoed those of Fothergill & Peek (2004) who argued that the way a community perceived risk and prepares for it is influenced by its poverty and dependency status.

The extension officers' sentiments were, in part, confirmed during workshops with communal farmers. At one workshop in Port Alfred, Cacadu district, it was observed that some farmers left the workshop as soon as they realized that there were no material benefits available for them. One left in a rage, shouting insults that *"it's a waste of my time…I do not have time to waste".* In a separate incident the respondent kept on telling the researchers about his need for a tractor and how he thought they had brought him money or the tractor itself. It was a general trend that the farmers who attended the workshops expected to receive money or other material benefits.

6.1.8 Education Level

Education is very important in developing a drought resilient community. Most studies associated lack of education with marginalization and poverty. The less educated or lower skilled a farmer is, the more susceptible he/she is to the negative impacts of drought (Adger *et al*., 2004).

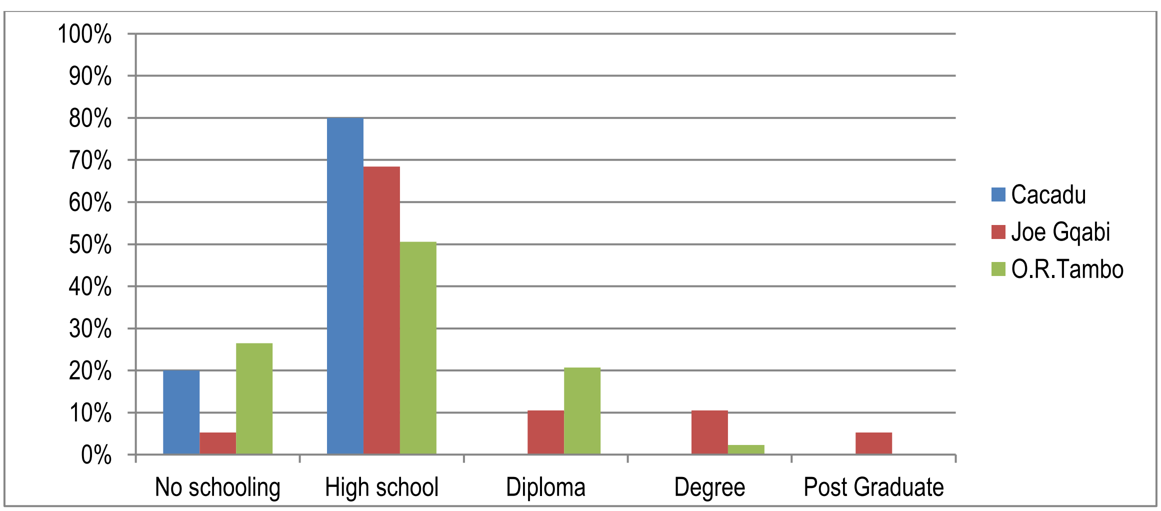

Fig 6.6: Education levels

The proportion of respondents who had, at minimum, a high school qualification was high considering the provincial illiteracy level of 27% (StatsSA, 2011). As illustrated in Figure 6.6, 80% of respondents in Cacadu district had at least a secondary school education. This was followed by Joe Gqabi with 68% while only 51% of respondents in OR Tambo completed secondary level education. The literate participants were usually chosen first to respond to questionnaires; hence it is possible that the rate of illiteracy could be lower than what was found in this study. Nonetheless, the results showed a farming community that was generally able to cope with the demands of farming and drought risk reduction as far as accessing, comprehending and utilising timely information.

6.1.9 Cultural Values Beliefs and Practices

Culture as an indicator was identified during the initial transect tour and supported by the literature. As shown in Figure 6.7, the majority of respondents indicated that cultural values, beliefs and practices have a significant influence on vulnerability to drought impacts.

It was a general consensus that Xhosa people, especially men, found it difficult to reduce their livestock before the onset of a dry period. They held on to their livestock for honour and status in the community until the livestock was either too thin to fetch a good price on the market or the animal died because of starvation. They believed that their wealth was locked up in their livestock, hence they resist selling and transferring that wealth into monetary terms.

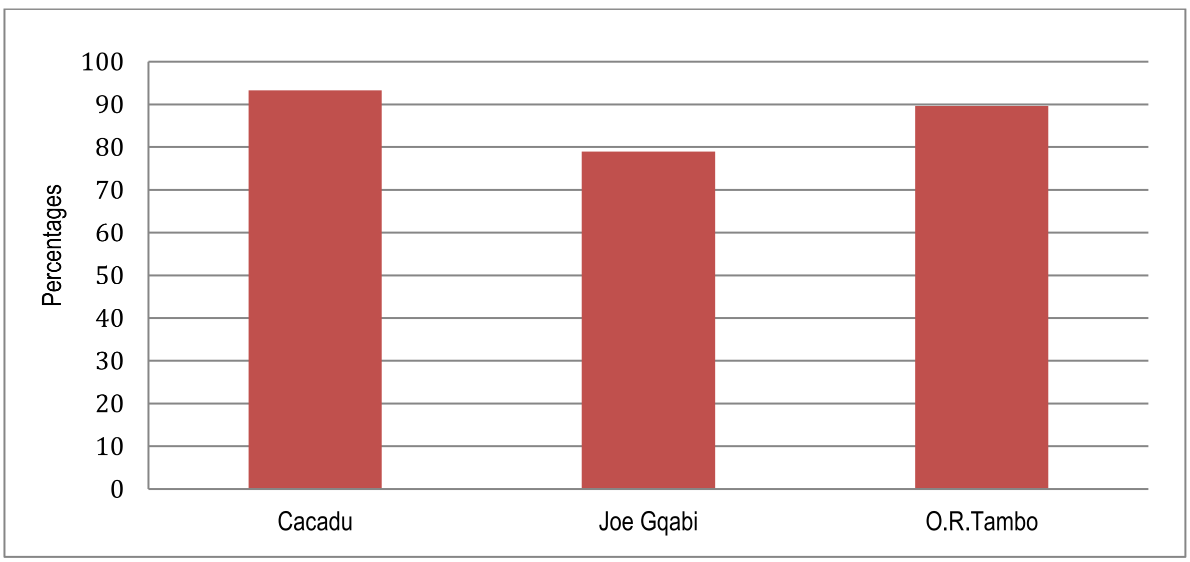

Fig 6.7: Farmers' perceptions on cultural values, beliefs and practices

The following were some of the responses from the respondents to the question on how cultural values and practices influence vulnerability to drought:

- *Our fathers do not want to reduce their number of animals because of pride – animals die of hunger*
- *At a cultural dance only a man with cattle can dance with his arms up and relaxed…a man with goats will lift his two index fingers…while a man without any livestock has to fold his hands*

Large numbers of goats were slaughtered for rituals in June and December, thereby increasing goat farmers' business. Increased income from goat sales increased drought resilience for goat farmers.

6.1.10 Security and Safety

A secure environment is paramount in farming, whether communal or commercial (Jordaan, 2011; Jordaan & Adoko, 2014). It was an important social vulnerability indicator because farmers who felt insecure did not invest in their farming business and they suffered more from drought impacts. The high rate of stock theft is shown in Figure 6.8. Between 50% and 80% of farmers reported that they lost livestock annually because of stock theft. Majavu (2013) already reported that the Eastern Cape has been ranked the highest in stock theft in the country. Except for Cacadu district, the results displayed in Figure 6.8 show an increase in the level of stock theft during drought years. Both OR Tambo and Joe Gqabi border on Lesotho which is known for an area where stolen animals roam.

It is important to note that stock theft, farm attacks and theft of other assets followed an increasing trend during drought. Figure 6.8 shows the increase in insecurity between drought and normal years.

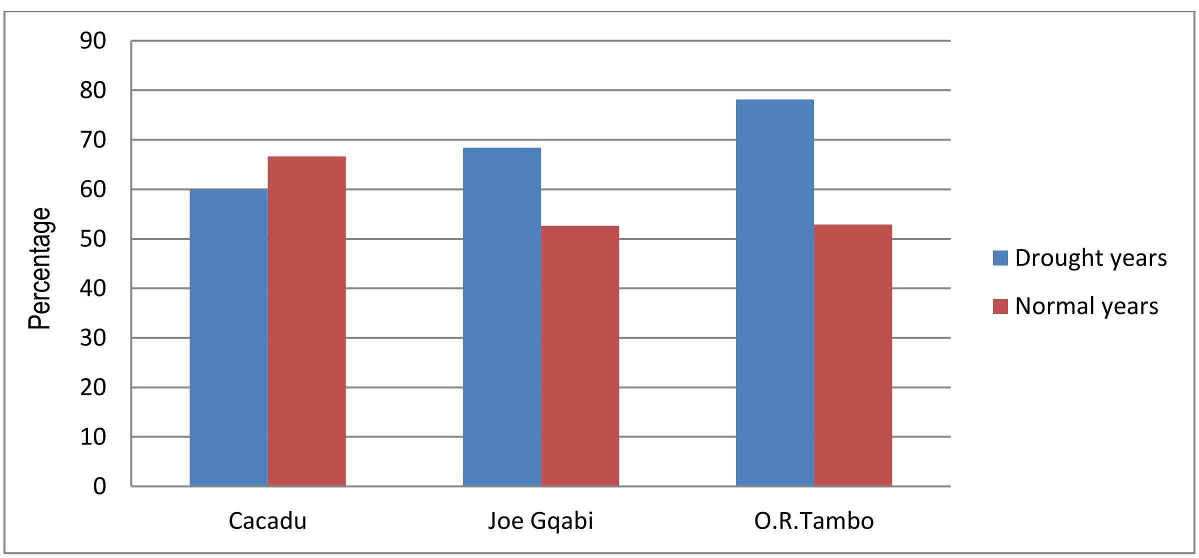

Fig 6.8: Comparison of stock theft in drought and normal years

The results showed an increase in stock theft of 25% and 16% for OR Tambo and Joe Gqabi during droughts. For Cacadu district, however, stock theft decreased by 7% during drought.

Another security challenge that was discovered during fieldwork was the issue of broken and unrepaired fences in most parts of OR Tambo DM. As a result cattle, sheep and goats could be seen unattended beside the roads or right on the road, as shown in Pic 6.1.

Pic 6.1: Picture showing no fence to secure livestock

One of the respondents expressed disappointment at the loss of his entire herd of cattle from stock theft in 2009. Thereafter, he lost interest in the welfare of his sheep and goats that remained. He stopped medicating them as he used to, hence most of them got sick and died. It took him some time to recover from that loss. Stock theft becomes even easier with broken and unrepaired fences, thereby increasing farmers' vulnerability during dry periods.

6.1.11 Indigenous Knowledge

The influence of indigenous knowledge to either resilience or susceptibility to drought is of particular interest in agriculture (Jordaan, 2011; Jordaan & Adoko, 2014). As shown in Figure 6.9, respondents from all three districts claimed to have considerable indigenous knowledge that helped them coping with drought.

Sixty-four per cent of respondents relied on indigenous knowledge to cope with drought and normal farm management. This result was in line with studies of Olatokun & Ayanbonde (2006), who found that 44% of respondents used indigenous knowledge in farming and drought risk reduction. Moreover, these findings corroborate with the findings of UNEP (2008), who documented the use of indigenous knowledge as an integral part of the knowledge system in African communities and agriculture.

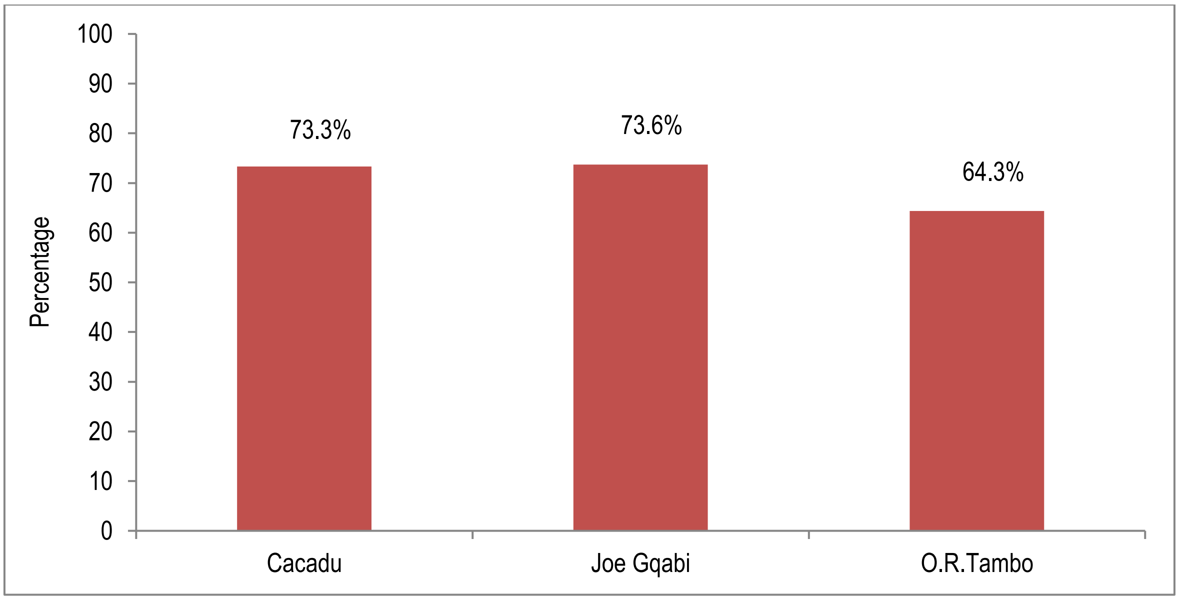

Fig 6.9: Proportion of respondents with indigenous farming knowledge

The respondents also revealed that indigenous knowledge contributed toward drought resilience. For the purpose of this research, indigenous knowledge were categorized under (i) early warning, (ii) preservation of seed and production, (iii) drought preparedness, and (iv) sacred animals.

5.1.1.8 Early warning signs

Nature and the behaviour of animals and insects are major early warning indicators for farmers. Communal farmers interpreted the movement of an army of locusts in the same direction as an early warning sign for drought. Farmers commented as follows:

- *If you see snakes moving in the same particular direction…you know for sure that there is going to be drought or rain*
- *Bees flying a certain direction means there will be drought or rain*
- *I believe on phases of the moon in planting vegetables…full moon you plant crops above the ground, when the moon goes down you plant under-ground.*

Farmers explained that the pending drought and rain could be predicted from the behaviour of different species such as:

- Snakes moving the same direction - drought when they move downhill and rain when they move uphill
- Bees flying to a certain direction – drought
- Frogs making a lot of noise in the afternoon – rain
- Horses jumping playfully – rain.
- Kaleidoscope of butterflies flying together – a good season.
- Army of locusts moving in same direction – drought.
- Higher than normal lamb percentages amongst livestock – a good season to be expected.

5.1.1.9 Preservation of the seed and production

Most livestock farmers also plant small amounts of maize and sorghum and some indigenous knowledge was found to be specific to crop production. The elderly people check the maize while still in the field for good quality cobs. The larger maize cobs are not used as green maize cobs. They are guarded strictly and reserved for seed. During harvesting those big maize cobs are set aside and kept for seed for the following growing season. Some of it was kept in their round huts, which in the local language are called "*Intanyongo* or *Iziswenye*". The maize cobs are hung onto the ceiling to ensure complete dryness. Some farmers sprinkle some ash around the seed to keep ants away. If the production of maize and sorghum was good enough, farmers took some of the bags after harvesting and kept them in big water tanks as a reserved for difficult periods. In previous times they used to dig a big deep hole in the centre of the kraal as a means of storage for excess food. This practice prevented thieves from having access to it. This ensured some form of food security in the past.

5.1.1.10 Drought preparedness and rituals

Local people perform ceremonies to their ancestors before and after harvest in the belief that ancestral spirits would give rain in answer to their prayers (Rusiro *et al.,* 2013). The practice of conducting ceremonies for rain is no longer as common in the villages as it used to be a few years ago, but farmers reported they still perform rain ceremonies in extreme cases of drought. The practice is still prevalent in most African countries. Ngara & Mangizvo (2013) reported the practice in Zimbabwe (Inyangani mountain), Lesotho and Eastern Cape province with their sacred hills, forests and wells.

Respondents mentioned that people associated many ants with droughts, and when they were spotted, the village leaders announced this during the Chief's meeting. The village leaders then set a date and time to go up a sacred mountain such as *Qwempe*. They conducted traditional dances called "*Imingqungqo"* or "*umxhentso wakwantu"* in IsiXhosa (the local language in Eastern Cape Province). The people carried along traditional beer and slaughtered cattle. By doing that it was a way of passing their request to their ancestors. Some would use a big river to perform a similar ritual. *Ngonyama* River is one such sacred river. They believed that it would rain after such ceremonies. Respondents who participated and explained this ritual added by stating that:

> *"…the present generation does not believe nor bother themselves about these important rituals which used to help reduce incidents of drought".*

5.1.1.11 Sacred animals

African communities all have their sacred animals. For example, for the *Shangwe* people in Gokwe, Zimbabwe, a lone baboon is an ancestral symbol. There were also lions, which do not attack local people and were associated with rain messages (Ngara & Mangizvo, 2013). Some of the farmers in OR Tambo district believed that a brown animal such as a brown Swiss (cattle breed which is good for beef and milk production) should not be kept together with their cattle, because these bring bad luck (affecting breeding) to the herd of cattle. Some people believed that the skin of a rabbit should not be put in the fire, because it caused dryness with little rain that might lead to drought.

5.1.1.12 Challenges in using indigenous knowledge

The respondents indicated that indigenous knowledge lost its significance in farming and drought risk reduction because the younger generation did not value it any longer. Places, animals and practices that used to be sacred and taboo were now treated lightly. In agreement with Boven & Morohashi (2002), poor documentation of indigenous knowledge was mentioned as one of the contributing factors to the decline of using indigenous knowledge. The respondents further blamed "*western science"* as a major cause for the deterioration of indigenous knowledge. They argued that "*western science*" is considered as more superior and civilized than traditional knowledge. Rusiro *et al*. (2013) found similar results. On the other hand, traditional knowledge was considered as demonic, inferior and mythical. Some claimed that the younger and more formally educated generation were embarrassed to be associated with it. Similar challenges have been highlighted by other scholars such as Dube & Musi (2002) and Daniels (2016) who found that people, particularly the youth, have a negative attitude towards indigenous knowledge.

6.1.12 Social Networks

Farmers with strong social network systems coped better with drought than those without any or with weak and ineffective social networks (Stone, 2000). The (i) coordination of drought response activities in the community, (ii) the presence of institutions (e.g. farmers' organizations, churches, clubs, stokvels, family networks), (iii) the ability of the community to collaborate in drought mitigation and (iv) the community's involvement in drought risk reduction were the four aspects mentioned by some as having had an influence on drought risk reduction. The results, however, showed that a smaller percentage of farmers acknowledged the importance of social networks as a contributor to drought risk reduction. The results illustrated in Table 6.4 show that only 37% farmers in Cacadu, 33% in Joe Gqabi and 18% in OR Tambo regarded social networks as relevant in drought risk reduction activities.

Table 6.4: Percentage of farmers' responses on social networks

District	Coordination	Institutions	Collaboration	Involvement	Average Score
Cacadu	33.3	46.6	46.6	20.0	36.6
Joe Gqabi	15.7	31.5	47.3	36.8	32.9
O.R. Tambo	20.6	12.6	32.1	6.9	18.1

This responses were confirmed by the comments from respondents such as the following:

- *We have never discussed drought issues in our church or club*
- *This is the first time I have attended a workshop or meeting on drought planning*

These comments show that although people may belong to certain social groupings, drought risk reduction was hardly, if ever, discussed. Farmers and extension officers stressed the absence and non-functionality of farmers' associations at grass root levels as a challenge. The average scores for each district shown in Table 6.4 indicates the perceptions of social network involvement in drought issues. The results show that social networks were generally not involved in drought issues. Hassen (2008) reported that where social networks were involved in drought issues, farmers were able to call on each other for help because they had rights and access to some resources as a result of their group membership status. Hence, the lack of effective social networks involved in drought mitigation contributed more to social vulnerability than to drought mitigation.

6.1.13 External support

Both farmers and extension officers expressed their dissatisfaction concerning the execution of the drought relief programmes. They argued that the governments' past promises of drought support had, to a large extent, not been fulfilled. Drought support, in terms of drought relief was usually too late, if it ever gets to farmers. By that time farmers have already lost livestock or crops. At most times the drought relief coincided with the end of the dry period. One farmer expressed the following concern:

"We hear the ECDRDAR is assisting farmers in the drought season, but as communal farmers we do not get any assistance though extension officers do fill applications for disaster when we lose our livestock, but we do not get any compensation".

The results shown in Table 6.5 illustrate the negative perception of farmers on previous government drought relief schemes and actions. The government's limited involvement in drought risk reduction was an indication of increased vulnerability of the communal farming sector to drought impacts. Farmers were left exposed to drought impacts without much support and reliable safety nets from government. Farmers from OR Tambo were the most negative regarding government drought relief, with only 22% of them responded positively about government support.

Table 6.5: Percentage of mean value of government involvement in drought issues

District	Past help	Govt. interest	Training	Funding	Info	Resource	Future help	Ave score
Cacadu	20	46.6	60	66.7	26.7	40	60	45.7
Joe Gqabi	5.26	26.3	42.1	52.6	10.5	21	21	25.6
OR Tambo	9.2	21.8	16.1	36.7	20.6	17.2	28.7	21.5

6.1.14 Preparedness Strategies

The availability of drought plans and preparedness strategies were regarded as an important indicator for drought risk reduction. The results shown in Table 6.6 indicate the lack of drought preparedness strategies and plans in all three districts. Only 17% farmers in Cacadu, 18% in Joe Gqabi and 9% in OR Tambo acknowledged that they had drought preparedness plans in place. None of the district municipalities nor local municipalities could show any drought preparedness or drought mitigation plans. During the workshops the farmers expressed their amazement at hearing about drought preparedness plans. Some of the comments that were made were:

- *I have never thought of preparing for drought…I just farm*
- *Not at all…we have never prepared for drought*

Table 6.6: Respondents' mean score for drought preparedness

District	Drought plans	Preparedness strategies	Average score
Cacadu	20.00%	13.33%	16,67%
Joe Gqabi	31.58%	5.26%	18.42%
OR Tambo	14.94%	2.30%	8.62%

To most of the farmers who attended the workshops the idea of planning for drought was new. In response they argued that it was difficult to prepare for drought without resources such as finances and land. Extension officers were all pleased with the opportunity to be exposed to drought risk reduction planning. They also confirmed that they had never received any training with a focus on drought risk reduction and acknowledged the importance of preparedness planning.

6.1.15 Estimating Vulnerability

This section shows how the indexing of vulnerability indicators was undertaken (see Appendix A). Equal weights were assigned to indicators used in the measurement of vulnerability for each district. Table 6.7 shows the calculation of vulnerability, which was based on the BBC model and adapted with the integration of the CCF7.

Index values were allocated according to the Lickert scale from 1 to 5 with:

- 1 - Resilient
- 2 - Moderately vulnerable
- 3 - Vulnerable
- 4 – Highly vulnerable
- 5 – Extremely vulnerable

The social vulnerability index was calculated using the following mathematical equation:

$$V^{SOC} = \sum_{i=1}^{11} w_i^{soc} v_i^{soc}$$

$$\mathrm{V}^{SOC} = f(w_1^{soc}v_1^{soc}, w_2^{soc}v_2^{soc}, w_3^{soc}v_3^{soc}, \dots \dots \dots w_{11}^{soc}v_{11}^{soc})$$

where: v_1^{soc} = Age

v_2^{soc} = Gender participation

v_3^{soc} = Psychological stress

v_4^{soc} = Social dependence

v_5^{soc} = Education level

v_6^{soc} = Cultural values and practices

v_7^{soc} = Security/safety

v_8^{soc} = Social networks

v_9^{soc} = External support

v_{10}^{soc} = Preparedness strategies

v_{11}^{soc} = Indigenous knowledge

and,

w^{soc} = equal weighting factor for all variables

The values and description of the different social vulnerability indicators for the three districts is summarized in Table 6.7. In Table 6.8 the different index values that were based on responses from respondents are explained.

Table 6.7: Estimation of social vulnerability to drought in ORT, Cac & JG

	O.R. Tambo District		Joe Gqabi District		Cacadu District	
Social Vulnerability Indicator		**Index**		**Index**		**Index**
Age	23% ≥ 60 yr.	3	45% ≥ 60 yr.	5	14% ≥ 60 yr.	2
Gender participation	62%	4	53%	3	20%	1
Psychological stress	79%	5	100%	5	20%	5
Social dependence	81%	5	71%	4	52%	3
Education levels	>70% only primary education	4	>60% only primary education	3	80%	3
Cultural values and practices	90%	5	79%	4	93%	5
Security/safety: Increase in stock theft	25%	5	16%	4	(-7%)	1
Social networks involved in drought management	18%	5	33%	4	37%	4
External support: . support	22%	4	26%	4	46%	3
Preparedness strategies: Farmers prepare for drought	9%	5	18%	5	17%	5
Use of Indigenous knowledge	64%	2	74%	2	73%	2
Total Score		47		43		34
SoVI (Total score ÷ no. of variables)	***47 ÷ 11 = 4.3***		***43 ÷11 = 3.9***		***34 ÷ 11 = 3.1***	

Table 6.8: Classification criteria for social vulnerability indicators

Indicator	Index	Description	Statement of Measure	Relationship with Vulnerability	Data Source
Age	1	≤10% of population is above 60 years	Proportion of population above 60 years old	The older the population the greater the vulnerability to drought	Survey/ StatsSA Observation
	2	11% - 20% of population is above 60 years			
	3	21% - 30% of population is above 60 years			
	4	31% - 40% of population is above 60 years			
	5	>41% of population is above 60 years			
Gender participation	1	≤20% say gender affects decision-making	Level of gender equality in decision-making concerning farming activities	The less gender balanced a community is the more vulnerable it is to drought impacts	Survey
	2	21 – 40% say gender affects decision-making			
	3	41 – 60% say gender affects decision-making			
	4	61 - 80% say gender affects decision-making			
	5	>80% say gender affects decision-making			
Initial well-being -Psychological stress	1	≤5% of farmers say stress influences vulnerability	Proportion of farmers who say stress influences vulnerability	The more stressed the farmers are the greater the vulnerability	Survey
	2	6%- 15% farmers say stress influences vulnerability			
	3	16%-30%farmers say stress influences vulnerability			
	4	31%-50%farmers say stress influences vulnerability			
	5	>51% farmers say stress influences vulnerability			
Social dependence	1	≤20% dependency ratio	Dependency ratio	The greater the dependency ratio the more vulnerable the population is to drought	StatsSA
	2	21% - 40% dependency ratio			
	3	41% - 60% dependency ratio			
	4	61% - 80% dependency ratio			
	5	>80 % dependency ratio			
Education levels	1	≥80% with high school education	Proportion of population with formal education	The more educated the community the less vulnerable to drought	Survey/ StatsSA
	2	>60% high school education			
	3	>50-60% with high school education			
	4	>50% with high school education			
	5	>80% only primary school education			
Cultural values and practices	1	≤20% say culture influences vulnerability	Proportion of farmers who say culture influences vulnerability	The stronger the cultural practices the greater the vulnerability	Survey
	2	21%-40% say culture influences vulnerability			
	3	41%-60% say culture influences vulnerability			
	4	61%-80%say culture influences vulnerability			
	5	>80% say culture influences vulnerability			
Security/safety	1	≤5% increase in stock thefts during drought	Increase in stock theft during drought	The greater the increase in stock theft the greater the vulnerability	Survey
	2	5.1%-10% increase in stock thefts during drought			
	3	10.1%-15% increase in stock thefts during drought			
	4	15.1%-20% increase in stock thefts during drought			
	5	>20% increase in stock thefts during drought			

Social networks	1	>80% say social networks are involved in drought issues	Extent of social network involvement in drought issues	The more involved the social networks the greater the coping capacity	Survey
	2	61%-80% say social networks are involved in drought issues			
	3	41%-60% say social networks are involved in drought issues			
	4	21%-40% say social networks are involved in drought issues			
	5	≤20% say social networks are involved in drought issues			
External support	1	>80% say government is involved in drought issues	Level of external support in drought mitigation and response	The greater the external support the greater the coping capacity in drought	Survey
	2	61%-80% say government is involved in drought issues			
	3	41%-60% say government is involved in drought issues			
	4	21%-40% say government is involved in drought issues			
	5	<20% say government is involved in drought issues			
Preparedness strategies	1	>80% farmers prepare for drought	Proportion of farmers that prepare for drought	The more prepared farmers are to drought the greater the resilience	Survey
	2	61% - 80% farmers prepare for drought			
	3	41% - 60% farmers prepare for drought			
	4	21% - 40% farmers prepare for drought			
	5	≤20% prepare for drought			
Indigenous knowledge	1	>80% farmers have indigenous farming knowledge	Level of indigenous farming knowledge	The greater the proportion of farmers with indigenous farming knowledge the greater the resilience	Survey
	2	61%-80% farmers have indigenous farming knowledge			
	3	41% - 60% farmers have indigenous farming knowledge			
	4	21% - 40% farmers have indigenous farming knowledge			
	5	≤20% farmers have indigenous farming knowledge			

No community was entirely vulnerable. Once social vulnerability was measured or quantified; the resultant Social Vulnerability Index (SoVI) provided a basis for prioritizing different indicators for the determination of drought risk reduction strategies.

It was clear from the results that farmers perceived government's involvement in drought risk reduction as very low, which was also reiterated by extension officers. Several other vulnerability studies have revealed governments' limited contributions to drought risk reduction. Hassen (2008), for example, documented that the respondents in the study conducted among pastoralists in Ethiopia complained that the Ethiopian government had neglected them. Government relief programmes were usually late and/or inadequate (Hassen, 2008; Jordaan, 2011; Ngaka, 2012). The training programmes by extension officers did not focus on drought risk reduction, but rather on farming in general. No drought awareness or early warning was issued to farmers until the drought was already in progress. Thus, where external support had been considered as a coping capacity indicator it contributed more to susceptibility than coping.

Social network and preparedness strategies were also initially considered under coping capacity. However, farmers were extremely exposed to drought impacts because of the lack of any drought preparedness strategies and the lack of support and involvement from their social networks. The extension officers attributed the lack of involvement of social networks in drought issues to mere ignorance of the potential of social networks as safety nets or mechanisms for drought preparedness. Most of the extension officers and farmers were surprised to learn that the involvement of clubs, churches and other community organizations in drought issues increased a communities' resilience to drought.

The absence of operational and active farmers' associations posed a challenge to farmers' preparation and responses to drought. The respondents argued that their associations, namely AFASO and NAFU, only operated at the national and maybe at provincial level. At the grassroots level, where the farmers needed the support, they were mostly absent or ineffective. Iglesias *et al*. (2007) also highlighted the importance of farmers' organizations and local institutions that led to reduced vulnerability to drought.

Psychological stress contributed to an *"extremely vulnerable"* situation. While it was impossible to deduce from this study the reason why such a large proportion of the respondents held this perception; the issue of stress needs more attention. As reported by Connor (2014),, stress has been termed *"the number one killer"* in the United States of America. The results in this research also showed the contribution of stress to drought vulnerability.

Dependence on government for social grants was very high in O.R. Tambo and Joe Gqabi districts and this increased farmers' vulnerability to drought impacts. Since drought mitigation was still more response-based than risk reduction-based the farmers depended on government for assistance during and after droughts. Dependency on social grants already indicated marginalisation and poverty (Adger *et al,* 2004), hence their inability to cope with, and recover from, drought. Dependency on social grants created a dependency syndrome among farmers and they were therefore reluctant to implement drought risk reduction measures; instead they waited for government for support.

The results also revealed that the respondents perceived indigenous knowledge as contributing to drought resiliency. The use of indigenous knowledge was relevant to a rural community with high illiteracy levels. Where they cannot access information due to illiteracy, the indigenous agricultural knowledge helped them to cope with drought.

Economic Vulnerability Analysis

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 and livelihoods of communities. The farmers are in the "*first line of defence"* from the drought impact, and they are the ones, whether as individuals or a group, that directly lose income and profits. Economic vulnerability indicators identified in the study area included: (i) Lack of access to resources, (ii) market access, (iii) unemployment, (iv) on/off farm diversification, (v) price sensitivity of products, (vi) level of farm debt, (vii) financial safety nets/alternative source of income, and (viii) management. Some of the indicators served as both vulnerability indicators and coping capacity indicators.

6.1.16 Access to Resources

Land, water, machinery, farm inputs, labour, timely information and finance were classified as crucial resources for farming success. Seventy nine per cent of farmers in OR Tambo had access to land, with 86% in Joe Gqabi and 58% in Cacadu (Figure 6.10). Communal farmers in the three districts were farming on communal land where demand for land is high. Alternative land was a key coping strategy for many farmers. It was, however, was mostly available for commercial farmers, therefore they were more resilient when compared to communal farmers. A communal farmer using one hectare of land for farming was more vulnerable to drought when compared to a farmer who had access to 100 hectares of land. Farm sizes also vary between districts with the larger farms located in Cacadu and smaller land sizes in OR Tambo and the eastern parts of Joe Gqabi.

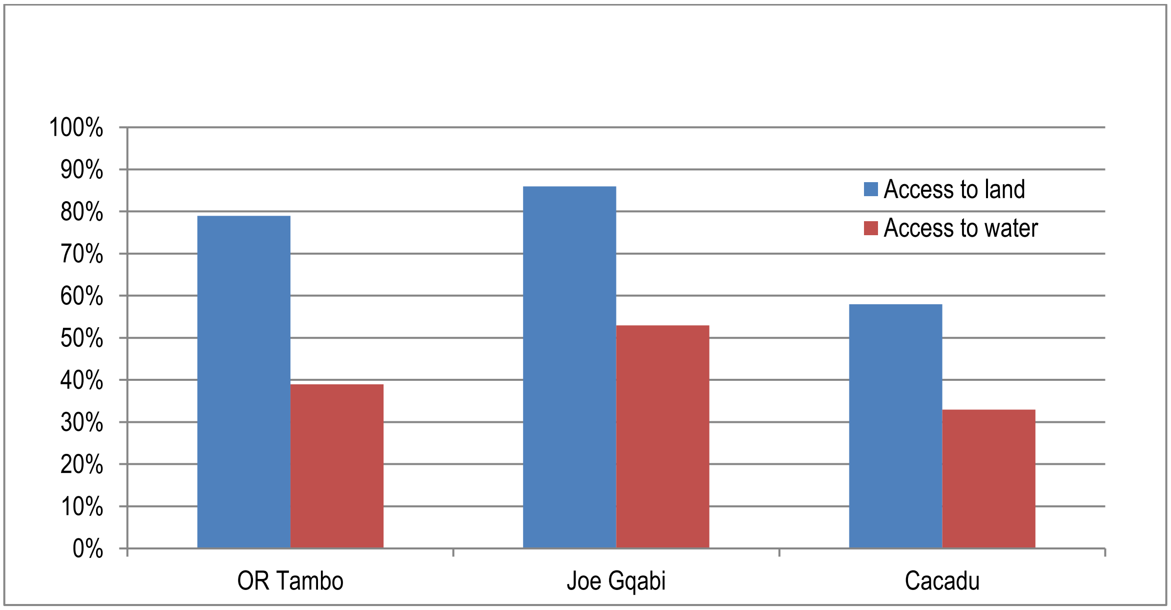

Fig 6.10: Percentages of farmers with access to land and water

Access to water was also an important indicator, especially in the more arid regions of Cacadu and Joe Gqabi districts. Forty per cent of farmers in OR Tambo indicated that they had access to water compared to 52% in Joe Gqabi and 32% in Cacadu. One would have expected a higher percentage of farmers with access to water in the OR Tambo district due to its high rainfall. Water sources in Cacadu and the western part of Joe Gqabi were mainly boreholes, while the higher rainfall regions of Joe Gqabi and the whole of OR Tambo depended mainly on rivers, streams and springs. Farmers reported groundwater stability during shorter dry periods, but boreholes dried up during more extreme droughts, which then rendered these farmers extremely vulnerable. Farmers in the higher rainfall areas reported the drying up of springs and smaller streams as the first signs of a drought. Dried up springs and streams resulted in extreme overgrazing near water sources as well as erosion due to animal footpaths to water sources.

A smaller percentage of farmers had access to land in Cacadu district. All farmers that participated in the research in Cacadu district farmed on municipal land. Farmers in Joe Gqabi had access to both municipal land and traditional land in the Sterkspruit and former Transkei regions. All farmers in OR Tambo farmed on traditional land with open access. Except for a few farmers in Joe Gqabi, none of the others hold title to their land and they were therefore not able to use the land as collateral to borrow money from banks. They only had access to land through arrangements with municipalities and traditional leaders. The land use system rendered communal farmers extremely vulnerable. They competed with each other for the same land in spite of land management plans managed by the traditional leaders and municipalities. The "*tragedy of the commons"* was evident on all communal land.

Interesting to note were the large percentage of farmers in Joe Gqabi with private ownership of land. Forty three per cent of farmers noted that they own the land, but could not use it as collateral for finance due to the lack of other resources, high-risk profiles (according to banks), farms being too small to be an economic unit and no infrastructure on the land. It became clear that land ownership alone was not a guarantee for access to finance.

Table 6.9: Percentages in terms of land control

	Chiefs	Municipalities	Private ownership	Others
OR Tambo	69	1	14	16
Joe Gqabi	29	14	43	14
Cacadu	13	87	0	0

Farming equipment important for agricultural production included tractors, Implements for cultivation, planters, harvesters and irrigation facilities. Farmers reported that they were more vulnerable due to the unavailability of equipment and implements. Machinery was expensive and out of reach for communal farmers. It was suggested that government could assist communal farmers in accessing some of this equipment in order to reduce their vulnerability to drought. Extension officers and some of the farmers pointed out that government provided contracting services, but it was normally too late or inadequate. In addition, farm inputs such as fertilizers, pesticides and improved seeds or cultivars were also important in increasing drought resilience.

Communal farmers did not have access to finance. They were unable to access credit because of the lack of collateral, lack of farm records and high-risk profiles. In addition, the traditional credit schemes did not cater for communal farmers. Even Land Bank loans were not accessible for the majority of communal farmers. Eighty six per cent of farmers in Joe Gqabi, 91% in Cacadu and 64% in OR Tambo confirmed that it was impossible to obtain loans from banks. Communal farmers were more dependent on government grants for start-up capital and this increased their level of vulnerability. It was emphasized in the EC Department of Agriculture Strategic Plan for 2003-2006 that the ability of communal farmer to access credit would continue to pose a challenge in the Province. Mega projects with a focus on input support to farmers, such as the massive food programme, also seemed to fail due to several reasons not covered in this research.

Access to labour also contributed toward vulnerability and it became clear that communal farming remained a family business with children, family members and community members contributed mostly to the labour force (See Figure 6.11).

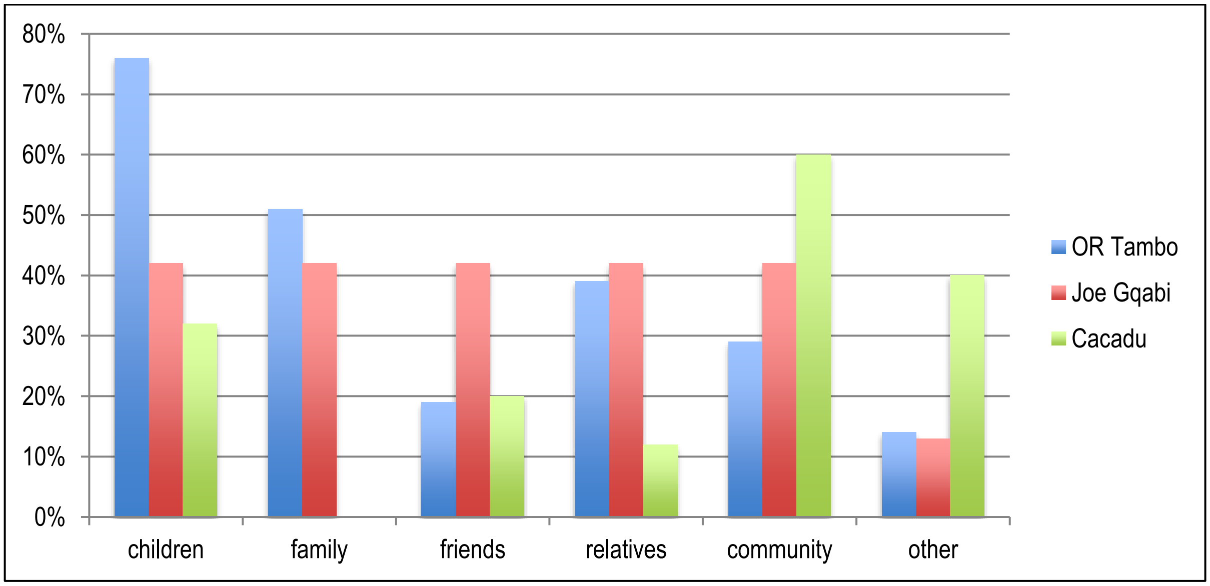

Fig 6.11: Percentages of labour contributions

Children were the main labour source in the more traditional areas such as OR Tambo. Farmers use more than one source of labour and the percentage of farmers indicated in Figure 6.11 represented the % of farmers that utilised the specific labour force. Farmers in OR Tambo source labour as follows: children (76%), family (51%), friends (19%), relatives (39%), community (29%) and other (14%). Labour sources in Joe Gqabi were more equally distributed with children (42%), family (42%), friends (42%), relatives (42), community (42%) and other (13%). Labour sources in Cacadu were children (32%), family (0%), friends (20%), relatives (12%), community (60%) and other (40%). Community members were much more involved in providing labour in Cacadu district where farmers had access to predominantly municipal land.

Drought also had a negative effect on people who provided labour. Ninety three per cent of farm labourers in Cacadu reported that they have been severely affected by drought, with 75% in OR Tambo and 43% in Joe Gqabi. The reasons mentioned were that farmers had to stop with agricultural production and they could not get income to even pay school fees and they were not able to take care of their family.

Information is vital when looking at drought risk. Timely information allowed farmers to prepare for production based on informed decision-making. Sources of early warning information were the South African Weather Service (SAWS) through television and radio, word of mouth amongst farmers and the extension officers from the Department of Agriculture and Rural Development (DARD). Figure 6.12 illustrates the sources of information for the three districts. Only few farmers sourced their information from farmers associations, the Internet and newspapers. Farmers emphasized that they also relied on the indigenous knowledge acquired from generation to generation. For example, when they see snakes going a certain direction it informs them that it is going to be dry.

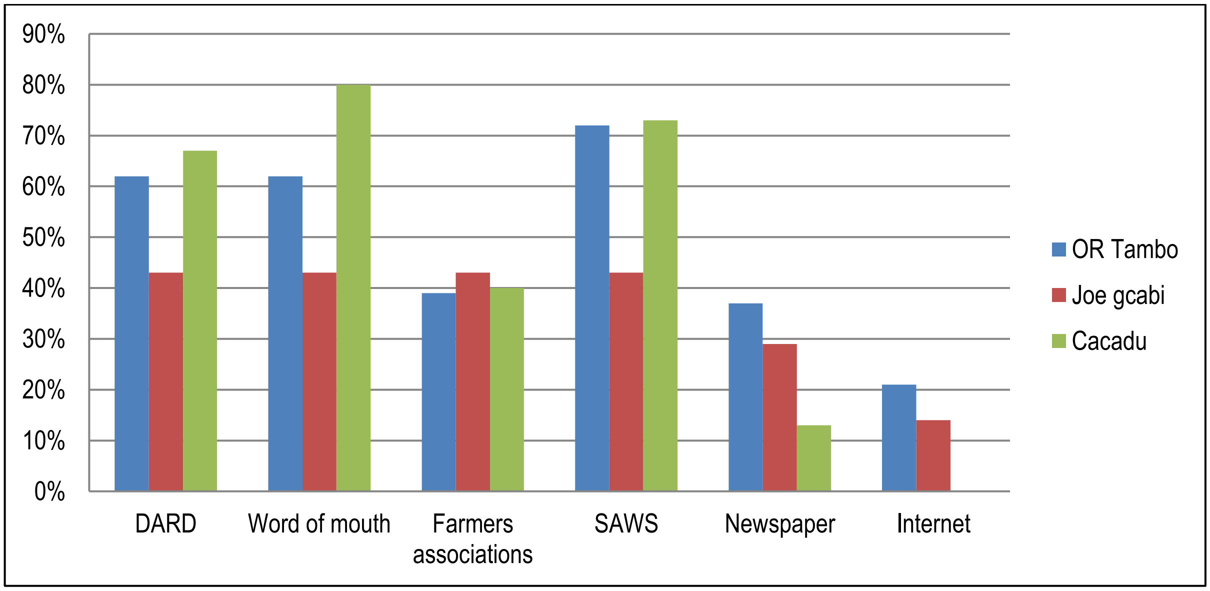

Fig 6.12: Early warning information per district

In order to analyse drought early warning, farmers were also requested to respond on the type of early warning used. The SAWS provided seasonal, monthly, weekly and daily forecasts and a surprisingly high number of respondents indicated that they also received seasonal forecasts. Figure 6.13 illustrates the forecast information received by respondents and it became clear that most farmers received most forecast types.

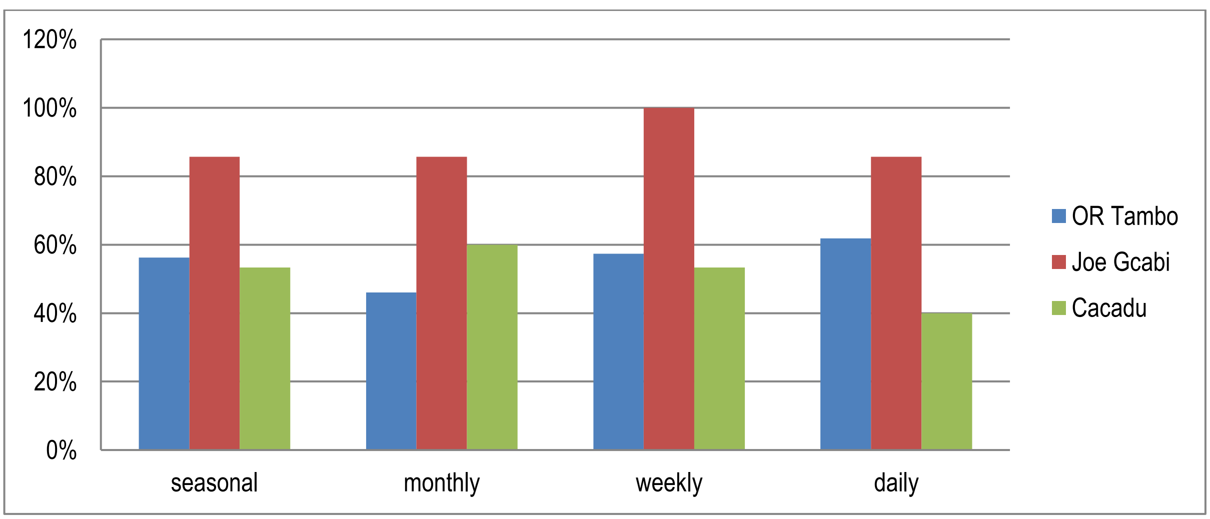

Fig 6.13: Forecast information per district

Perceptions of farmers regarding the accuracy of early warnings were also tested. As illustrated in Figure 6.14 the majority of respondents perceived most types of forecasts as inaccurate. They rated accuracy on a scale of 1 to 5 with 1 inaccurate and 5 accurate. The daily forecasts, however, were perceived as being accurate.

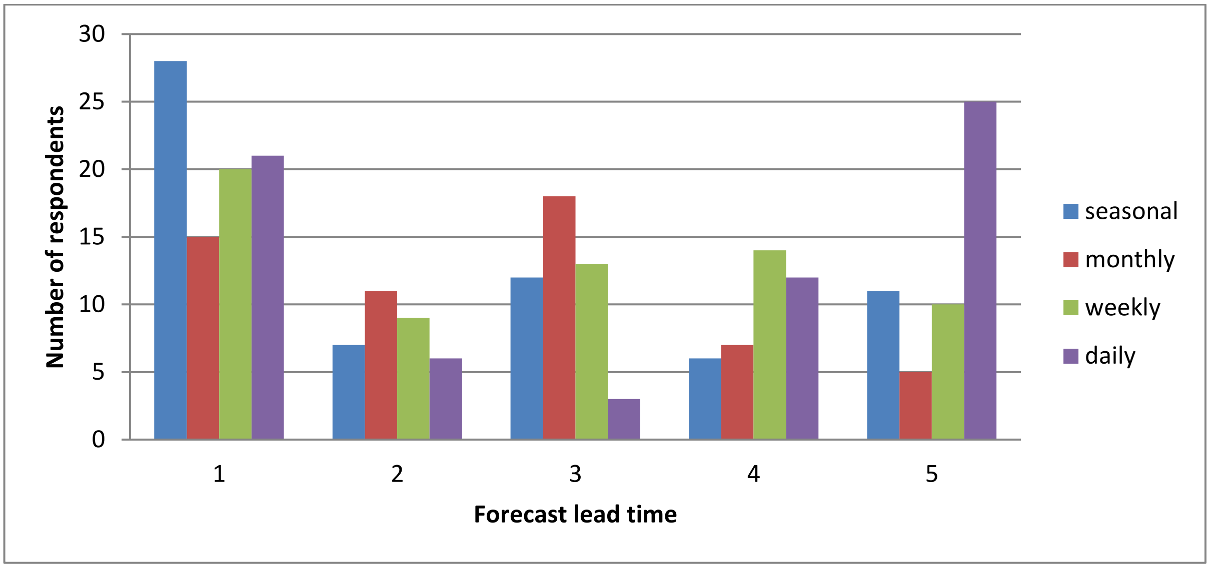

Fig 6.14: Accuracy of forecast received by farmers

6.1.17 Unemployment

Stimulating community participation in drought risk reduction should also take place through improving employment and education (Wilhite, 2000; Jordaan, 2011). The main source of employment in rural areas was agriculture, but unemployment remained high due to the decline in agricultural production and fewer agricultural producers. Communal farmers were more vulnerable during droughts because their only source of income was from farming. One of the main factors that increased farmers' vulnerability to drought was the low level of income. Summarized in Table 6.10 is the income distribution of communal farmers. Most communal farmers were making profits of less than R10 000 per year. Only 2% out of 87 communal farmers in OR Tambo were able to earn more than R200 000 per year. This confirmed findings of Raat (2008) that Eastern Cape Province farmers made a net profit of R10 000 per annum. Farmers struggled to make ends meet and to make reasonable profits due to a lack of resources and poor management practices.

Table 6.10: Annual income from farming activities

Income per annum	OR Tambo	Joe Gqabi	Cacadu
Less than R10 000	69%	86%	80%
R10 001 – R50 000	27%	-	20%
R50 001 – R100 000	2%	14%	-

R200 000 and above	2%	-	-

Communal farmers also had good experience in basic production practices, but not in the management of their farming as a business. They were mostly subsistence farmers and were therefore not in a position to make large profits and thereby earn a proper livelihood. As a result farmers had no reserves or alternative income sources and therefore remained extremely vulnerable to drought.

Since there were no alternative sources of income during drought or dry periods, communal farmers found it difficult to cope with the adverse impacts of droughts. The loss of income to farmers caused stress, increase dependence, and in addition, they could not prepare for the following season and drought or buy additional feed and fodder to cope with the drought. It was found in Joe Gqabi that community members destroyed infrastructure such as fences and water reticulation systems and sold equipment to earn a living, which then left livestock farmers more vulnerable. According to StatsSA (2012), OR Tambo (44%) had the highest unemployment rate, compared to Joe Gqabi (35%) and Cacadu districts (25%). Most communal farmers were not making an adequate income and profits and together with high unemployment, everybody in the community were more vulnerable to drought.

6.1.18 Price Sensitivity of Products

Prices of livestock and crop produce are sensitive to changes in season, particularly between normal periods and drought. Dellal (2010), Jordaan (2011), Resnick (2012) and National Drought Mitigation Centre (2014) reported that prices of certain products increased at the onset and during previous drought periods due to an expectation of scarcity. Livestock prices on the other hand, normally decreased at the onset of a drought when most farmers wanted to sell, and increased after the drought when farmers were re-stocking. Communal farmers and extension officers reported that the common recommendation at the onset to a drought was to sell at least one third of their livestock in order to avoid losses during the drought. The cultural belief that the wealth of a man is measured in the number of cattle owned was still prevalent amongst most communal farmers and was therefore one of the reasons why farmers tended to sell cattle too late and in poor condition. Prices obtained then for poor conditioned cattle were very low.

Table 6.11: Percentages of decreases in prices of commodities due to drought

Districts	Goats	Cattle	Sheep	Crops	Fruits
OR Tambo	88%	84%	78%	75%	86%
Joe Gqabi	75%	71%	80%	80%	0%

Cacadu	80%	87%	87%	13%	7%

Table 6.11 indicates the decrease in prices of livestock, crops and fruits during previous droughts. Price sensitivity of livestock was extremely high amongst communal farmers due to several factors. The major contributor to price decreases was the fact that communal farmers start selling animals when the condition of animals is already poor and no additional feed and fodder was available. In addition to this were the imperfect market conditions that prevailed for communal farmers. Communal farmers did not have access to most marketing channels and had to depend on only one or two buyers. Normally these speculators realized the dilemma of farmers in that they were forced to sell and thus pushed prices down.

Prices of animal products such as wool, mohair and milk were not as sensitive as the prices for animals themselves. Milk was mostly used for own household purposes while wool and mohair farmers sold their produce on the international market[4] for income. The shearing shed system in OR Tambo and Joe Gqabi district contributed toward drought resiliency. The National Wool Growers Association of SA (NWGA) contributed much toward the sustainability of communal wool farmers in that they provided shearing services and assisted farmers to pool their products and thereby compete on the international market. The shearing shed system and accompanying support from the NWGA is a good example of how one can reduce drought vulnerability. The Elundini livestock programme in the Mount Fletcher area was another good example where farmers' resilience increased. Mncgunumbe developers implemented a highly successful mentorship programme that assisted farmers with livestock management, including livestock disease management and pooling of resources for marketing.

6.1.19 Farmer Debt Ratios

The data shown in Table 6.12 is a summary of the debt situation of communal farmers in the three districts. Seventy two per cent of farmers struggled to pay debt in OR Tambo, as against 71% in Joe Gqabi and 93% in Cacadu. Debt was not necessary linked to farm debt. In most cases it was household debt for school fees, funerals and other expenses. Being communal farmers with farming as the only income, these farmers were more vulnerable to drought under a debt burden. Farmers without debt were less vulnerable during drought/dry periods in comparison to farmers with debt. Farmers with debt could not acquire additional loans for feed and fodder during dry periods and droughts. Farmers also mentioned the lack of financial record keeping, no proper business and marketing plans and the lack of collateral as

[4] Wool was sold at international auctions in Port Elizabeth

the main reasons for not qualifying for loans. Some farmers made use of so-called “loan sharks”, which is a poverty trap due to exorbitant high interest rates charged.

Table 6.12: Percentages of farmers with debt

	Level of debt	Struggling to pay debt	Debt increase	Difficult to get loan
OR Tambo	67.8	72.4	61	64.3
Joe Gqabi	85.7	71.4	71.4	85.7
Cacadu	93	93	93	91

6.1.20 Market Access

Market access is a key element in drought vulnerability since it has a direct impact on price sensitivity of products (Wilhite 2000; Jordaan, 2011). Communal farmers operated under imperfect market conditions where they had to sell products through speculators or middlemen and were therefore price takers that depended on offers made by the speculators. In many cases farmers did not received the desired prices; they kept the animals only to be forced to sell at a later stage when the condition of animals were very poor. The whole system exposed farmers to exploitation, especially during dry periods when feed and fodder were limited and expensive.

The main market outlets were (i) individual speculators (ii) *boya boya* tuck shops, (iii) at roadsides, (iv) in town to community members and in some cases at (v) auctions. Extension officers noted that farmers could get better prices if they sold animals at auctions. Unlocking local markets therefore remains a key challenge to reduce drought vulnerability.

Market access was not the only challenge. In order to secure good prices farmers had to provide good quality products at the right time at the right place. Continuity in supply was another key factor and communal farmers could not comply with this basic requirement for product marketing. Crop farmers had better access to markets, but they could not continually produce and supply the required and expected quantities and, in some cases, quality products.

Farmers were extremely well informed about market prices, which was a surprise considering the remoteness of many farming areas. One of the challenges was that farmers were informed about market related prices, but they did not consider the distance from major markets and therefore sometimes expected unrealistic prices. As a result they did not sell and were forced to sell at a later stage at reduced prices. Farmers used radio, television, community leaders and neighbours as sources of market information (Figure 6.15). Extension officers were particularly important as a source of market information in OR Tambo while newspapers, radio, TV, the Internet, the Farmers Weekly[5], community leaders and neighbours played equally important roles in other districts.

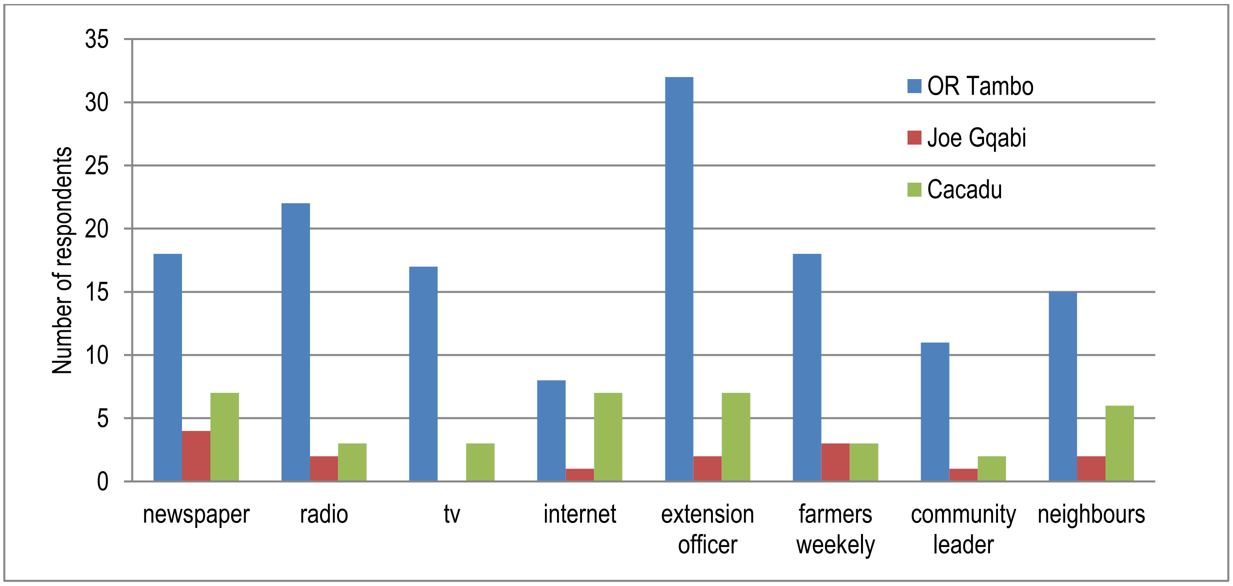

Fig 6.15: Sources of market information

6.1.21 On/Off Farm Diversification

On farm diversification involves having more than one source of income through a combination of products and mixed farming. This enables farmers to be less vulnerable to drought (Wilhite, 2000; Jordaan, 2011). The results showed that in OR Tambo farmers were farming with at least two systems, namely sheep and vegetables, in Joe Gqabi the main products were sheep and cattle, while Cacadu district farmers were more into cattle, sheep and crops under irrigation, except in the higher rainfall areas along the coast. The extension officers indicated that farmers could shift to goat and ostrich production since it has potential in the Joe Gqabi and Cacadu.

In order to manage drought effectively, diversifying livelihood strategies and income generating options outside agriculture is also important (Wilhite, 2000; Jordaan, 2011). Off farm income in all three districts was limited due to the high unemployment rate and high levels of poverty. Findings showed that almost all of the respondents had no formal employment or other sources of income such as crafts, shebeen

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[5] Weekly agricultural magazine

operations, taxis, etc. Only one respondent indicated that she was into bead making, which she sold to community members for additional income.

6.1.22 Financial Safety Nets

Unavailability of financial safety nets increases the level of vulnerability to drought. Sources of safety nets were personal savings, remittances, stokvels, government subsidies, fodder banks and cooperatives (Wilhite, 2000; Jordaan, 2011). In all the three districts, none of respondents had safety nets listed except drought relief from government schemes. Safety nets are meant to protect vulnerable farmers during dry periods and drought and the lack of safety nets amongst farmers in the study area rendered them extremely vulnerable. Government reliefs schemes were viewed as ineffective and farmers complained that it were too little too late.

6.1.23 Estimation of Economic Vulnerability

The estimation for each indicator was done with reference to the classification criteria for selected economic vulnerability indicators as shown in Table 6.14. Vulnerability describes the reduced ability of farmers to cope with the event and stresses to which they are exposed (Rygel *et al*., 2006; Wilhite, 2000; Jordaan, 2011). The calculation was done based on the BBC framework and adjusted by the CCF7. The index values for each indicator are shown in Table 6.14.

Table 6.13 represents the economic vulnerability calculation for the three districts. The level of farm debt and financial safety nets were "*extremely vulnerable*" for the three districts. All farmers struggled with debt repayments, which made them extremely vulnerable to drought conditions. Farmers did not cope with droughts as financial safety nets were not available. The lack of farm and income diversification rendered farmers "*extremely vulnerable"* in OR Tambo and Joe Gqabi, while farmers in Cadacu were "*moderately vulnerable"* owing to better access to groundwater for irrigation.

All farmers were vulnerable or highly vulnerable as a result of limited market access and imperfect markets. The overall economic vulnerability index results for OR Tambo and Joe Gqabi was "*extremely vulnerable"* and "*highly vulnerable*" for Cacadu. Cacadu district farmers were less vulnerable compared to other districts, especially in the coastal areas where they could diversify agricultural activities. Economic vulnerability was high amongst all communal farmers and that rendered them extremely vulnerable to dry periods and droughts. Economic vulnerability was closely linked to social factors such as management skills, the dependency syndrome and education levels. Access to resources was also one of the main contributing factors to economic vulnerability.

Table 6.13: Estimation of economic vulnerability to drought in the OR Tambo, Cacadu & Joe Gqabi Districts

Economic vulnerability Indicator	OR Tambo District		Joe Gqabi District		Cacadu district	
	Study findings	Index	Study findings	Index	Study findings	Index
Lack of resource	Access to land only	5	Access to land and inputs	4	Access to land, inputs and water	3
Unemployment	>60% unemployed	5	30-39% unemployment	3	20-29% unemployment	2
Price sensitivity	Product prices will definitely be lower during drought due to over-supply and poor conditions of animals	5	Product prices will definitely be lower during drought due to over-supply and poor conditions of animals	5	Product prices might decrease during drought due to over-supply resulting from drought	4
Level of farm debt	72.4% of the farmers struggle to pay debts	5	71.4% of the farmers are struggling to pay debts	5	93% of the farmers are struggling to pay debts	5
Market access	Only one irregular buyer and far from main markets	4	Only one irregular buyer	3	Good market but limited access	2
On-farm diversification	Apply one method	4	Apply 2 methods	3	Apply 3 methods	2
Off-farm diversification	No off farm diversification	5	No off farm diversification	5	At least two different economic activities	3
Financial safety nets	No financial safety nets	5	No financial safety nets	5	No financial safety nets	5
Total score		38		33		26
EcoVI (Total score ÷ no of variables)		**4.8**		**4.1**		**3.3**

Key (EcoVI rating)
Resilient 0 - 1 moderately vulnerable 1.1 - 2 vulnerable 2.1 – 3 highly vulnerable 3.1 - 4 extremely vulnerable

Table 6.14: Classification criteria for economic vulnerability indicators

Indicators	Index	Description of indicator classification	Statement of Measurement	Relationship with Vulnerability	Data Source
Lack of access to resources	1	Land, water, inputs, equipment, finance	Proportion of farmers that has access to resources	The less the resources they have the more the vulnerability	Survey
	2	Land, water, inputs, finance			
	3	Land, water, inputs			
	4	Land, inputs			
	5	Land			
Unemployment	1	No unemployment	% of population without formal employment	The higher the % of unemployment the more vulnerability	SA Stats and Survey
	2	10 – 29% unemployed			
	3	30 – 39% unemployed			
	4	40- 60% unemployed			
	5	> 60% Unemployed			
Price sensitivity of products	1	Increase in product prices as a result of drought			
	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.	The likelihood of getting higher price	The increase in price of products the more vulnerability	Corporative/ private company/ questionnaire
	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			
On farm diversification	1	Practiced (fodder banks, drought resistant crops, crop mixing, change to different enterprises)	Indication that on farm diversification is practiced	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 practiced – only 1 activity			
Level of debt	1	No debt	% of farmers struggling to pay debt	The more the farmers struggle to pay debt the greater the vulnerability	Survey
	2	>20% of the farmers struggle to pay debt			
	3	20% to 50% of the farmers struggle to pay debt			
	4	51% to 70 % of the farmers struggle to pay debt			
	5	More than 70% of the farmers struggle to pay debt			
Market access	1	Good market and open access through different channels	Indication of market availability	No market accessibility the greater the vulnerability	Survey
	2	Good market but limited access			
	3	Only 1 regular buyer			
	4	Only 1 irregular buyer and far from main markets			
	5	No market			
Financial safety nets/ Alternative source of income	1	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 coping capacity	Survey
	2	At least two sources of income from agriculture			
	3	At least 2 sources from above			
	4	At 2 source from above			
	5	Only one drought sensitive source of income			
Off farm diversification	1	Many alternative economic activities. Irrigation farming, tourism, mining, forestry, services etc.	Indication of other economic activities	The more economic activities the greater the coping capacity	Survey/StatsSA
	2	At least 3 different economic activities			
	3	At least 2 different economic activities			
	4	Farming plus 1 potential economic activity			
	5	Farming the only economic activity			
On farm diversification	1	Practiced (fodder banks, drought resistant crops, crop mixing, change to different enterprises)	Indication that on farm diversification is practiced	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 practiced – only 1 activity

Environmental/Ecological Vulnerability Analysis

Zuma-Netshiukhwi *et al*. (2013) mentioned that farmers regularly experience destructive disasters that are weather and climate related, for example floods, below average rainfall, severe dry periods, and strong winds that contributed and intensified veld fire impacts, while Knutson *et al*. (1998) stated that the lack of water during drought increased the difficulty of fighting veld fires.

It was recognized that farmers were aware and concerned about ecological changes and damages that affected agricultural production such as soil erosion, overgrazing and land degradation. They understood that the physical environment is deteriorating. Ecological indicators that were identified in the study area were (i) overgrazing, (ii) soil erosion, (iii) land degradation, (iv) surface and groundwater supply, and (v) land use. Forty four per cent of farmers in OR Tambo, Joe Gqabi, and Cacadu districts reported insufficient water supply during dry periods.

6.1.24 Overgrazing

Overgrazing was one of the major environmental/ecological indicators for drought in the study area. Overgrazing was described as a shortage for pasture to livestock and a failure to match animal grazing to forage growth and production. Overgrazing arose as a result of having too many animals on the land or not properly controlling grazing activities. It reduced ground cover and also increased the likelihood of crusting conditions during rainy periods. The crusting conditions decreased water infiltration and prolonged plant recovery from previous droughts.

Overstocking, the absence of grazing management practices and lack of infrastructure such as fences and water reticulation systems were amongst the main reasons for severe land degradation in OR Tambo district and the eastern part of Joe Gqabi in the Mount Fletcher region, despite relatively high rainfall. The Sterkspruit region in Joe Gqabi was also severely overgrazed with extreme erosion evident. Joe Gqabi and Cacadu were characterized by heavily overgrazed land on municipal land surrounding all the towns. The rest of Joe Gqabi and Cacadu were fairly well managed, with most commercial landowners mentioning an increase in vegetation cover since the livestock reduction schemes of 1982/83 and 1992/93.

The lack of grazing systems increased vulnerability to drought. In some cases communal farmers did apply a rotational system of 6 months whereby they allowed certain areas to rest for 6 months. Animals rotated in camps or under the supervision of herders between summer and winter, but this was not sufficient to allow re-vegetation and proper re-growth. When rotational grazing camps are properly demarcated and planned, it allows the grass to recover (Snyman, 2003). At the core of the problem was the lack of infrastructure such as grazing camps and water reticulation systems. Where infrastructure was in place, for example at communal municipal land, the problem remained because land management plans were not enforced. Pictue 6.2 shows affected overgrazed pastures.

Pic 6.2: Picture showing overgrazed land by animals

The effect of overgrazing in the OR Tambo district was dramatic. Virtually no camps or proper water reticulation systems were available. Communal farmers therefore depended on the skills of herders to move animals between water points and toward areas where grazing was available. As a result OR Tambo area was the most vulnerable to drought in spite of the fact that it is the district with the highest annual precipitation. The Sterkspruit area in Joe Gqabi was also classified as extremely overgrazed and vulnerable.

6.1.25 Soil Erosion

Soil erosion was identified as one of the important environmental indicators for drought. Erosion is the detachment and transportation of soil materials by water and wind. As much as 70% of South Africa is affected by different types and levels of soil erosion (Garland *et al.,* 2000; Le Roux, 2008). Sheet, rill and gully erosion were the two most prominent types of erosion in the study area. Sheet erosion is the detachment of soil particles by raindrop impact and transportation by shallow overland flow. Rill erosion describes the process where numerous small channels of up to 30 cm are formed (Lal & Elliot, 1994). Gully erosion describe the process where surface water concentrates in narrow footpaths and transports the soil in channels that are too large to flatten with normal tillage operations (Kirby & Bracken, 2009). These small gullies eventually develop into large gullies. The Eastern Cape is the province most severely affected by sheet and rill erosion with 6 188 581 ha affected. It is also the province with most gully erosion at 151 759 ha affected, second only to the Northern Cape (160 885 ha). Le Roux (2011) named the most important factors influencing erosion as (i) climate erosivity, (ii) soil erodibility, (iii) slope gradient and length, (iv) topography, (v) vegetation cover, (vi) rainfall, (vii) lithological factors, (viii) pedological factors, (ix) land use, and (x) land management. Beyene (2011) urged that soil erosion is a global environmental problem that causes loss of fertile topsoil. Agricultural productivity is severely affected by eroded areas and land is especially vulnerable to dry periods. Farmers farming on eroded soil are extremely vulnerable to droughts and even to normal dry periods.

The Sterkspruit area in Joe Gqabi is possible amongst the most eroded areas in South Africa. Soil erosion was evident in all three districts, but the Sterkspruit area and OR Tambo are possibly the most eroded areas in South Africa. Pictures 6.3 and 6.4 show examples of soil erosion in OR Tambo district. Agricultural production is adversely affected on eroded the land. Through observations and feedback from farmers in all three districts, it became clear that farmers who farm in areas with high soil erosion were not able to cope with dry periods.

Soil erosion is indicative of overgrazing and poor management practices and was used in the research as an indicator for drought vulnerability. The lack of vegetation growth is clearly illustrated on the picture in Picture 6.3.

Picture 6.3: Soil erosion on sloped area near Mount Frere

6.1.26 Land Degradation

Land degradation is normally characterized by soil erosion, lack of vegetation or invasive species (Snyman, 2003). Land degradation through soil erosion was of major concern in the semi-arid areas of the study area. Land degradation in the study area was also described in Chapter 2 of this Report. Land was degraded in all three districts, but more so in OR Tambo.

Picture 6.4 shows an example of severely degraded land in Tsolo near Umtata. Wessels (2005) also concluded that the communal farming system was at the root of land degradation in OR Tambo and the rest of the Eastern Cape. The central and western region of OR Tambo, namely the Tsolo and Umtata regions, were more degraded compared to the coastal areas at Lusikisiki and Port St Johns. Hoffman *et al.* (1999) supported this in their national review on land degradation in South Africa.

Degraded land in Cacadu and Joe Gqabi was more visible on municipal land around towns and again this was linked to the communal farming system. Hoffmann *et al.* (1999) mentioned that there was insignificant land degradation in all of Cacadu except on communal land.

Picture 6.4: Severely degraded land in Mfolozi village near Tsolo

Land degradation as an environmental problem predisposes farmers to the adverse impacts of drought. In the badly degraded areas, agriculture was affected negatively as vegetation cannot grow, resulting in low potential grazing for animals. Farmers in such areas were more vulnerable to drought when compared to farmers in areas where there was no land degradation.

6.1.27 Surface and Groundwater Supply

The disappearance or drying up of surface and groundwater made farmers more vulnerable to drought. The level of groundwater supply (e.g. springs, boreholes and wells), surface water (e.g. rivers, streams), and dams in the study area was of great concern to the communities in general, and to the communal farmers in particular. The effects of severe dry spells or droughts on both the surface and groundwater became evident during the later stages of the research in 2016 when the Eastern Cape also experienced a dry period. A large number of dried up wells and streams were reported while flow in rivers dropped dramatically and major dam levels were very low. For example, the Great Fish River (among others) in Cacadu district had almost dried up (Picture 6.5). OR Tambo district received average precipitation during the same period, but most of the water was not harvested and ended up in the ocean unused.

Pic 6.5: The Great fish river outside Grahamstown on R67 towards Fort Beaufort in Cacadu district

Surface water and groundwater supply get recharged when water from rainfall is absorbed into the ground. The failure to do so increases farmers' vulnerability to drought. Peters *et al.* (2005) mentions that the performance of groundwater systems under dry conditions is becoming imperative. No evidence was found of groundwater recharge in the study area in spite of a high dependence on groundwater in the western parts of the study area.

6.1.28 Land Use and Land Management Practices

Examples of land use or land management practices that lead to land degradation and soil erosion were (i) removal of trees for agriculture, housing or other needs, (ii) overgrazing due to too many animals or poor grazing practices, (iii) cultivation on steep slopes, (iv) disregard for water and soil conservation practices, (v) high per capita water consumption (vi) poor water run-off planning in developmental projects, etc. These were identified as vulnerability indicators to drought in the study area. Food crops were grown on shallow and low potential soils, soils with stones, or soil on steep slopes. The use of low potential soil for crop production or horticulture increases drought vulnerability. Grazing by livestock in rough pastures, mixed scrub or wooded areas alters and degrades vegetation zones, accelerates soil and nutrient loss and renders areas susceptible to the negative impacts of drought.

The results in the research showed poor land use and land management practices in most of the communities in the study area. Wilhite (2000) and Jordaan (2011) also reported land use management as a major contributor to land cover depletion and ultimately drought vulnerability.

6.1.29 Estimation of Level of Vulnerability using Indicators

Table 6.15 shows calculations for drought vulnerability. Each indicator was calculated using index values from 1 to 5 for selected indicators. Index values were allocated according to the *Classification criteria for selected vulnerability indicator* shown in Table 6.16.

The results highlighted the ecological/environmental vulnerability to drought in OR Tambo district in spite of the fact that it was the highest rainfall area. One would expect the more arid regions to be more vulnerable, which was not the case. Certain areas in other districts were also vulnerable, such as all the municipal land, and communal or traditional land in Sterkspruit and the Mount Fletcher area in Joe Gqabi district. The commercial farming areas are reasonably resilient against drought due to proper vegetation cover and well developed infrastructure such as fencing and water reticulation systems. Small areas such as those close to Umtata have grazing camps with infrastructure, but these areas are poorly managed and proper grazing systems were not applied.

Table 6.15: Estimation of environmental vulnerability to drought in OR Tambo, Cacadu & Joe Gqabi districts

	OR Tambo District		Joe Gqabi District		Cacadu District	
Environmental Vulnerability Indicator	**Study findings**	**Index**	**Study findings**	**Index**	**Study findings**	**Index**
Overgrazing	Most of the district overgrazed	5	Serious overgrazing in some areas (Sterkspruit, municipal land, Mount Fletcher)	4	Serious overgrazing in some areas (municipal land)	3
Soil Erosion	Serious erosion in most areas	5	Serious erosion in some areas	5	Moderate erosion in some areas	3
Land Degradation	Very high land degradation	4	Highly degraded	3	Moderately degraded	2
Surface and Groundwater Supply	Either groundwater or surface water available at some places during drought	3	Either groundwater or surface water available at some places during drought	3	Limited amounts of groundwater or surface water available at some places during droughts	4
Land Use Management	No planning at all	5	Planned but large areas not planned (Sterkspruit, Mt Fletcher)	3	Well planned in most of the area	2
Total Score		23		18		14
EnVI (Total Score ÷ no. of variables)	20÷5 =	4.3	18 ÷ 5 =	3.7	17 ÷ 5 =	2,9

Resilient 0 - 1 moderately vulnerable 1.1 - 2 vulnerable 2.1 – 3 highly vulnerable 3.1 - 4 extremely vulnerable

Table 6.16: Classification criteria for environmental vulnerability indicators

Indicator	Index	Description of indicator classification	Statement of measurement	Relationship with Vulnerability	Data Source
Overgrazing	1	Zero overgrazing	% Of affected grass cover	As grazing pressure increases the land is more vulnerable	Observation and survey
	2	Moderate overgrazing in some areas			
	3	Serious overgrazing in some areas			
	4	Serious overgrazing in large areas			
	5	Total area seriously overgrazed			
Soil Erosion	1	100% excellent, no soil erosion	% of soil eroded in a period of 30 years	The greater the extent of soil erosion the greater the vulnerability	Survey and observation
	2	Few examples of erosion detected			
	3	Moderate erosion in some areas			
	4	Serious erosion in some areas			
	5	Serious erosion in most areas			
Land Degradation	1	Slightly degraded	Proportion of degraded area over a period of 30 years	The more degraded the land the more vulnerable	Observation and survey
	2	Moderate			
	3	High			
	4	Very high			
	5	Severe			
Land Use and Land Management Practices	1	Very well planned in total area	Extent of land use planning	The less well planned the land is, the greater the vulnerability	Observation and survey
	2	Well planned in most of the area			
	3	Planned but large areas not planned			
	4	Poorly planned in most of the area			
	5	No planning at all			
Surface and Groundwater Supply	1	Groundwater and surface water always available everywhere	The amount of available water in recharged areas	The higher the groundwater supply the greater the coping capacity	Observation
	2	Both groundwater and surface water available at most places during drought			
	3	Either groundwater or surface water available at some places during drought			
	4	Limited amounts of groundwater or surface water available at some places during droughts			
	5	No groundwater or surface water supply during drought			

6.1.30 Vulnerability Index

The summary of results for social, economic and environmental vulnerability is shown in Table 6.17. The average vulnerability index value of 4,5 for OR Tambo is an indication of extreme drought vulnerability for this district. Joe Gqabi district was highly vulnerable with an index value of 3,9 and Cacadu is moderately vulnerable to drought. It is important, however, to note that the values indicated are for the districts as a whole. The communal farmers who farm on communal land were all categorised as highly to extremely vulnerable. They might have better access to markets and infrastructure than communal farmers in remote areas of OR Tambo, but they were equally vulnerable in terms of ecological/environmental vulnerability. All communal farmers who participated in workshops and in questionnaires were of the opinion that they are extremely vulnerable to drought and that they needed government support in order to survive dry periods.

Table 6.17: Summary of vulnerability index values

Districts	OR Tambo	Joe Gqabi	Cacadu
Social	4.3	3.9	3.1
Economic	4.8	4.1	3.3
Environmental	4.3	3.7	2.9
$\sum (V_{Econ}\ V_{Soc}\ V_{Env})$	**13,3 (4,5)**	**11,7 (3,9)**	**9,3 (3,1)**

The value of this methodology of vulnerability calculation was not that much in the final values or index values, but rather in the identification of indicators or factors that contributed toward drought vulnerability. One cannot influence rainfall patterns, but is possible to prepare and build resilience against drought periods once the vulnerability factors are identified and known. The vulnerability to drought of communal farmers was not linked to a single problem such as land management, but rather to a combination of many multi-disciplinary factors.

The extension services and particularly extension officers should play a major role in drought risk reduction through the application of well-designed extension programmes. The Elundini livestock programme, for example, showed that farmers could increase their income ten-fold through proper management. This programme was implemented through a well-designed mentorship programme. Extension services occupied themselves with individual projects and project management instead of focusing on the primary task of extension, namely the improvement of living standards of farmers through the implementation of good agricultural and management principles,

Coping Capacity

UN/ISDR (2009) defines coping capacity as "*the ability of people, organization and systems, using skills and resources, to face and manage adverse conditions and disasters".* Shiferaw *et al.* (2014) classified drought coping capacity into *ex ante* and *ex post*. *Ex ante* is when exposure to risk is reduced and *ex post* when impacts are minimized. *Ex-ante* strategies include diversification of on farm and off farm activities, *Ex post* is designed to prevent shortages in consumption when income drops below normal levels as a result of climate impacts. Coping strategies are remedial actions undertaken by people/communities whose livelihoods are threatened. This involves managing resources both during drought and in normal times in order to withstand the effects of drought risk. Diversification is a typical coping strategy and allowed farm workers, towns and people living in villages to "*survive*" dry periods or droughts.

Figure 6.16 illustrates the risk reduction strategies applied by communal farmers in the three districts. Irrigation seems to be the most popular strategy in Cacadu, with farm diversification in Joe Gqabi and the use of drought resistant cultivars in OR Tambo. Less than 10% of farmers actually employed these strategies mainly due to (i) lack of access to resources such as water and irrigation equipment in Cacadu, (ii) lack of access to alternative land in Joe Gqabi and (iii) lack of access to finance, land and machinery in OR Tambo. Farmers who applied these strategies were indeed more resilient than those without such alternatives. That caused the majority of farmers to remain extremely vulnerable to drought. Alternative farming systems such as ostrich farming and goat farming seem to be more resilient to droughts.

Diversifying livelihood strategies and income generating options within and outside agriculture was also required as a coping strategy, especially through non-farm enterprises and employment opportunities. Off-farm income in all three districts should be explored during drought, but the lack of economic activity and employment opportunities limited these options. Some farmers also have food gardens at the back of their houses through which they managed to support their families. A few of the farmers kept chickens as an additional source of income. In almost all cases, these alternatives were only on a subsistence scale and provided only a means of survival. A number of farmers mentioned that family members worked in the Western Cape and Gauteng, who then sent money home in support of people living in the study area.

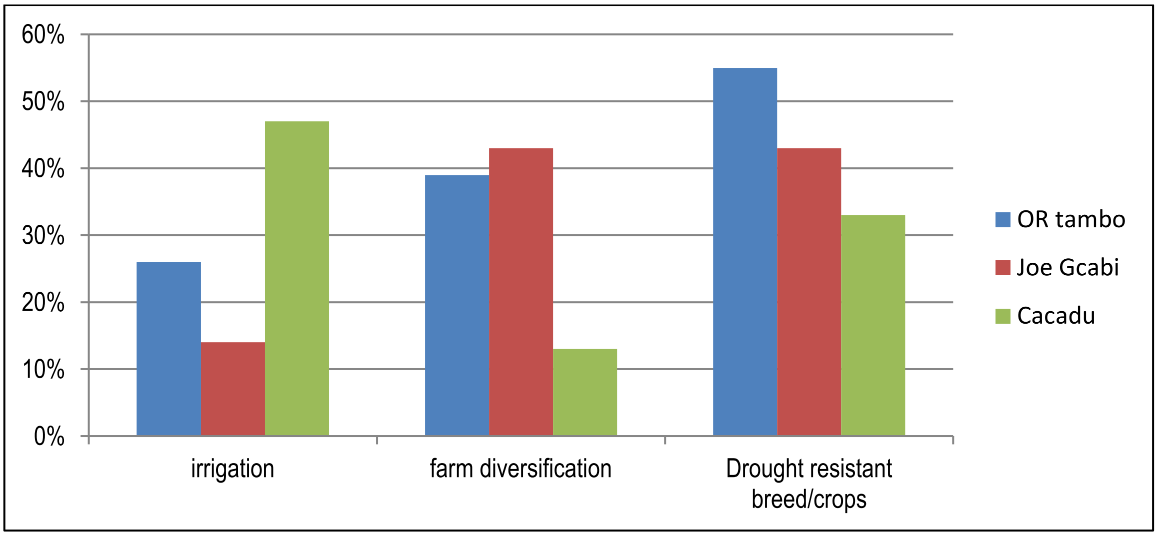

Fig 6.16: Diversification options per district

Grants and pensions from the government on a monthly basis also helped to lessen the impacts of drought or during dry periods for farmers in OR Tambo, Joe Gqabi and Cacadu districts. More than 60% of families in the eastern part of Joe Gqabi and the whole of OR Tambo received one or another grant from Government (StatsSA, 2012).

Farmers applied different strategies to cope with droughts and dry conditions. Amongst these were selling of small animals, selling of non-farm assets, the use of fodder banks and borrowing of money for additional feed and fodder. Illustrated in Figure 4.17 are the different strategies applied per district. Most farmers started selling smaller animals such as chickens, goats and sheep but they remained reluctant to sell their cattle at the onset of drought and would rather keep the cattle and buy feed and fodder or use available fodder banks. Less than half of the farmers also reported that they sold non-farm assets in order to cope during previous droughts.

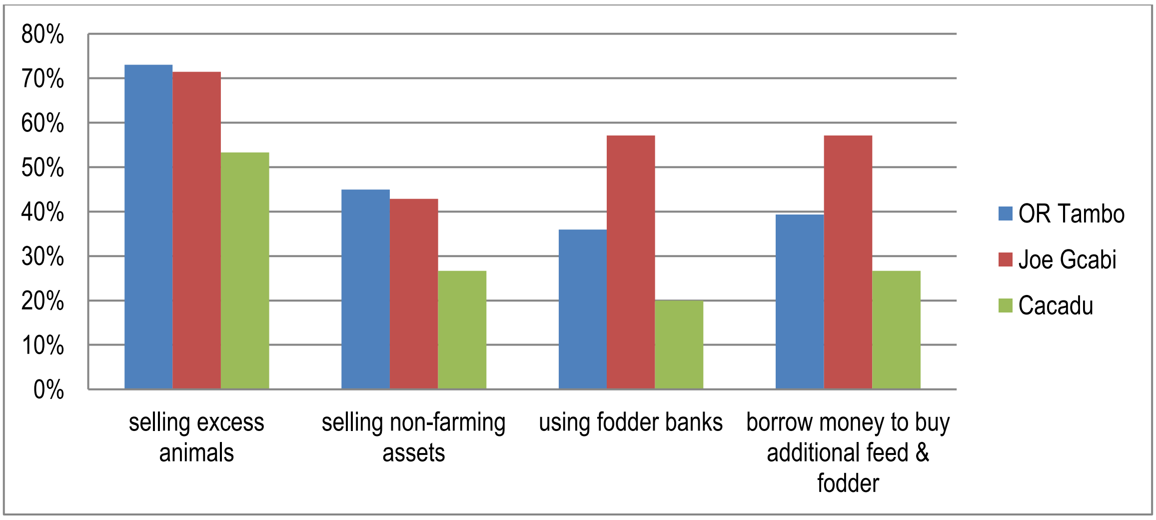

Fig 6.17: Coping mechanism for communal farmers per district

A few farmers with access to land and irrigation also planted oats in order to build a fodder bank. Extension officers mentioned that they promoted the planting of lucerne and other crops as fodder banks, but farmers in most cases lacked the funding and machinery and access to irrigation water in the drier areas to do so. These coping mechanisms could assist farmers to overcome most drought impacts.

Indigenous knowledge was an important element in *ex ante* (prevention and preparedness) and *ex post* coping strategies. Farmers from all three districts indicated that they have indigenous farming knowledge. The use of indigenous knowledge helped them to cope better with drought in that they knew in which areas to graze, what plants are best for survival and what plants are poisonous for animals during and immediately after droughts. Notsi (2012) supported the feedback from farmers and argued that this indicator is important especially in a rural context, such as the study area, with high poverty levels, high unemployment and limited formal education.

6.1.31 Analysis of Coping Strategies

In this study the multinomial probit model was used to investigate the factors influencing farmers' choice of specific coping methods. According to Munizaga, & Daziano (2005), Ziergler (2012) and Burgette & Reiter (2013) multinomial probit model applications include constrained and unconstrained versions of the covariance matrix of the multivariate normal distribute of error term. Assumption of a particular covariance structure was unnecessary as the data revealed the substation patterns.

The multinomial probit is a statistical model used when there are several possible categories that the dependent variable can fall into. The coping strategies choice model concerns the decision made by farmer *i, i*=1, 2,…, *I* of the alternative *j* in the set $w_i = (1,...., j)$ which produces the highest utility level (Vij). Thus, $V_{i1} < V_{ij,} \forall j \in w_i$ in this notation indicates the choice set is allowed to vary across individuals to account for their own specific coping strategy available. The drought coping strategies choices 1, 2, 3, 4 and 5 denoted to: none of the strategies, irrigation, farm diversification, resistant crops/breed and more than two coping strategies respectively. Resistant crops/breed was chosen as base category (option 4). The utilities of other choices (1, 2, 3 and 5) were compared to that of the base category. The individual decision was based on the differences between utility derived from the other drought coping mechanisms and the base category (resistant crops/breed). This can be represented as:

$$Y^{*}ij = Vij - Vij \qquad (1)$$

where $Y^{*}ij$ denotes unobservable choice made. $Yi = j$. If individual *i* make choice *j*, If $Y^{*}ij < 0$ for $j = 1,..., J$, then farmer *i* choices the base category option (drought resistant crops/breed) and $Yi = 0$. Otherwise, farmer *i* makes choice which yields the highest value for $Y^{*}ij$ and $Yij = j$.

Assuming that each farmer *i* faced the same *J* alternatives, a multinomial probit model formulation based on linear-in-parameters utilities was written as follows:

$$Vij = Zij\beta + \varepsilon ij, \varepsilon ij \sim N(0.\Sigma) \qquad (2)$$

$$y_{ij} = \begin{cases} 1 \;\; if \;\; Vij \; \leq Vij \;\; for \; i = 1, \ldots., I; \; j = 1, \ldots, J \\ 0 \;\; otherwise \end{cases} \qquad (3)$$

The variable Yij denotes the choice made by farmer i , Vij is the unobservable utility of alternative j as perceived by individual *i*, Zij is a (1 x *K*) vector explanatory variables characterizing both alternative *j* and the individual *i*. β is a (*K* x 1) vector of fixed parameters and finally Ɛ*ij* is a normally distributed random error term of mean zero assumed to be correlated with the errors associated with the other alternatives *j* , *j* =1,..., *J* , *j* ≠ *i* ; and covariance matrix of :

$$\sum = Cov(\varepsilon i = \begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma 31 & \sigma 32 & \sigma 33 \end{pmatrix} \qquad (4)$$

With $\boldsymbol{\sigma ij > 0, \forall j}$ (positive definiteness). The predicated probability of choosing any of the coping strategies choices represented with the following equations (5)-(9):

$$P(yi = 1)P(V_{i1} + \varepsilon_{i1} > V_{i2} + \varepsilon_{i2} \text{ and } V_{i1} + \varepsilon_{i1} > V_{i3} + \varepsilon_{i3} \qquad (5)$$

$$P(yi = 2)P(V_{i2} + \varepsilon_{i2} > V_{i1} + \varepsilon_{i1} \text{ and } V_{i2} + \varepsilon_{i2} > V_{i3} + \varepsilon_{i3} \qquad (6)$$

$$P(yi = 3)P(V_{i3} + \varepsilon_{i3} > V_{i1} + \varepsilon_{i1} \text{ and } V_{i3} + \varepsilon_{i3} > V_{i2} + \varepsilon_{i2} \qquad (7)$$

$$P(yi = 4)P(V_{i4} + \varepsilon_{i4} > V_{i1} + \varepsilon_{i1} \text{ and } V_{i4} + \varepsilon_{i4} > V_{i5} + \varepsilon_{i5} \qquad (8)$$

$$P(yi = 5)P(V_{i5} + \varepsilon_{i5} > V_{i1} + \varepsilon_{i1} \text{ and } V_{i5} + \varepsilon_{i5} > V_{i4} + \varepsilon_{i4} \qquad (9)$$

Assuming that the response categories are mutually exclusive and exhaustive, then $\sum_{j=1}^{J} Pij = 1$.

For each *i*, the probabilities add up to one for each individual and we have only J-1 parameters. This implied that equation (5) + (6) + (7) + (8) + (9) = 1 which was rewritten as:

$$P(y_i = 1) + P(y_i = 2) + P(y_i = 3) + P(y_i = 4) + P(y_i = 5) = 1 \tag{10}$$

Multinomial probit was adopted to avoid limitations of the simpler multinomial Logit, i.e. makes nonsensical predictions, since the dependent variable is not continuous, recoding the dependent variable can give different results (Rosella, & Walton, 2013). Multinomial probit has to estimate correlation if choices are large and the number of such correlation grow huge. Therefore, multinomial probit is designed to be used only if the options are relatively small (Donkor & Owusu, 2014). Empirically, the multinomial probit regression can be written as follows:

$$L_{ij} = \alpha_{0ij} + \alpha_{ij} D_{ij} + \alpha_{2ij} K_{ij} + \alpha_{3ij} Fs_{ij} + \alpha_{4ij} Aw_{ij}$$

$$+ \alpha_{5ij} Al_{ij} + \alpha_{6ij} Es_{ij} + \alpha_{7ij} Rk_{ij} + \alpha_{8ij} Ed_{ij} + \alpha_{9ij} I_{ij} + e_{ij} \tag{11}$$

where *ij* denotes coping strategies (j = 1 denotes no coping strategies, 2 denotes irrigation, 3 denotes farm diversification, 4 denotes drought resistant crop/breed and 5 more than one coping strategies). D*ij* equals 1 if the farmer received information from Department of Agriculture and Rural Development; *K* denotes knowledge of a farmer and *Fs* represents farming experience. *Aw* equals 1 if the farmer has access to water and *Al* denotes access to land. *Es* equals 1 if the farmer receives extension services. *Ed* denotes the educational level (primary, high school or degree). *Rk* equals 1 if the farmer does record keeping. *I* denotes income level. α_{oij} denotes the constant term and $\alpha_{1ij,}\alpha_{2ij,\ldots\ldots,}\alpha_{10ij}$ represent the coefficients of the explanatory variables in the model, and e_{ij} the disturbance term.

6.1.32 Determinants of the Choice of Drought Coping Strategies

The multinomial probit regression model was used to examine the factors that influence communal farmers' choice of coping strategies during drought in the Eastern Cape Province. Table 6.18 represents maximum likelihood estimates of the multinomial probit regression model. Drought resistant crops/breed was used as reference category for the multinomial probit analysis because most farmers opted for it. Income, experience, access to land and water and information from the Department of Agriculture and Rural Development (DARD) were variables fitted to the model because of significant influences to the farmers' probability to decide/choose which coping mechanisms to use.

The coefficient for the DARD is negative related to the probability of farmers not adopting any coping strategies and was highly significant at the 1% level. This implies that farmers who received information from the DARD were more likely to adopt resistance crop varieties and new animal breeds rather than not adopting any drought coping strategies. Information on earlier drought impacts was very important for planning future drought responses. By comparing most severe impacts of drought, policy makers can plan to minimize the most severe impacts (Dziegielewski *et al*., 1997; Udmale *et al*., 2014).

Table 6.18: Multinomial probit regression analysis.

	No Coping Strategy		Irrigation		Farm Diversification		More Than Two Coping Strategy	
Variables	**Coef.**	***p* > lzl**	**Coef.**	***p* > lzl**	**Coef.**	***p* > lzl**	**Coef.**	***p* > lzl**
DARD	−1.954	0.002 ***	−0.753	0.247	0.357	0.59	0.299	0.597
Knowledge	0.942	0.159	−0.449	0.529	0.367	0.571	0.657	0.235
Agricultural training	−0.214	0.734	−1.219	0.121	−0.705	0.296	−0.346	0.559
Experience	−0.042	0.046 **	−0.094	0.043 **	−0.011	0.654	−0.003	0.952
Access to land	1.309	0.065 *	3.602	0.000 ***	0.7	0.331	0.6	0.227
Access to water	1.421	0.024 **	−0.333	0.586	0.674	0.203	0.389	0.424
Risk level	−0.499	0.296	−0.019	0.014 *	0.902	0.365	−0.085	0.667
Extension services	0.907	0.165	−0.734	0.364	−0.859	0.222	−0.654	0.286
Farmers associations	−1.362	0.0018 **	−42.73	—	−1.882	0.007 ***	−1.084	0.044 **
Record keeping	0.392	0.497	2.533	0.000 ***	1.889	0.001 ***	0.484	0.351
Education2	−0.983	0.274	0.285	0.758	0.959	0.293	−1.086	0.201
Education 3	0.41	0.524	0.781	0.392	−0.318	0.613	0.799	0.172
Education 4	42.78	—	1.109	0.345	0.242	0.738	−0.438	0.53
Income 2	−1.288	0.149	1.272	0.081 *	2.601	0.000 ***	2.03	0.006 *
Income 3	−1.621	0.093*	3.823	—	4.082	—	5.3	0.000 ***
Base category	Drought resistant crop or animal breed							
Number of observations		—	—	—	—	—	—	121
Wald chi2(76)		—	—	—	—	—	—	0.000
Log pseudolikelihood		—	—	—	—	—	—	−108.56
Prob> chi2		—	—	—	—	—	—	0.000

The coefficient for access to water was significant at the 5% level and was positively related to the probability of farmers not adopting any coping strategies. This result was plausible because the farmers who had access to water already have mitigation strategies to address drought, therefore there was no need for them to adopt any other strategies. Communal farmers had access to water, but it was found not to be sufficient and this limited their ability to expand their farming business.

The detailed result of multinomial probit regression model is shown in Table 6.19.

Table 6.19: Multinomial probit regression analysis.

Multinomial Probit Regression				***N* =**		**121**
Log Pseudolikehood = −108.5604				Wald chi2(76)		0.0000
				Probability > chi2		0.0000
Variables	Coefficient	Robust Standard Error	z	*p* > lzl	(95% Conf. Interval)	
		1 (no strategy)				
DARD	−1.9542	0.6353	−3.08	0.002	−3.1994	−0.7090
Private sector	0.9709	0.5756	1.69	0.092	−0.1574	2.0991
Knowledge	0.9423	0.6695	1.41	0.159	−0.3699	2.2545
Agricultural training	−0.2148	0.6329	−0.34	0.734	−1.4552	1.0257
Indigenous knowledge	−0.6139	0.5859	−1.05	0.295	−1.7622	0.5345
Experience	−0.0429	0.0216	−1.95	0.046	−0.0852	−0.0007
Access to land	1.3092	0.7097	1.84	0.065	−0.0817	2.7001
Access to water	−1.4209	0.6304	2.25	0.024	0.1853	2.6566

Level of debt	−1.0506	0.7255	−1.45	0.148	−2.4728	0.3714
Risk level	0.2647	0.1937	1.37	0.172	−0.1149	0.6443
Extension services	−0.9069	0.6526	−1.39	0.165	−2.1860	0.3723
Farm associations	−1.3618	0.5743	−2.37	0.018	−2.4875	−0.2361
Record keeping	0.3915	0.5758	0.68	0.497	−0.7370	1.5200
Education 2	−0.9826	0.8988	−1.09	0.274	−2.7442	0.7790
Education 3	0.4103	0.6439	0.64	0.524	−0.8517	1.6723
Education 4	0.6261	0.7762	0.81	0.420	−0.8953	2.1474
Education 5	−42.7807	—	—	—	—	—
Income 2	−1.2883	0.8924	−1.44	0.149	−3.0373	0.4608
Income 3	−1.6212	0.9663	−1.68	0.093	−3.5152	0.2727
Income 4	−32.33932	—	—	—	—	—
2 (irrigation)						
DARD	−0.7533	0.6505	−1.16	0.247	−2.0283	0.5218
Private sector	−0.0098	0.6611	−0.01	0.988	−1.3055	1.2859
Knowledge	−0.4498	0.7147	−0.63	0.529	−1.8507	0.9511
Agricultural training	−1.2185	0.7865	−1.53	0.121	−2.7599	0.3230
Indigenous knowledge	−0.6964	0.5818	−1.20	0.231	−1.8367	0.4439
Experience	−0.0938	0.0463	−2.03	0.043	−0.1845	−0.0031
Access to land	3.6015	0.9826	3.67	0.000	1.6756	5.5274
Access to water	−0.3335	0.6117	−0.55	0.586	−1.5325	0.8654
Level of debt	0.1356	0.6973	0.19	0.846	−1.2311	1.5023
Risk level	−0.4986	0.2961	−1.68	0.092	−1.0789	0.0817
Extension services	0.7340	0.8083	0.91	0.364	−0.8502	2.3182
Farm associations	−42.7349	—	—	—	—	—
Record keeping	2.5334	0.6671	3.80	0.000	1.2258	3.8409
Education 2	0.2847	0.9238	0.31	0.758	−1.5260	2.0954
Education 3	0.7810	0.9132	0.86	0.0392	−1.0089	2.5710
Education 4	1.1093	1.1738	0.95	0.345	−1.1913	3.4098
Education 5	−0.6677	0.9370	−0.71	0.476	−2.5042	1.1688
Income 2	1.2716	0.7297	1.74	0.081	−0.1586	2.7019
Income 3	3.8234	—	—	—	—	—
Income 4	−22.9572	—	—	—	—	—
3 (farm diversification)						
DARD	−0.3569	0.6615	−0.54	0.590	−1.6535	0.9397
Private sector	1.1449	0.6413	1.79	0.074	−0.1121	2.4018
Knowledge	0.3674	0.6449	0.57	0.571	−0.9049	1.6396
Agricultural training	−0.7046	0.6737	−1.05	0.296	−2.0249	0.6158
Indigenous knowledge	−1.1342	0.5459	−2.08	0.038	−2.2041	−0.0644
Experience	−0.0108	0.0241	−0.45	0.654	−0.0579	.0364
Access to land	0.7003	0.7200	0.97	0.331	−0.7108	2.1115
Access to water	0.6735	0.2167	1.27	0.203	−0.3636	1.7105
Level of debt	1.3780	0.7037	2.06	0.039	0.0690	2.6870
Risk level	−0.0193	0.2167	−0.09	0.929	−0.4441	0.4055
Extension services	−0.8596	0.7037	−1.22	0.222	−2.2388	0.5196
Farm associations	−1.8816	0.6920	−2.72	0.007	−3.2378	−0.5253
Record keeping	1.8894	0.5761	3.28	0.001	0.7601	3.0186
Education 2	−0.9587	0.9110	−1.05	0.293	−2.7443	0.8269
Education 3	−0.3175	0.6278	−0.51	0.613	−1.5480	0.9130
Education 4	0.2418	0.7826	0.33	0.738	−1.1775	1.6611
Education 5	0.3997	0.8626	0.46	0.643	−1.2911	2.0904
Income 2	2.6012	0.5964	4.36	0.000	1.4324	3.770

Income 3	4.0823	—	—	—	—	—
Income 4	21.66639	—	—	—	—	—
4 (crops/breed- Base category- most of the farmers' opted for it (44%))						
5 (more than two coping strategies)						
DARD	0.2989	0.5653	0.53	0.597	−0.8091	1.4070
Private sector	0.4729	0.5290	0.09	0.929	−0.9894	1.0840
Knowledge	0.6571	0.5528	1.19	0.235	−0.4263	1.7405
Agricultural training	−0.3456	0.5915	−0.58	0.559	−1.5050	0.8138
Indigenous knowledge	−0.5770	0.4865	−1.19	0.236	−1.5305	0.3765
Experience	−0.0026	0.0278	−0.09	0.925	−0.0571	0.0518
Access to land	0.6000	0.5515	1.09	0.277	−0.4809	1.6809
Access to water	0.3899	0.4875	0.80	0.424	−0.5656	1.3454
Level of debt	0.3453	0.5640	0.61	0.540	−0.7601	1.4507
Risk level	0.1654	0.1781	0.93	0.353	−0.1837	0.5144
Extension services	−0.6538	0.6123	−1.07	0.286	−1.8539	0.5463
Farm associations	−1.0839	0.5389	−2.01	0.044	−2.1401	−0.0276
Record keeping	0.4837	0.5185	0.93	0.351	−0.5326	1.5001
Education 2	−1.0856	0.8497	−1.28	0.201	−2.7510	0.5797
Education 3	0.7997	0.5857	1.37	0.172	−0.3482	1.9477
Education 4	−0.4378	0.6976	−0.63	0.530	−1.8051	0.9296
Education 5	−0.7915	0.8666	−0.91	0.361	−2.4900	0.9071
Income 2	−2.0301	0.7457	2.72	0.006	0.5685	3.4917
Income 3	5.300	0.9555	5.55	0.000	3.4270	7.1724
Income 4	21.7229	—	—	—	—	—

The coefficient of the access to land had a positive association with the likelihood of choosing irrigation in favour of resistant crop/breed. It was significant at the 1% level. This indicated that farmers were more likely to engage in irrigation, especially when in the Cacadu district, because 47% indicated the use of irrigation. Most of the farmers in Cacadu were engaged in small scale crop and vegetable production that requires higher amounts of water compared to other districts. Contrarily, access to land was significant at the 10% level and negatively related to not adopting any of the drought coping strategies. This result suggests that farmers were more likely to adopt resistant crop varieties or animal breeds. The possible reason was that most of the farmers who produce crops and potentially adopt resistant crops curtailed the effects of climate change on their production. Previous studies found that farmers having secure land tenure were likely to take up adaptation strategies (Hisali *et al*., 2011; Deressa *et al.,* 2009).

The coefficient of experience correlated with the probability of not adopting any drought coping strategies in favour of adopting drought resistant crop or animal breeds. The variable was significant at the 5% level. The negative sign of experience implied that farmers who had been in agricultural production for long were more likely to adopt drought resistant crop/animal breeds to mitigate the impact of climate shocks and climate change. Experienced farmers had gathered enough information on the weather patterns for some period of time and therefore were able to choose the appropriate means of addressing climate shocks. Similarly, experience was positively correlated with the probability of adopting irrigation as a mitigating drought strategy in favour of drought resistant crop or animal breeds. The result implied that experienced farmers are more likely to adopt irrigation as a drought coping strategy. Developing irrigation facilities were more costly when compared to using drought resistant crops or animal breeds. This implied that communal farmers were more vulnerable as they do not receive enough income or have enough reserves to invest in irrigation infrastructure. Hisali *et al.* (2011) highlighted the importance of experience in drought resistance and that the more experience in farming, the more likely farmers are to have good knowledge about the weather and climatic conditions, and thus to adapt.

The coefficient of income 3 (R50 001- R100 000) was significant at the 10% level and had negative effects on the likelihood of not adopting any of the drought coping strategies. The result suggested that farmers with income ranges between R10 000 and R50 000 per annum were likely to adopt any of the drought coping strategies. In other words, they were more likely to adopt crop resistant or animal breeds as a mitigating strategy against drought. The reason was that these farmers have less income and they were more likely to be vulnerable to drought. This also suggested that they were more food insecure during droughts. Farmers with income of R100 000 - R200 000 could afford to purchase drought resistance crops or animal breeds. Moreover, farmers at the income level 5 (>R200 000) were more likely to adopt more than one drought coping strategy as they have additional crops or livestock to support their main farming enterprises. For example, money can be used to buy additional feed for livestock to survive until the dry period is over or they could invest in irrigation infrastructure.

The variable risk level was significant at the 10% level and negatively related to the probability of adopting irrigation as a strategy to address drought. This implied that farmers with higher risk levels were less likely to adopt irrigation as a drought coping strategy. However, risk levels were positively related to the probability of using farm diversification as a drought mitigating strategy in favour of drought resistant crops or animal breeds. This result indicated that farmers with higher risk levels tend to opt for farm diversification in order to cope with drought. Farm diversification helped farmers to cope better during drought as they had additional crops or livestock to support the main farming activity. This strategy was viewed as a better option when compared with a strategy that focused on drought resistant crops or animal breeds only. The level of perceived risk associated with the capacity to adapt to climate change determined the likelihood for adaptation measures (Hisali *et al.,* 2011). The contribution of farmers associations was significant at 1%, meaning a probability that those farmers who received information from farmers associations had a higher probability of adopting farm diversification as a coping strategy. However, this was not happening, as the associations did not operate properly at grass root level.

Record keeping was highly significant at the 1% level and positively associated with the probability of using farm diversification to address drought issues. The result implied that farmers who kept farm records were more likely to use farm diversification as a drought coping mechanism. Record keeping helped the farmer to know and monitor climate patterns and the performance of the production output. This assisted farmers in exploring alternative methods to reduce risks associated with drought. Most communal farmers did not keep proper records and were therefore not in a position to select alternatives.

Contributions from education and extension services were not significant and therefore negatively influenced the probability of farmers to select alternative coping strategies. This suggests that farmers remained vulnerable to drought and posed a challenge to government for the improvement of better education and extension support. Education and good extension are key determinants in adaptation strategies. Higher education level increases the individual awareness of different alternatives (Jordaan, 2011; Alam, 2015).

Summary and Conclusion

The vulnerability index for OR Tambo was 4,5 which was an indication of extreme vulnerability. Social, economic as well as environmental (ecological) vulnerability added up to more than 4. The vulnerability index value for Joe Gqabi was 3,9 and 3,1 for Cacadu district. In all cases economic vulnerability was the highest, which reflected the poverty levels amongst communal farmers in all three districts. Communal farmers, however, were not completely vulnerable. They also showed some resiliency and the fact that they *"survived"* previous droughts was an indication that they had some resilience against drought. Amongst the major contributors towards resilience were some form of alternative income sources during dry periods where they either sold non-productive items, started with small informal businesses or received support from family members in other areas. Indigenous knowledge also played an important role and the fact that farmers could cut on overheads and managed to survive on little income was at the core of their survival or resiliency.

This research also provided insight into factors that influenced communal farmers' choice of coping strategies. First, the results indicated that the communal farmers' choice of coping strategies were linked to numerous variables such as access to land, income, experience, education and extension. The research also showed that drought vulnerability and limited coping capacities of farmers were highly correlated with their inability to access resources such as land, water, finance, markets and timely information. Providing valid information on time about vulnerability and risk created a basis for informed decision-making by farmers to reduce drought vulnerability. Any viable strategy to reduce a farmer's vulnerability to drought and to improve productivity should be incorporated into the farmer's existing strategy to adapt and cope with uncertainty. Measures such as rainwater harvesting, tilling practices and reserves might help farmers to survive and would increase their resiliency.

The factors contributing to drought vulnerability were multi-disciplinary in nature and required several interventions in order to build resiliency. The extension services of the Department of Agriculture and the district disaster management centres should play a key role in drought risk reduction. Implementation of good agricultural practices was only part of the solution. Extension services should develop an extension programme and educate and assist farmers through study groups through which they can implement adaptation, mitigation and coping strategies. The disaster management centres, on the other hand, should develop a drought management plan in order to ensure timely and efficient relief to farmers at the onset of droughts.

The final index values were useful in order to compare districts with each other and to identify the indicators that contributed mostly to vulnerability, The value of these calculations, however, was not in the index value of the different indicators, but rather in the identification of indicators that contributed toward vulnerability.

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7 Drought Resilience: Commercial Farmers

Jordaan, A.J., Mashimbye, C. & Muyambo, F.

Executive Summary

This chapter contains the results for drought resilience with the focus on commercial farmers. Vulnerability indicators and vulnerability amongst smallholder farmers were discussed already in Chapter 6. The community capitals framework (CCF7) proposed by Flora & Flora was used as framework to explain drought resiliency and to explain why a commercial farmer is more resilient than communal farmers. The capitals discussed in the CCF7 framework were (i) natural, (ii) financial, (iii) built, (iv) human, (v) social, (vi) political, and (vii) cultural. Identification of the indicators served as a good source for future planning of beneficiary selection for land reform, as well as for the development of extension programmes in support to all new entrants. The communal farmers can also learn from the results in order to increase their own drought resiliency.

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 reticulation systems were equally important.

Introduction

The majority of the frameworks stated that understanding of the characteristics of vulnerability or resilience indicators also required an understanding of the characteristics of the population concerned. It also needed to be measured in response to actual or potential shocks, i.e. probability of a drought or an impact of drought period. Alinovi *et al*. (2010b) assumed that the resilience of a given household at different times depended on options available to that household. Therefore, for the development of drought resilience indicators for this research, the following were considered.

- Populations that contain resilient and vulnerable groups or systems in order to distinguish and determine indicators that build resilience and identify indicators that promote vulnerability, with the commercial and communal farming sectors being two sectors ideally placed to test this;
- Identification of the factors that explain whether a population was resilient or not;
- Understanding which of these factors should be measured and tracked in order to ultimately increase the proportion of resilient households;

- Bringing together experts in the fields of livelihoods, drought, household economy, vulnerability, social science and the community to identify, propose or develop indicators that can be used to measure resilience; and
- Thereafter collecting data through survey and different methods, with the measuring of resilience being mainly qualitative, while an effort is made to quantify the qualitative in the final risk assessment in a subsequent chapter.

Research Methodology

The research methodology applied for this part of the research was analytical, theoretical, and descriptive. Both deductive logic and inductive reasoning were applied to analyse the data and to draw conclusions. Understanding of the concept of resilience was done through a comprehensive literature study regarding vulnerability and resilience as discussed in Chapter 3. The literature study was an important source for question formulation for questionnaires and individual interviews. Structured questionnaires were compiled and distributed through the network of AgriEC and through the mail, but the response rate was extremely poor. This was then replaced by individual farm visits and interviews with farmers, interviews with experts and group discussions. An experienced researcher with 23 years of farming experience and a good understanding of agriculture in the Eastern Cape conducted the interviews. This method proved to be highly successful since farmers opened up and spoke freely about their experiences, strategies and challenges. Each interview lasted for approximately three hours. The technique followed in this research was based on the Rapid Rural Appraisal (RRA) techniques.

The RRA consisted of a series of techniques for research that supposedly generated results of less apparent precision, but greater evidential value than classic quantitative survey techniques. The method, also described by Duraiappah *et al*. (2005) and Leedy & Ormond (2010) was neither exclusively rural nor rapid, but was an economic way of obtaining evidential information. It was essentially extractive as a process. This method emphasized the importance and relevance of situational local knowledge, and instead of achieving spurious statistical accuracy; it rather focused 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.

The research techniques eventually applied in this research included (i) direct observation, (ii) familiarization and participation in activities, (iii) Interviews with farmers, extension officers and experts, (iv) local histories and literature studies.

Fifty-six farmers with experience of previous droughts were formally interviewed. Visits to five farmers' association meetings provided valuable information and insight and opportunity for informal discussions and information gathering. The research was also explained at an Annual General meeting of Agri Eastern Cape in Nelson Mandel Bay. Farmer leaders provided valuable information after this first meeting. Senior officials in the Department of Agriculture were consulted. More than 40 extension officers also provided their inputs. The private sector such as branch managers at banks, BKB, CMW and VKB also provided valuable information and insights into the coping capacity and drought challenges in agriculture. Discussions were also held with the insurance industry at a national and international level in order to understand drought risk reduction strategies from their perspective. Excellent feedback was also obtained from workshops, symposia and conferences. The preliminary results of the research were presented through several presentations at international and national conferences and feedback at this level was also included in final results.

Commercial Agriculture and Drought Resilience

The commercial agricultural sector in the Eastern Cape is well developed with high inherent and adaptive resilient capacity characteristics compared to the highly vulnerable smallholder or communal agricultural sector. The commercial sector is characterized by inherent resilient characteristics such as:

- Access to resources: Farmers had access to finance, insurance and other risk transfer mechanisms.
- Farmers were well connected to markets with well-organized market agents such as BKB, CMW, VKB and others.
- Institutions such as Agri Eastern Cape together with farmers' associations and commodity organizations were well developed
- Secure land ownership allowed farmers to plan ahead and used property as collateral.
- Institutional memory and experience of fellow farmers or previous generation was imbedded in knowledge base of farmers.
- Farmers in general were well educated and therefore also well connected to early warning systems and new technology
- Farms were well planned with good infrastructure such as water reticulation and camp systems.
- Many farmers had surplus capacity in that they have more than one farm or investments outside agriculture.
- Many farmers had access to water and utilised irrigation technology as a resilience building strategy.
- Farmers had the support of family members which provided them the inherent belief that they could take correct decisions even when under stress.

The adaptive resilient capacity of commercial farmers was particularly high. Rose & Krausman (2013) refer to adaptive capacity as "*ingenuity under stress*". The well-known South African concept of "*n boer maak n plan*" explains adaptive resilient capacity best. In this regard. The history of the Eastern Cape farmer was evidence of their dynamic resilient capacity in that they always managed to adapt and overcome challenges and remained successful and motivated in the process. In this regard the following characteristics were evident from the commercial farmers in the study area.

- Farmers were characterized by perseverance in the face of external shocks such as droughts, floods, animal diseases and market shocks.
- Farmers attitude remained positive for agriculture in spite of external natural shocks, economic shocks and political threats for so-called “land grabbing”.
- Farmers were adaptive in that most of them managed to change farming systems that were adapted to current climate conditions.
- Farmers were informed and could make informed decisions while under stress.
- Farmers were willing to work harder (and smarter) in order to survive external shocks.
- Many examples existed of family members that started with entrepreneurial activities in order to support the farm during and after external shocks.

Community Capitals Framework (CCF7)

Cornelia Flora, Jan Flora and Susan Fey (2007) developed the community capitals framework (CCF7) as an instrument to analyse how communities work to try and address poverty through the management of natural resources (Guitierrez-Montes *et al*., 2009). The majority of rural communities are dependent on natural resources such as rain, land and grazing for agricultural purposes. In order to sustain their livelihoods, local communities often overlook the management of natural resources. This, unfortunately, led to increased poverty and environmental degradation (Guitierrez-Montes *et al*., 2009). Guitierrez-Montes *et al*. (2009) further argued that the CCF7 framework provided a suitable technique to analyse inputs and impacts that emerged from both inside and outside the local community. These inputs and outputs played a key role in determining the success of sustainable livelihoods activities (Flora *et al*., 2007).

Flora et al. (2007) posit that communities that succeed in supporting sustainable development considered seven kinds of capitals. These are (i) natural, (ii) human, (iii) social, (iv) political, (v) cultural, (vi) financial and (vii) built or infrastructure capital. The community capitals offered a suitable framework that could be used to identify the various resources and activities required for local economic development. As a result of this research we add an additional capital, namely, institutional capital that is as equally important as the other capitals.

The community capitals framework (CCF7) was regarded as good method for analysing drought resilience amongst commercial farmers. Following below is a summary of the resilient characteristics of commercial farmers according to the CCF7 framework. Characteristics of smallholder farmers were discussed in the previous chapter as vulnerability, but reference is also made to some drought resilient characteristics amongst smallholders in this chapter. Table 7.1 summarizes the different resilience indicators according to the CCF7.

TABLE 7.1: SUMMARY OF RESILIENCE INDICATORS ACCORDING CCF7

CCF7 Capitals	Inherent Indicator	Dynamic Indicator
Natural/ecological	* Land * Water sources * Soil quality	
Financial	* Access to finance * Access to insurance * Financial reserves * Production capital	* Alternative sources * Emergency funds
Built	* Camps through good fencing * Water reticulation * Access roads * Communication networks * Livestock handling facilities * Irrigation	* Innovation characteristics
Human	* Education level * Experience * Labour * Management	* Risk profile * Innovative * Flexibility * Perseverance / hard working
Social	* Farmers organizations * Farm networks * Churches * Family networks * Extension and mentorship	* Charitees * Support groups
Political	* Importance of agriculture for food security * AgriSA and structures * Political connections * International relations	* Govt support to agriculture * Land grab threats * Security
Cultural	* Work ethics * Inheritance * Conservationist	* Perseverance / hard working * Flexibility * Risk profile

An analysis of the resilience indicators according the CCF7 framework is provided in the next section

7.1.1 Natural/Ecological Capital

Natural. or ecological, capital is an important asset for commercial farmers in that land ownership and access to land provided them the opportunity to plan ahead, improve infrastructure on the land and to use the land as collateral for wealth creation or as a reserve during external shocks. Most farmers continued to invest in agriculture during surplus years by buying additional farmland. Horizontal development by investing in more land seemed to be the most popular drought risk reduction strategy amongst commercial farmers. Interestingly though, was that farmers did not use this consciously as a drought risk reduction strategy, but rather as a strategy for wealth creation. When challenging farmers at first on what is their "*drought risk reduction strategy or strategies*", they responded that they do not have a specific strategy for drought risk reduction since droughts were regarded as a normal occurrence in their farm management plan. During the interviews and discussions on drought strategies, farmers eventually acknowledged that they were prepared to sell surplus land as a coping strategy during extreme droughts and therefore acknowledged that subconsciously they invested in additional farmland as a strategy for drought risk reduction. Additional grazing camps were also an important drought coping strategy in that farmers could move animals to camps with available grazing. Furthermore, additional farmland allowed farmers to apply a more conservative grazing capacity. The majority of farmers indeed reported that their grazing quality and vegetation cover improved dramatically since the inception of the livestock reduction programme implemented by the Department of Agriculture after the 1992 drought. Some of the larger farmers had alternative land in different districts and they were therefore in a position to reduce drought risk on one farm.

Water was an important natural capital and farmers were willing to invest sufficiently in order to buy land with adequate water resources or to protect current water resources from over-exploitation. Farmers were also willing to invest in the search for additional and reliable water sources. Groundwater was the main source of livestock drinking water and was available on all the farms visited during the research. Water availability also allowed farmers to irrigate and therefore produce additional feed and fodder. In the higher rainfall areas of Joe Gqabi, farmers with access to good quality soil were also able to produce cash crops such as maize, dry beans, soya beans and potatoes and this provided them with alternative income sources. Dairy production was an important source of income in the coastal regions of Cacadu where farmers had access to irrigation and good soil.

Commercial farmers saw political threats about land ownership and so-called “land grabbing” as a serious threat to the resilience and stability of the farming sector. Farmers also perceived the fracking for gas in the Karoo as a real threat to the groundwater supply and reliability.

Vertical development such as irrigation, water reticulation etc. is discussed under the section on built capital.

7.1.2 Financial Capital

Financial capital refers to the access to finance, insurance, other capital related risk transfer products and alternative capital reserves. Commercial farmers viewed capital reserves as an important element for drought resiliency. In contrast, farmers reported that high debt ratios were amongst the single most important indicators that rendered them vulnerable to drought or any external shock. According to the commercial farmers, the freedom to make decisions was at the core of drought resilience. Drought, like any other external shock, forces the entrepreneur or farmer to make unplanned decisions. Even if the decision was the correct one, when the timing is not correct the farmer has lost control and income. High debt ratios put the farmer under additional stress during drought and dry periods and forced farmers to sell productive assets in order to service debts and to cope with reduced production as a result of drought.

Financial reserves were regarded by all farmers as an important factor for drought resilience and almost all farmers reported that they tried to save funds in order to withdraw them at short notice. Few farmers invested their savings on the stock market for fear of not earning interest on investment and because they felt that they had less control over their investment. Most farmers, however, reported that they also invested vertically on the farm into improved infrastructure or replacement of liquid assets such as vehicles and implements. Farmers did not trust the investment scheme at the Land Bank and they reported that they did not make sufficient use of the scheme for fear of the Bank’s collapsing because of poor management. Many farmers, on the other hand, were not well informed on the Land Bank savings scheme. Most farmers preferred to invest in additional land and they would go to great lengths in order to purchase more land. That provided for better planning and reserves, as discussed in the previous section, but it was also regarded as an investment strategy.

Drought insurance was not available to stock farmers. Insurance companies are now investigating the potential of index insurance, which might open insurance packages not only for commercial farmers, but also for communal farmers. Discussions with insurance companies in South Africa such as Swiss Re, SANTAM and AgriSeker are on-going, but it was clear that government must support such schemes by subsidizing the premiums.

7.1.3 Built / Infrastructure Capital

Infrastructure development was good at most commercial farms with well-planned camp and water reticulation systems. Built capital is a strong inherent resilience factor, but it is under threat since most infrastructure such as fences were already older than 50 years and required regular maintenance. Farmers regarded the infrastructure subsidy scheme provided by the Department of Agriculture during the 1960s and 70s as one of the best initiatives to build drought resilience. Farms were properly planned and fenced with water reticulation systems that provided livestock drinking water in all the camps. This allowed for proper veld and livestock management. In addition to camps and drinking points, farmers mentioned the importance of proper and efficient livestock handling facilities.

Pic 7.1: Small camps with irrigated lucerne used for lambing

The lambing and calving season is normally a critically important period on the farm and the importance of these periods were exacerbated by dry periods and drought. Lactating livestock requires special care and additional feeding and that was not possible without proper facilities. Predators seems to be the single largest factor contributing to livestock loss and all livestock farmers reported that they had to move lactating and young animals closer to the homestead or to centralized places on the farm in order to protect them from predators. This required good handling facilities and smaller camps with predator secure fences. An example of such infrastructure in the Joe Gqabi district is shown in the picture in Picture 7.1.

Pictures 7.2 & 7.3: Farm access roads

Access roads are an important indicator for resiliency and was of concern in the rural areas. Farmers reported that some had to change farming systems from dairy cows to an alternative system due to poorly maintained access roads. The milk transporting companies refused to travel on certain routes because of the poor quality of roads. This limited the options for farmers in that they had to abandon dairy farming and opted for alternatives. In many cases farmers themselves took over the maintenance of roads. Illustrated in Pictures 7.2 and 7.3 are typical smaller roads maintained by farmers themselves.

Communication infrastructure was relatively well developed with cell phone coverage over the largest part of the research area. Farmers obtained Internet access mostly through cell phone companies and in addition to television and radio (which is accessible in all areas) were able to access drought early warnings and stay in contact with the latest technology.

The electricity network was well developed and all farmers interviewed during the research reported that they were connected to the national ESKOM grid. On farms and remote places where farmers required electricity, for example, for water pumps, renewable energy such as sun panels seem to be popular and have gained ground. Farmers had innovative plans to protect these rather small installations from theft.

One of the main risk reduction strategies applied by farmers was the introduction of new technology for irrigation. Water availability in the arid regions of Joe Gqabi and Cacadu districts was limited on most livestock farms except on farms enlisted in the irrigation schemes of the Fish River, the coastal regions near Alexandria and south of Port Elizabeth and in the higher rainfall regions of Joe Gqabi and OR Tambo. Farmers in the arid regions with water utilised irrigation to produce fodder (mostly lucerne) as a reserve for dry periods. The introduction of pivot and drip irrigation systems allowed farmers to utilise available water more efficiently.

7.1.4 Human Capital

Human capital refers to the potential of the manager (farmer) and his/her labourers to implement, combine and integrate the other capitals in order to build resilience against external shocks. Education and experience were the two most important factors contributing toward resiliency amongst commercial farmers in the study area. All farmers interviewed had at least a matriculation qualification with the vast majority a tertiary qualification. All farmers interviewed reported that they attended or participated in farmers' days, training courses or study groups. The knowledge base of the older farmers about the natural resources was a revelation to the research team.

Most of the more experienced and older farmers could explain, with the addition of scientific nomenclature, the names of plants on their farms and how each species should be treated to obtain optimal production. All the farmers applied a grazing management system where they allowed grass to recover in a systematic way.

The more senior farmers acknowledged the important contribution of the extension work done during the 1970s and 1980s when extension programmes focused on natural resource management. Study groups were one of the most important tools for extension and knowledge transfer and farmers acknowledged the extension work of 30-50 years ago as key to their success and drought resilience today. When asked about a grazing system, the older farmers were all able to explain what plants should be monitored and at what stage animals should be moved to another camp. The younger farmers on the other hand – even those with tertiary qualifications in agriculture – reported that they followed their "*gut feel*" or they follow the guidelines provided by their parents or neighbours.

Knowledge and experience was regarded as extremely important and contributed significantly to the resilience of farmers. This was an important indicator considering the challenge of land reform in South Africa. The institutional knowledge of this generation of farmers should be transferred to the newer generation, whether they are new land reform farmers or new commercial farmers. Mentorship programmes could be one of the solutions and many farmers mentioned their willingness to mentor new land reform beneficiaries. Mentorship to be discussed as part of social capitals.

The ability to manage the natural resources available also seems to be an important resilience-building factor amongst commercial farmers. Farmers who applied a conservative grazing capacity on their farms seem to be more likely to withstand the negative effects of D3 and D4 droughts. A number of successful farmers mentioned that they had a grazing capacity load on their veld equal to approximately 30% less than the prescribed MEISSNER table for their region. They also mentioned the importance of including game numbers in the calculation of livestock numbers for grazing capacity. Jordaan (2011) found the Northern Cape as being 25% over-stocked during 2011, and that renders livestock farmers highly vulnerable to droughts.

Management skills of some of the farmers were at an extraordinarily high level, with some farmers reported lambing percentages of more than 200% per annum for sheep due to innovative planning and good management. Sound management, which was the result of knowledge, experience, education, and a certain attitude towards farming, was a key drought resilience indicator.

Pictures 7.4 & 7.5: Molasses wheel for cattle

Innovative thinking and actions were found to be a characteristic of most farmers. They developed and implemented some excellent innovations to enhance productivity and drought risk reduction. An example is the molasses trough designed and built by a farmer in order to feed molasses to cattle during droughts (See Pictures 7.4 and 7.5). Filling of molasses was required once a week, depending on the number of cattle, and the particular farmer could save much on labour by allowing cattle to lick the molasses from the steel "*wheels".* Although a simple technology it was developed based on many trials about the width of the "*wheel*" as well as the diameter. These types of innovations were found on the majority of farms visited.

A large number of farmers reported that an important element for drought resilience was the fact that they stayed on the farm and therefore managed to keep their finger on the pulse of the farming enterprise. Farmers were able to monitor the natural resources, the livestock and the crops closely. This was confirmation of the proverb "*it is the footsteps of the farmer that makes the crops grow".*

Labour was another important human capital asset that contributed to drought resilience. In spite of negative media reports and political rhetoric about farm workers, the relationship between farm workers and farmers were in good standing. Informal discussions with farm workers revealed excellent knowledge about drought risk strategies such as drought feeding, grazing systems, and other managerial aspects such as animal selections, livestock diseases and lambing or calving practices. Farm workers in general were experienced with many of them staying and working with livestock on the farm for as long as the farmer himself. Most farmers still trusted their herders and reported that farm workers were valuable and they were not be able to manage their business successfully without them.

7.1.5 Social Capital

Social capital has to do with networks, linkages and support systems. Social capital portrayed inherent as well as dynamic resilience capacity characteristics. The most important social capital in drought resilience for commercial farmers was the families/household of farmers living with them. Most successful farmers resided on farms together with their spouses who, in many instances, were also involved in the activities on the farm, whether in an administrative role or also in a managerial role. Many farmers cited examples of spouses who were forced to earn an extra income during severe external shocks and through that additional income supported them to stay on farm.

Official farming networks were well established and well organized for the commercial farming sector. Agri Eastern Cape was the main organized agricultural organization but there was also a small group of farmers belonging to Transvaal Agri. Agri Eastern Cape was organized in district Agricultural Unions and Farmers Associations. The majority of farmers were affiliated to Eastern Cape Agri through their own farmers' associations. Agri EC in turn was affiliated to Agri SA, which represented farmers' interests at national and international level. Commodity organization such as the Red Meat Producers Organization (RPO), the Mohair Growers Association (MGA) and the National Wool Growers Association (NWGA) were all well supported and well organized. They aggressively advocated for the interests of their members and were also involved in research projects and the development of new technology through research institutions. They were also responsible to disseminate information and news to members through different communication channels. These organizations were important role players in drought resilience through the provision of platforms for discussions about early warning and drought related solutions. These organizations also had a sound history of active support to farmers during droughts in that members supported each other with emergency grazing and fodder when required. The farmers' organizations were also utilised by the Department of Agriculture and Disaster Management Centres to assist with drought surveys and drought relief activities.

Extension services from the Department of Agriculture used to be a strong contributor to resilience building, but it has lost all its credibility, with the majority of extension officers not in a position to advise commercial farmers because of lack of experience or higher-level knowledge required for commercial farming. In addition, the strategy of the Department of Agriculture to utilise extension officers as project managers was counter-productive and did not serve the primary objective of extension. The majority of commercial farmers made use of agricultural information services from private companies or consultants or scientists from Universities. The Internet and the printed media were also mentioned as important sources of information and new technology. The fact that the majority of farmers shifted their focus to alternative sources of information was an indication of strong dynamic resiliency.

Most farmers mentioned the important role of the former soil conservation committees and requested the institutionalization of a similar committee.

Mentorship was an important source of knowledge transfer, with many farmers reporting that they learn from each other through inheritance, through social structures such as farmers' associations and from neighbours. They regarded mentorship, whether formal or informal, as an important part of resilience building. This was an important consideration for new entrants to agriculture. Mentors were not necessarily the persons with the qualifications. At most agriculturalists and extension officers can qualify as advisors and not as mentors. A mentor was regarded as somebody who *"walk the talk";* somebody with experience who could guide the new farmer in the subtleties of farming and assisted him/her with decision making as if it was his/her own farm. Of concern in many parts of the Eastern Cape was that the Department of Rural Development appointed mentors with no practical farming experience as mentors. These mentors just duplicated the work of extension officers from the Department of Agriculture and the mentorship programme in the EC was doomed to fail with such an approach.

7.1.6 Political Capital

The commercial farming sector was well represented at national level by AgriSA who consult with government on a regular basis. The fact that only approximately 30 000 commercial farmers produce food for more than 55 million people is important in the decision making of government policy. Government has realized the importance of the agricultural sector in spite of negative political rhetoric towards the agricultural sector. Government provided more than 2 Billion Rand in drought relief during the 2015/2016 drought; proof that they were not totally ignorant to the importance of agriculture.

On the other hand commercial farmers, together with communal farmers, complained that government relief was totally inadequate. Farmers reported that past drought declaration and application processes were cumbersome, with relief realized very late. In spite of the critique against the administrative process, farmers were in general satisfied with the type of relief, but not the amount and time span of relief. Relief was provided in terms of subsidies for feed and fodder up to a maximum of 50 large stock units (LSU) for two months, which proved to be inadequate during prolonged droughts. One of the challenges mentioned by farmers was the discrepancy between provinces. Farmers with farms in the Western Province received drought relief for six months compared to only two months in the Eastern Cape.

The general feeling amongst farmers was that the EC Government – including the Department of Agriculture – had no sympathy with the commercial farming sector and the inefficiency in governance did not contribute to rural development. Almost all farmers regarded successful land reform as important and most of them were willing and able to assist with mentorship if required. Their concern, however, was that mentorship in the Eastern Cape was another scheme destined to fail because of the incapacity of the Department of Rural Development to implement it in a proper way.

Farmers did not trust government at provincial and at local level and government did not trust the commercial farmers. The lack of trust was counter-productive to resilience building and increased the vulnerability of the agricultural sector, not only to drought, but also to all exogenous shocks.

7.1.7 Cultural Capital

Cultural capital is seldom mentioned separately and most frameworks classify cultural capital as part of social capital. Scientists today realize the importance of cultural capital in that it explains why we do things in a certain way. In this research the most significant resilience indicator classified under cultural capital had to do with the work ethic of commercial farmers. When asking farmers what was required to have resilience against drought and what helped them to overcome previous droughts, the majority of them were quick to reply with two phrases; "*perseverance and hard work"*. The literature refers to the "Protestant work ethic" and the biblical belief *"in the sweat of your face you will earn your bread"* (Genesis 3:17) and *"….you will eat only through hard work*" (Genesis 3:19). For many years the role of religion and religious background was overlooked as a contributing factor to resilience. The belief system of most farmers also emphasized the importance of support to each other and that was demonstrated by the willingness of farmers to take the lead in various community projects. The majority of the farmers interviewed were in some way or another leaders within their communities. Farmers were involved in (i) development programmes, (ii) they provided transport for farm worker children to get to school, (iii) they helped farm workers to obtain medical care when required, (iv) they provided transport for farm workers, (v) they provided mentorship to new and younger farmers and (vi) assisted each other in times of distress.

Most farmers realized the importance of conservation farming and they were in essence conservationists who realised that they had to preserve the natural resources for future generations. A number of farmers observed that plant coverage increased since the livestock reduction programme instituted by the former Department of Agriculture in 1992/93. They measured that based on much lower stormflows and relatively higher groundwater tables. Some farmers cited the example of many empty smaller dams in spite of normal and above normal rainfall as an example of less stormflow. Drought resilient farmers "*live close to their land*" (their own words) and that allowed them to observe and be sensitive to changes in the climate, the natural resources and the behaviour of animals. This entrenched the indigenous knowledge systems and allowed farmers to make timely decisions.

Inheritance and the transfer of knowledge and experience were also important for drought resilience. Older farmers transferred skills and knowledge to their children from childhood and many of the farmers witnessed the importance of the knowledge inherited form their fathers/mothers. Farmers talked about a "*gut feeling*" on what strategy to implement, when to sell, when to buy, when to move animals from one camp to another and when to expect a drought. It was not possible to teach this type of experience; it could be transferred to young inexperienced farmers or they could share in that experience and knowledge through mentorship.

In essence most farmers were risk takers. They were willing to invest large amounts of capital (financial capital) and trusted that it would rain in order for them to reap the progeny and the yields. Not only were they willing to invest in farming, which remained a high risk undertaking; they were also willing to stay in rural areas which were unsafe, away from towns and cities with schools, medical facilities and other amenities. Security on farms had a negative impact on drought resilience since farmers had to invest additional funds into security arrangements. Few of the farmers were not directly or indirectly affected by a farm murder.

Drought Risk Reduction Strategies

Most farmers instinctively applied drought risk reduction strategies as part of their farming activities in spite of the fact that they did not name it as such.

The most common and successful coping strategies are listed as follows:

- Irrigated lucerne or fodder for reserve fodder. Some farmers reported that they had enough fodder reserves to feed all livestock on their farms for at least 1 year. These were the farmers with sufficient water for irrigation, mostly from rivers and streams. Many farmers irrigated small amounts of lucerne and other crops for reserve fodder in case of dry periods and as supplementary feed during lambing season.
- Most farmers reduced animal numbers at the onset of a dry period by selling older animals and animals not at the core of their breeding flock. The rule of thumb was to reduce animal numbers by at least 30% at the onset of a drought.
- Farmers applied drought feeding in small camps during dry periods. Chocolate maize was an example of a popular drought feed.
- The use of molasses and other supplements enabled animals to also utilise unpalatable plants.
- The use of drought resistance fodders such as sisal and prickly pears was encouraged.
- The larger farmers had farms in different regions (climatic zones) and managed to move animals to alternative land.
- Farmers exploited alternative income sources such as the introduction of farm-stays and farm tourism. Once introduced as a coping strategy it became a permanent feature on the farm.

The following prominent adaptation strategies were noted:

- Maintaining of a conservative grazing capacity of up to 30% below MEISSNER guidelines. Farmers who applied a conservative grazing capacity had surplus feed and fodder during dry periods and that allowed them the freedom to make good management decisions in terms of when to sell animals and when to keep animals. These farmers also reported an increase in plant density and grazing capacity because of better quality grazing.
- Introduction of drought resistant animals such as ostriches in the farming system

- Introduction of game farming either on part of the farm or on all the land. Many farmers changed to game farming with success, but initial costs were extremely high and not all farmers could afford the high initial capital investment. Game farms, on the other hand, increased drought vulnerability for neighbouring farmers in that no predator control was taking place on game farms and game parks. Neighbouring farmers reported that they could not utilise camps bordering game farms due to predators, which in some cases killed up to 50% of progeny and young animals.

Conclusion

Most of the theoretical frameworks highlighted the access to resources, human capital, social capital and political capital as the core elements for resilience building. The CCF7 model used in this research elaborated on most models by differentiating between access to natural resources and financial resources. In addition the CCF7 model also included human capital, political capital, infrastructure capital, social capital and cultural capital. The value of the use of indictors for measuring resilience was in the identification of the factors that distinguish successful or resilient farmers from vulnerable farmers. The resilience indicators served as a checklist of what is required for a farmer to survive a drought. This is particularly important for new farmers and especially the land reform farmers and extension services which are tasked to support the land reform process. Table 7.1 can serve as a checklist to determine if a specific farmer will survive a drought or not, or even if such a farmer is resilient against any other form of external shock.

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8 Drought Loss Functions for Livestock and Maize Production

Jordaan, A.J., Bahta, Y.T., Mashimbye C., van Heerden, P. & Owusu-Sekyere, E.

Executive Summary

The calculation 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 they 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, on the other hand, could use the MAL as a guideline on what they could afford in terms of premiums.

There was no correlation between precipitation and wool yield and we therefore rejected the null hypothesis that drought impacted on wool production without considering additional inputs during dry years. These results were in contrast to what farmers believed and what the initial assumption of the research team was. 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 under current climatic conditions and mentioned 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 farm level data. We could obtain historical farm level maize production data only from 2006 onwards, but that was not sufficient to develop a robust drought loss function for maize. In desperation the SAPWAT3 programme was adjusted for use for dry land conditions. The potential of the SAPWAT3 model as a decision support tool for dry land crop production was tested. After a few adjustments to the software we could calculate and demonstrate the use of the SAPWAT3 model for dry land conditions. More work is still required to ground-truth the results and to adapt the model fully for dry land applications.

Introduction

The lack of long term historical data restricted the exact calculation of a loss function for droughts. The severity of a drought is the function of the intensity and duration of a dry period, and losses vary according to drought duration and intensity. Farmers had different opinions regarding the losses experienced during dry periods. Some were of the opinion that duration was more important than intensity while others were convinced that intensity of a drought determines major losses. Fouche (1992), Snyman (2003) and Narasimhan & Srinivasan (2005) reported that the situations might differ from farm to farm and differ from dry period to dry period as well as considering the seasonal pattern of the drought. The impact of drought on water provision on a specific farm could also determine the eventual loss. The literature was not clear on this and much research is needed to determine drought loss functions for extensive livestock farming in arid and semi-arid areas (Grove, 2015; Viljoen, 2015).

In the context of this study it was decided to use available production data that are linked to meteorological data at the same farm or the same district. One of the main challenges in obtaining data was the fact that few farmers could provide historical production data that is linked to accurate precipitation data[6] on their farms.

Farmers reported average losses in wool production during droughts of more than 1 kg per SSU and a loss of 10 kg per SSU in meat production. The dramatic increase in meat prices and the good wool market during the 2010 drought cancelled the negative financial impact of the drought to a large extent and most farmers agreed that production losses were then buffered by the excellent product prices. However, it is worth mentioning that the good market prices were rather an impact of global market forces than the drought and less supply in South Africa. Future research and development of drought loss functions should therefore rather consider production outputs and losses and keep in mind the price volatility of product prices during droughts. During 2010, exogenous factors such as, *inter alia*, the worldwide recession, impacted on product prices and it could prove difficult to consider all these factors in the development of drought loss functions.

Calculations of drought loss functions for the livestock sector are probably one of the most neglected topics of research due to the unpredictability of variables and the lack of historical and reliable data. Jordaan (2011) developed a methodology to calculate mean annual loss (MAL) for the livestock sector in the Northern Cape, but he also highlighted the lack of rigour in his methodology and recommended further research by using quantitative data analysis. His methodology was based on the perception and experience of farmers regarding losses in production and profit during dry years. Gross margins for the livestock sector and percentage losses were used as basis for the calculation of MAL. For example, farmers in the Northern Cape reported 1 kg loss in wool production per SSU and up to 10 kg weaning weight loss for lambs during severe droughts when SPI<-1,5 (Jordaan, 2011). The purpose of this study was to calculate production loss during droughts and to use that as a basis for the development of loss functions.

[6] According to the definitions used for drought in this study, a severe drought has 12-month SPI<-1,5 and extreme drought has 12-month SPI<-2 and on-farm meteorological historical data is needed to do proper calculations.

Fouche (1992) calculated grazing yield loss during dry years and suggested yield loss as the basis for loss function development. Farmers, however, do not sell grass; they sell wool, mohair, mutton and meat. Grass was therefore transformed into marketable products, which should be used as the basis of measurement for loss functions. A more accurate methodology on the other hand would be to consider the net income as the dependent variable. Price volatility of products – especially mutton and beef – during dry periods might increase the complexity and accuracy of calculating drought loss functions. The lack of reliable data regarding income and expenditure specifically linked to the livestock sector also limited the use of net profit as the dependable variable.

In order to test the hypothesis of wool production losses during dry periods this research focused on total wool production and wool production per SSU as the dependent variables and annual precipitation translated to the SPI as the independent variable. The null hypothesis (H_0) in this case was that wool production decrease during dry years.

Historical production data were extremely difficult to obtain since data should cover at least three dry periods and both production data as the dependent variable and precipitation data as the independent variable were required. After extensive consultations with farmers, farmer groups and commodity organizations it became clear that the only available historical data were wool production data. The research team decided then to use wool production at farm level and wool production at district level as dependent variables and correlate these with precipitation data on both farm and district level as the independent variables. In order to identify dry and wet periods all precipitation data were transferred to the standardized precipitation index (SPI)

Drought Impact on Extensive Livestock Farming

As a result of the lack of good quality grazing during dry periods, commercial farmers reported the following direct production impacts. It is important to note that reported drought impacts discussed here were based on the perception of farmers and not on calculations made on actual data.

Livestock sales are in most cases the first coping activity performed by farmers during droughts. Indications from farmers and farmers' groups were that a reduction in livestock numbers of at least 30% is common prior to droughts. One of the main challenges with livestock sales was when to sell. Many farmers did not trust drought early warnings, and farmers tended to wait too long before they started with "*drought sales*" [7]. "Drought sales" were mostly characterized by high supply and low demand, which resulted in lower than normal prices at the onset of the dry period. In addition, animals were not market ready and in poor condition, thereby worsening the situation with even lower prices than under normal conditions.

[7] Drought sales are linked to a drought and is not the normal annual sales

Wool Production was one of the major commodities produced in the Cacadu and Joe Gqabi districts and wool farmers reported a reduction in wool yield of at least 1 kg per adult sheep during drought. That represented a wool production loss of at least 25% and higher. In addition to the loss in yield per animal, reduced animal numbers during drought added to the loss in total wool production. A farmer with 2 000 sheep, for example, produces 8 000 kg wool at 4 kg per sheep during normal years. With 30% fewer animals and a loss of 1kg wool per sheep on the remaining 1 400 sheep, this farmer could only produce 4 200 kg wool in a worst-case scenario – a reduction of nearly 50% in wool yield alone. This was the perception of farmers. However, actual calculations disproved this assumption.

Meat and mutton production was negatively affected during droughts. Farmers and auctioneers indicated losses of about 10 kg for weaner lambs. Normal selling weight of 6 month old lambs was 36 kg whereas the average weight for the same age lambs during severe dry periods was only 24 to 26 kg.

Additional feed and fodder purchases for drought-stricken animals had a large impact on farm profitability. Agricultural businesses reported a ten-fold increase in feed and fodder sales as the norm during severe dry periods. During interviews with commercial farmers, they reported increases in expenditure of at least 100%.

Mortalities during severe dry periods can be as high as 50% of the livestock in extreme conditions. Most farmers, however, reported average mortalities of 30% of animals during severe droughts if timely action was not taken. The governmental guideline for drought support was a reduction of 30% of animal numbers at the onset of severe dry periods. If applied as prescribed, farmers reported minimum mortalities. Several farmers reported that they reduced their animal numbers to 70% of normal grazing capacity guidelines and they successfully managed to pull through previous droughts.

Quality of products was negatively affected during droughts. Wool quality, for example, was lower due to higher levels of dust and dirt in the wool, and a larger percentage of wool tended to break during dry periods. In most cases the condition of animals was poor and not market-ready because of emergency sales during droughts. This became a serious problem if farmers waited too long to reduce animal numbers.

Progeny was negatively affected during severe dry periods and this became evident only during the following lambing/calving season. Farmers reported a reduction in progeny of 10% to 50% during the following season depending on drought severity, the time of drought and individual mitigation actions.

Loss in genetic material due to “drought sales” can take years to be replaced. The average time to recover breeding stock after drought was three to five years.

Land sales as a result of drought were reported by a small number of farmers.

Only a few farmers reported **sales of non-farm assets** as a result of drought as a coping mechanism. Non-farm assets could be an excellent form of insurance against drought and should be promoted as a drought coping strategy.

Farmers had consensus that their income was reduced by at least 50% during most dry periods while extreme drought causes a reduction in net income of 100% to 200% for more than one season. They reported that it took them between three to five years to recover financially from a drought. Owing to the cut in maintenance expenditures during drought, infrastructure deteriorated and repair costs at a later stage became much higher.

8.1.1 Calculating Drought Loss

5.1.1.13 Mean Annual Loss (MAL)

Calculation of financial impact of droughts alone was not sufficient since probability and severity of different droughts were important and should be considered in the final calculation of drought impacts. According to the literature, calculation of Mean Annual Damage (MAD)[8] was, thus far, focused on flood and earthquake damages, but the same principles can be applied to drought with the use of SPI data (Viljoen, 2015). The calculation of mean annual loss (MAL) is a methodology to show the year-to-year impact of droughts on an enterprise or system. The exceedence probability for the different types of drought is known through the SPI calculation, and that provides the basis for the calculation of MAL. Using production data and the exceedence probability for droughts SPI<-1,5 and SPI<-2, one can calculate the mean MAL.

The mean annual loss (MAL) for a disaster (in this case drought) is predicted by calculating the area under the fixed line illustrated in Figure 8.1 (highlighted in blue) below (Viljoen *et al*., 1977; du Plessis & Viljoen, 1996; Booysen *et al*., 1999).

Apart from the social and environmental effects of drought the direct financial impact of drought was calculated by considering direct loss of income, probability and drought severity as follows:

$$MAL_m = \int_i^e L_{ij}\, dp$$

where: MAL_m = Mean Annual Loss for region m

and, L_{ij} = Annual drought loss with probability of dp of a greater loss and standard deviation, σD, given, by:

[8] du Plessis and Viljoen used the term mean annual damage (MAD) in their research on flood impacts but in the context of drought in this study MAD = MAL.

$$\sigma_D = \sqrt{\left(\int_1^0 (D_i - D_m\right)^2 dp}$$

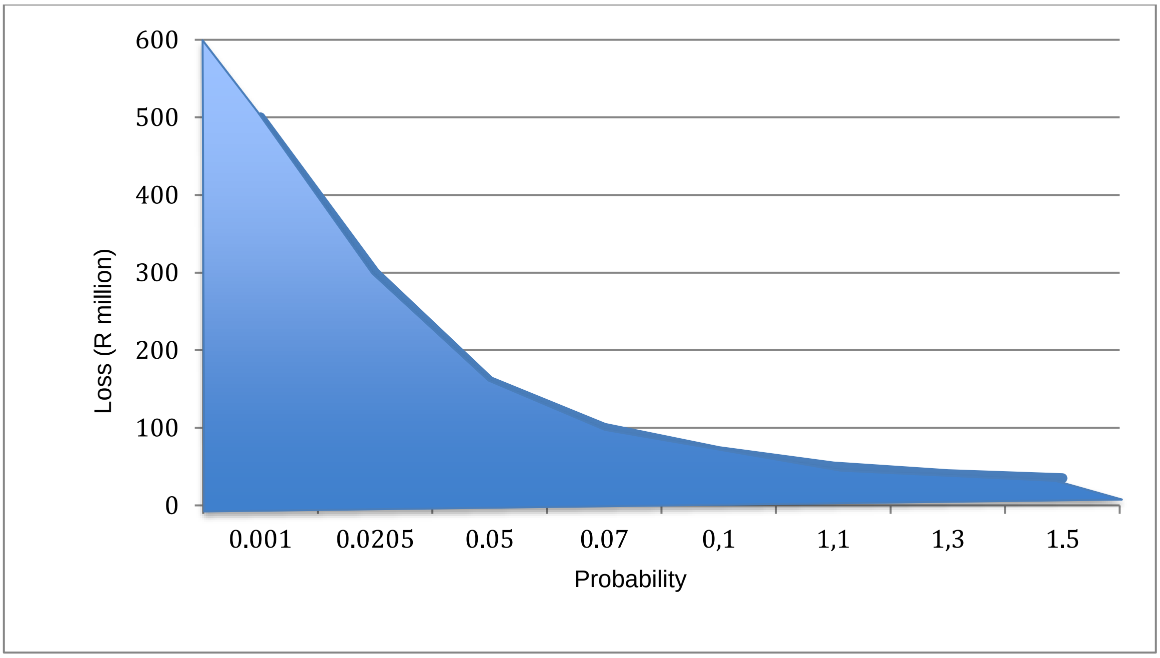

Fig. 8.1. Example of a Mean Annual Loss curve

The MAL is an average annual loss and differs from the total economic loss of a specific drought, for example the 1982-1983 or 1992-1994 drought. Hence, the MAL can be used to determine the yearly cost of drought and provide an indication of what can be spent annually to reduce the risk of drought. The benefit of the MAL is that farmers can budget accordingly and set aside reserve funds equal to or more than MAL or pay insurance premiums to the amount of MAL in order to have a reserve during droughts. The use of MAL for purposes of insurance premiums, however, is not as simple since tax benefits, for example, could influence the cost-benefit of such a scheme.

8.1.1.1 Loss functions

The loss function (or cost function) is a crucial ingredient in all optimizing problems such as statistical decision theory, policy making, estimation, forecasting, learning, classification, financial investment, etc. (Lee, 2007). Loss functions and MAL are particularly useful for the calculation of premiums for index insurance products. Loss functions are also important for the calculation of *ex-ante* drought impacts.

Frequently used loss functions include lin-lin, linex and quad-quad loss, which allow for asymmetries through a single shape parameter (Elliott & Timmermann, 2008).

Loss function L is defined by:

$$\mathcal{L}(p,\alpha,\theta) \equiv [\alpha + (1-2\alpha)\cdot 1(Y_{t+1} - f_{t+1}(\theta) < 0)] \cdot |Y_{t+1} - f_{t+1}(\theta)|^p,$$

where p ∈ N∗ , the set of positive integers, α ∈ (0, 1), θ ∈ Θ and Yt+1 − ft+1 corresponds to the forecast error ε_{t+1}.

We let α_0 and p_0 be the unknown true values of α and p used by the forecaster. Hence, the loss function in the equation above is a function of not only the realization of Y_{t+1} and the forecast f_{t+1}, but also of the shape parameters α and p of $\mathcal{L}$. Special cases of $\mathcal{L}$ include:

(i) squared loss function $\mathcal{L}(2, 1/2, \theta) = (Y_{t+1} - f_{t+1})^2$,

(ii) absolute deviation loss function $\mathcal{L}(1, 1/2, \theta) = |Y_{t+1} - f_{t+1}|$, as well as their asymmetrical counterparts obtained when $\alpha \neq 1/2$, i.e.

(iii) quad-quad loss, $\mathcal{L}(2, \alpha, \theta)$, and

$\mathcal{L}(1, \alpha, \theta)$

(iv) lin-lin loss, .

$$\min_{\theta \in \Theta} E[\mathcal{L}(p_0, \alpha_0, \theta)].$$

We let ε^*_{t+1} be the optimal forecast error, $\varepsilon^*_{t+1} \equiv y_{t+1} - f^*_{t+1} = y_{t+1} - \theta^{*\prime} w_t$, which depends on the unknown true values p_0 and α_0. Optimal forecasts have properties that follow directly from the construction of the forecasts.

8.1.1.2 Calculating SPI

It is relatively straightforward to calculate the Standard Precipitation Index (SPI) based on a normal distribution (Lloyd-Hughes & Saunders, 2002; Jenkins, 2011), using the following equation:

$$SPI = \frac{x_m - \hat{x}_m}{\sigma_m}$$

where X= precipitation value (observed or simulated) δ = Standard deviation

X^= precipitation mean (observed)

Before calculating the SPI it is necessary to check the normal distribution of the precipitation (mm) series data from 1981-2015 using a CDF (commutative distribution function), an expected value and the Z-value using the following equations:

CDF= 1/(2*n); (CDFi +2)/(2*n)……………….

where n= number of observations – 35 (1981-2015)

Expected value = NORM.INV(CDF, mean, standard deviation(sd))

Z-value = NORM.INV (CDF)

Precipitation in arid areas is not normally distributed and a more accurate method for SPI calculation was discussed in Chapter 4.

The test of the precipitation (mm) series indicated a normal distribution, and as a result the calculation of SPI is straightforward. Data from Aliwal North was used in the example calculation shown in Table 8.1.

The graph of Z-values against - perception (mm) and the expected value shows that the series of precipitation (mm) is normally distributed (Figure 8.2).

Table 8.1: Normality Distribution test of precipitation (mm)

Precipitation (mm)	CDF	Expected	Z- value
256	0.014286	159.9397	-2.18935
299	0.042857	252.6116	-1.71845
327	0.071429	302.4445	-1.46523
331	0.1	338.5928	-1.28155
372	0.128571	367.794	-1.13317
382	0.157143	392.7678	-1.00627
437	0.185714	414.9015	-0.8938
443	0.214286	435.0069	-0.79164
463	0.242857	453.6037	-0.69714
473	0.271429	471.0486	-0.6085
488	0.3	487.5989	-0.5244
501	0.328571	503.4488	-0.44386
504	0.357143	518.7509	-0.36611
505	0.385714	533.6288	-0.29051
513	0.414286	548.1864	-0.21653
578	0.442857	562.5143	-0.14373

585	0.471429	576.6936	-0.07168
589	0.5	590.8	2.78E-16
590	0.528571	604.9064	0.071679
602	0.557143	619.0857	0.143729
626	0.585714	633.4136	0.216534
629	0.614286	647.9712	0.290507
635	0.642857	662.8491	0.366106
638	0.671429	678.1512	0.443861
649	0.7	694.0011	0.524401
651	0.728571	710.5514	0.608498
678	0.757143	727.9963	0.697141
727	0.785714	746.5931	0.791639
755	0.814286	766.6985	0.893801
766	0.842857	788.8322	1.00627
791	0.871429	813.806	1.13317
809	0.9	843.0072	1.281552
976	0.928571	879.1555	1.465234
982	0.957143	928.9884	1.718452
1128	0.985714	1021.66	2.18935
590.8	Mean		
196.7983	SD		
35	Count (Number of observation)		

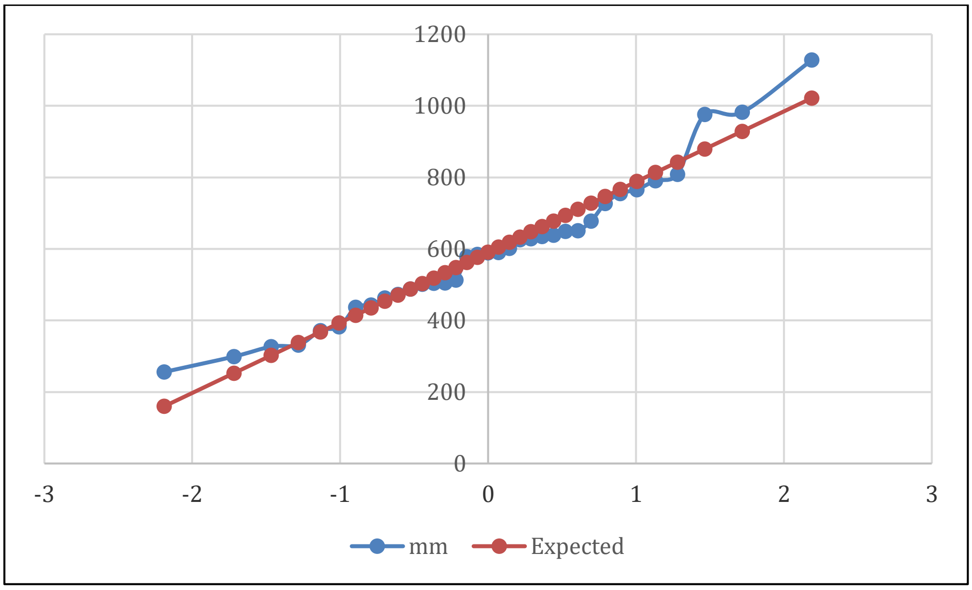

Fig. 8.2: Z-values against - perception (mm) and expected value

The resulting output of SPI values for a given precipitation data series is shown in Table 8.2.

A drought can be categorized based on its SPI value. The SPI can be used to establish a definition of drought, drought start and end dates and drought duration. For example, McKee *et al.* (1993) defined a drought event as a period in which the SPI was continuously negative and reached a value of -1.0 or less. In other words drought was defined as a period where negative SPI values could be identified. McKee *et al.* (1993), McKee *et al.* (1995), Hayes (1999) and Jordaan (2011) classified different droughts according to SPI values as follows:

- 0.0 to -0.99 mild drought
- -1.0 to -1.49 moderate drought
- -1.5 to -1.99 severe drought
- < -2.00 extreme drought

Table 8.2: SPI values of precipitation for Aliwal North (1981 – 2015)

Precipitation (mm)	SPI	Category		Drought magnitude
635	0.224595	Near Normal		-13.15661677
504	-0.44106	Near Normal	DRY	
513	-0.39533	Near Normal	DRY	
382	-1.06098	Dry	DROUGHT	
585	-0.02947	Near Normal	DRY	
589	-0.00915	Near Normal		
488	-0.52236	Near Normal	DRY	
1128	2.729698	Extremely moist	WET	
590	-0.00407	Near Normal		
299	-1.48274	Severely dry	DROUGHT	
976	1.957334	Severely moist	WET	
256	-1.70123	Severely dry	DROUGHT	
629	0.194107	Near Normal		
463	-0.6494	Near Normal	DRY	
505	-0.43598	Near Normal	DRY	
651	0.305897	Near Normal		
473	-0.59858	Near Normal	DRY	
649	0.295734	Near Normal		
331	-1.32013	Severely dry	DROUGHT	
638	0.239839	Near Normal		
809	1.108749	Moderately moist		
755	0.834357	Near Normal		
372	-1.1118	Severely dry	DROUGHT	
626	0.178863	Near Normal		
443	-0.75102	Near Normal	DRY	
982	1.987822	Severely moist		
578	-0.06504	Near Normal	DRY	

501	-0.4563	Near Normal	DRY
678	0.443093	Near Normal	
727	0.692079	Near Normal	
791	1.017285	Moist	
602	0.056911	Near Normal	
437	-0.78151	Near Normal	DRY
766	0.890252	Near Normal	
327	-1.34046	Severely dry	DROUGHT

*Drought magnitude is the sum of drought period.

Wool production for corresponding years were also analysed for Aliwal North. The normal distribution of wool production (kg) was tested and the results indicated that the wool production series was not normally distributed, as indicated in Figure 8.3. Annual wool production and precipitation for the period 1981 to 2015 is shown in Figure 8.3

Wool production was the only reliable set of time series data available. Wool and mohair production outputs were available per district. We also managed to obtain farm level time series data for precipitation and wool production from a few farmers.

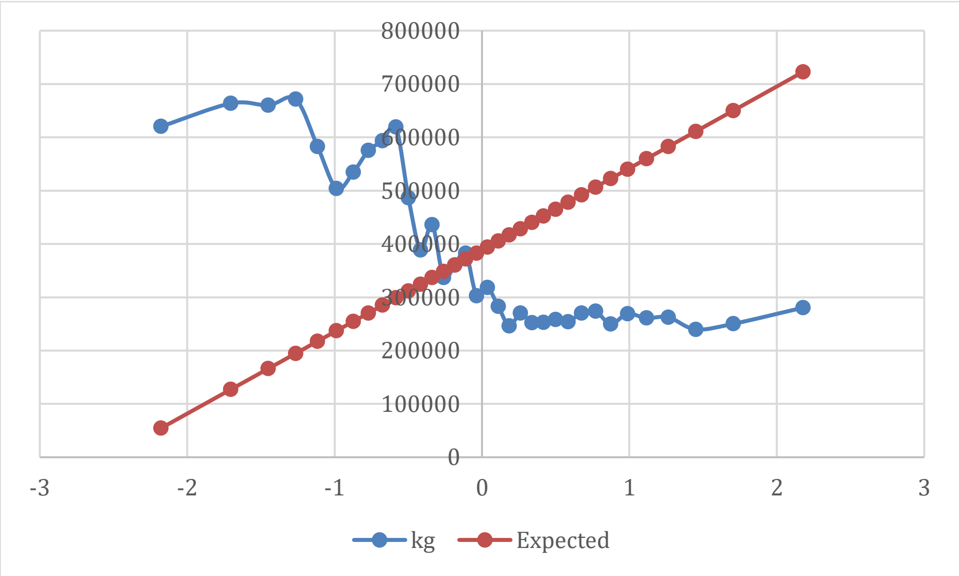

Figure 8.3: Z-values against – wool production (kg) and expected value

8.1.2 Correlating Precipitation and Wool Production

Before we tried to formulate the drought loss function, we undertook a correlation analysis and established that there was no correlation in all the data sets at both farm level and district level between:

- Total wool production and precipitation (CORREL = -0.10608)

- Wool production per SSU and precipitation (CORREL = 0.04358)
- Lag of production of wool and precipitation (CORREL = -0.08936)
- SPI and wool production (CORREL = -0.10608)
- SPI and lag of wool production (CORREL = -0.08936)

It was difficult to formulate the drought loss function if the variables are uncorrelated. We undertook an in-depth literature review and we found that there was a possibility of formulating the drought loss function even if the variables were uncorrelated. Taguchi (undated) adopted a squared-error loss function for several reasons.

Table 8.3: Precipitation, production and SPI for Aliwal North

Year	Precipitation (mm)	Production (kg)	SPI	Categories		Drought magnitude
1981	635		0.224595	Near Normal		-13.2
1982	504	620312	-0.44106	Near Normal	DRY	
1983	513	663561	-0.39533	Near Normal	DRY	
1984	382	660095	-1.06098	Severely dry	DROUGHT	
1985	585	671546	-0.02947	Near Normal		
1986	589	582452	-0.00915	Near Normal		
1987	488	504062	-0.52236	Near Normal	DRY	
1988	1128	534341	2.729698	Extra moist		
1989	590	575161	-0.00407	Near Normal		
1990	299	593375	-1.48274	Severely dry	DROUGHT	
1991	976	619109	1.957334	Severely moist		
1992	256	486818	-1.70123	Severely dry	DROUGHT	
1993	629	388847	0.194107	Near Normal		
1994	463	435949	-0.6494	Near Normal	DRY	
1995	505	337090	-0.43598	Near Normal	DRY	
1996	651	360510	0.305897	Near Normal		
1997	473	382731	-0.59858	Near Normal	DRY	
1998	649	302688	0.295734	Near Normal		
1999	331	318065	-1.32013	Severely dry	DROUGHT	
2000	638	282763	0.239839	Near Normal		
2001	809	246068	1.108749	Mod moist		
2002	755	270109	0.834357	Near Normal		
2003	372	252400	-1.1118	Severely dry	DROUGHT	
2004	626	253011	0.178863	Near Normal		
2005	443	258017	-0.75102	Near Normal	DRY	
2006	982	254301	1.987822	Sev moist		
2007	578	270259	-0.06504	Near Normal		
2008	501	273734	-0.4563	Near Normal	DRY	
2009	678	249924	0.443093	Near Normal		
2010	727	268991	0.692079	Near Normal		

2011	791	261030	1.017285	Mod moist	
2012	602	262434	0.056911	Near Normal	
2013	437	239931	-0.78151	Near Normal	DRY
2014	766	250233	0.890252	Near Normal	
2015	327	280440	-1.34046	Severely dry	DROUGHT

Even if there is room for improvement regarding methodological aspects, the results (Table 8.3) indicated that wool production was higher during dry seasons. Average wool production per annum for the period 1981 to 2015 was 388 540 kg with the average wool production for the 6 driest years being 431 866 kg per annum. Calculating the lag effect provided the same result, with production of 443 055 kg per annum for the 6 years following a dry season, which is also higher than the mean for the entire period.

Table 8.4: Precipitation and wool production for Willowmore

Year	Mm/yr	SPI	% Of normal	Wool yield (kg)	Classification
1981	441,0	1,77	174,4%	535671	
1982	210,0	-0,40	83,0%	457677	DRY
1983	211,0	-0,39	83,4%	342091	DRY
1984	66,5	-1,75	26,3%	323776	DROUGHT
1985	408,0	1,46	161,3%	312123	
1986	155,0	-0,92	61,3%	261666	DRY
1987	146,0	-1,00	57,7%	255437	DROUGHT
1988	172,4	-0,76	68,2%	275491	DRY
1989	275,5	0,21	108,9%	307305	
1990	110,5	-1,34	43,7%	366322	DROUGHT
1991	143,0	-1,03	56,5%	165929	DROUGHT
1992	158,5	-0,89	62,7%	232070	
1993	370,0	1,10	146,3%	162522	
1994	300,0	0,44	118,6%	188325	
1995	345,0	0,86	136,4%	191580	
1996	447,5	1,83	177,0%	166437	
1997	153,0	-0,94	60,5%	163526	DRY
1998	129,8	-1,16	51,3%	158073	DROUGHT
1999	122,6	-1,22	48,5%	138391	DROUGHT
2000	402,0	1,40	159,0%	157433	
2001	323,5	0,66	127,9%	148693	
2002	251,0	-0,02	99,3%	164043	
2003	207,0	-0,43	81,9%	183290	
2004	263,5	0,10	104,2%	232759	
2005	272,0	0,18	107,6%	223360	
2006	275,0	0,21	108,7%	248058	
2007	268,7	0,15	106,3%	230272	
2008	177,6	-0,71	70,2%	136758	DRY
2009	241,7	-0,11	95,6%	241316	DRY

2010	208,7	-0,41	82,5%	168543	DRY
2011	445,2	1,81	176,0%	226135	
2012	387,2	1,26	153,1%	234836	
2013	211,2	-0,39	83,5%	249747	DRY
2014	318,4	0,61	125,9%	248095	
2015	268,3	0,14	106,1%		
	252,9			238169	

The same results were evident for Willowmore (Table 8.4) and other districts. Mean wool yield for the six driest years in Willowmore was 234 655 kg, which is nearly the same as the long term average of 238 169 kg from 1981 to 2014. Pearson correlation analysis for precipitation and wool production was 0,0490, which is indicative of no correlation and it was therefore not possible to develop drought loss functions based on current data.

Farm level data were also tested for farms with both precipitation and wool production time series data. Data for a farm between Lady Grey and Barkley East are shown in Table 8.5.

Table 8.5: Precipitation and wool production for Lammermoor farm, Lady Grey district

Year	mm/yr.	SPI	% Of normal	Wool prod (kg)	Classification
1969	543,6	-0,40	88%	4800	DRY
1970	457,5	-0,88	74%	4203	DRY
1971	534,9	-0,45	87%	4940	DRY
1972	750,8	0,75	122%	4740	
1973	359,9	-1,42	58%	4787	DROUGHT
1974	1004,8	2,16	163%	5484	
1975	661,7	0,26	108%	5555	
1976	893,3	1,54	145%	6374	
1977	696,2	0,45	113%	6758	
1978	752,6	0,76	122%	6533	
1979	546,6	-0,38	89%	6140	DRY
1980	389,1	-1,26	63%	6981	DROUGHT
1981	671,3	0,31	109%	6975	
1982	573,8	-0,23	93%	8513	DRY
1983	483,4	-0,73	79%	8759	DRY
1984	397,8	-1,21	65%	9129	DROUGHT
1985	652,3	0,20	106%	9000	
1986	597,2	-0,10	97%	7049	
1987	537,5	-0,43	87%	8085	DRY
1988	1089,7	2,64	177%	9000	
1989	671,3	0,31	109%	10275	
1990	541,0	-0,41	88%	9693	DRY
1991	936,0	1,78	152%	10310	
1992	371,9	-1,35	60%	9472	DROUGHT

1993	609,3	-0,03	99%	10514	
1994	423,7	-1,07	69%	9463	DROUGHT
1995	606,6	-0,05	99%	8999	
1996	826,8	1,17	134%	9532	
1997	432,6	-1,02	70%	6973	DROUGHT
1998	847,6	1,29	138%	9049	
1999	492,8	-0,68	80%	8837	DRY
2000	579,4	-0,20	94%	8422	DRY
2001	877,8	1,46	143%	10011	
2002	754,9	0,78	123%	8869	
2003	457,7	-0,88	74%	9000	DRY
2004	706,6	0,51	115%	10112	
2005	538,0	-0,43	87%	9198	DRY
2006	898,4	1,57	146%	9427	
2007	385,3	-1,28	63%	9234	DROUGHT
2008	508,5	-0,59	83%	9431	DRY
2009	682,0	0,37	111%	9192	
2010	387,4	-1,27	63%	9232	DROUGHT
2011	762,5	0,82	124%	8617	
2012	531,1	-0,47	86%	9601	DRY
2013	468,6	-0,82	76%	9907	DRY
2014	644,9	0,16	105%	9148	
2015	391,2	-1,25	64%	8681	DROUGHT
Mean	615,5		Mean	8192	
Stdev	179,9		Mean	8372	DROUGHT

Mean wool production for the eight driest years were 8 372 kg with standard deviation 179,9 kg. Production for the eight driest years was higher than the mean of 8 192 kg for the entire period from 1969 to 2015. Pearson correlation analysis for precipitation and wool production was 0,0473, which was indicative of no correlation. Few farmers had reliable farm level data for wool production as well as precipitation. District level production, however, is the result of farm level production and was found to be sufficient for the analysis.

8.1.3 Conclusion and Recommendations

Calculations of MAL and the development of loss functions are particularly important to the insurance industry since they provides 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 should, however, 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 they 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, on the other hand, could use the MAL as a guideline on what they could afford in terms of premiums.

There was no correlation between precipitation and wool production and the null hypothesis was therefore rejected, namely that previous droughts impacted negatively on wool production. Important to note was that the additional inputs during dry years were not considered. The results were in contrast to the initial assumption of the research team and to what farmers believed. 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 a possible increase in the intensity and frequency of dry periods and droughts, wool sheep farming seems to be a resilient system with high potential as an adaptation strategy. Wool farmers in fact reported excellent income levels even during the 2015/16 drought and mentioned predators as the biggest threat to small stock farming and not droughts and dry periods. This concurred with the results of the Northern Cape drought risk assessment, where farmers also highlighted the threat of predators as a larger threat than droughts (Jordaan, 2011).

Reasons for the unexpected result could be the following:

- Wool sheep have, over time, been traditionally better adapted to more arid regions.
- Most farmers sold lambs and weaker animals at the onset of drought and increased the care of higher quality producers during dry periods. That could have led to a higher average yield per SSU (although this does not explain higher or normal total production).
- Farmers took special care of the remaining high yield producers during dry periods and provided a more balanced feeding ration to animals.
- Wool was normally finer during dry periods with a resultant lighter fleece per SSU and in spite of this no change in production was detected. The special care given to high producers during dry periods might explain this.

The best way to develop loss functions is to consider the entire production process since farmers in fact maintained normal production through higher inputs. Additional research should thus consider all additional inputs during dry periods. It is therefore important to analyse financial production data of the different systems. The lack of historical data remains a challenge and modelling of expected income and outputs might resolve this challenge. We now only know that total wool yield is not affected by drought, but at what overall cost? This should be determined.

Loss Function for Maize Production

8.1.4 Introduction

Commercial agriculture in the Eastern Cape study area 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. A summary of some crops and livestock produced in the EC is shown in Table 8.6.

Table 8.6: Production of crops and livestock in the Eastern Cape

	Total SA (t where relevant)	EC production (t where relevant)	% 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

According to data derived from the Abstract of Agricultural Statistics (DAFF, 2012), crop production in the EC contributes little, at less than 1% of the 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 produces about 25% of the milk supply of SA (ECDC, 2009).

Maize is a strategic crop and its production and the potential for future maize production in Joe Gqabi and OR Tambo is important. It was therefore selected for further analysis. Because it is a staple food in SA the development of crop loss functions for maize is thus important. The 2015/2016 drought in SA again highlighted the importance of maize production in SA, and many believe that the eastern parts of Joe Gqabi district, most of OR Tambo district and parts of the Chris Hani district have suitable climates and soils for maize production.

Loss functions have been developed and are available for maize production under irrigation. The development of drought loss functions for maize production under dry land conditions is important in that the farming sector would be able to easily calculate the impact of different types of drought. Important for maize production is the timing of drought and the use of the 12-month SPI does not have the same impact on crop production as is the case with grazing and the livestock sector. The 3-month and 6-month SPI is of greater value for the purpose of maize production.

Important variables for drought loss functions for maize were meteorological data, soil type, soil depth (which together can be expressed as soil potential) and yield. In order to develop MAL and loss functions, historical data for precipitation and yield per ha were required for different types of dry periods. The timing of precipitation was also important and had to be considered.

Availability of historical data again was be the biggest stumbling block for this research. Both maize production data and daily rainfall was required for the same farm or region. Maize production was not the main agricultural activity in the study areas and most of the maize farmers did not have historical yield records together with historical precipitation data in order to determine the impact of dry years on production. Data were available from a few farmers only from 2006 when farmers started with precision agriculture, but not sufficient dry years were included in the data to be of any use.

8.1.5 Modelling of Maize Loss Functions

Out of desperation (because of a lack of data) the research team decided to investigate the possibility of using the SAPWAT3®[9] model as a tool for maize yield estimates and the long term potential yield for maize. SAPWAT3 was developed with WRC funding and is a computer programme for the estimation of crop irrigation requirements and for the planning of water requirements by Water User Associations. SAPWAT3 was developed to satisfy a need for a user-friendly and credible aid for the (i) estimation of crop irrigation requirements, (ii) for the planning of irrigation schemes and (iii) for water management by Water Users Associations (WUA) that plan for development in irrigation practice and management. SAPWAT3 was not originally designed as a tool for dry land crop yield estimates. After consultations with the developer, van Heerden[10], we decided to adjust and test the programme for dry land conditions.

A few adjustments were required on the programme software, which were undertaken by van Heerden. The results for maize production were tested with dry land maize farmers in a few catchments in the Joe Gqabi district. Feedback from farmers convinced the research team that the SAPWAT3 model can be adjusted for dry land use as well. The potential application of the SAPWAT3 programme for production planning under dry land conditions could be immense. The input variables currently required are catchment, soil moisture content at beginning of season (RAW), soil depth and potential yield. The programme then calculates the potential yield loss based on the long term mean climate data for the specific catchment. Modelling potential yield based on SAWS' seasonal forecast would then allow farmers to adjust inputs accordingly.

The results for selected catchments are shown in Table 8.7. Projected crop losses varied from 11% to 47%, with potential yields ranging from 3,7 ton/ha to 9 ton/ha. The RAW value was set at 75% in all cases. The practical application of the SAPWAT3 model is in the potential of the model to plan for dry and wet seasons. For example: Farmer A received the seasonal forecast from SAWS to expect a below normal rainfall during the growing season. His RAW value (soil moisture content prior to planting) is 60%. Farmer A now adjusts his soil potential (soil depth) according his own conditions, "penalises" the meteorological data for his catchment by a specific percentage (depending on the severity of the seasonal weather forecast) and calculates the potential yield and water stress periods for maize. Based on the results Farmer A can then make an informed decision on risk planting or to adjust the potential yield downwards in order to minimize water stress during the growing season.

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[9] Since the date of research SAPWAT3 has been updated to an improved SAPWAT4 version.
[10] Project leader; SAPWAT product development

Farmer B, on the other hand, might have a high RAW of 80% with a seasonal forecast of above normal rainfall. He can then calculate potential yield and adjust plant density and fertilization accordingly.

Selected catchments are shown in Figure 8.4. Selection of these catchments was based on data from Schulze (2006) that identified the selected catchments as medium to high potential catchments for crop production.

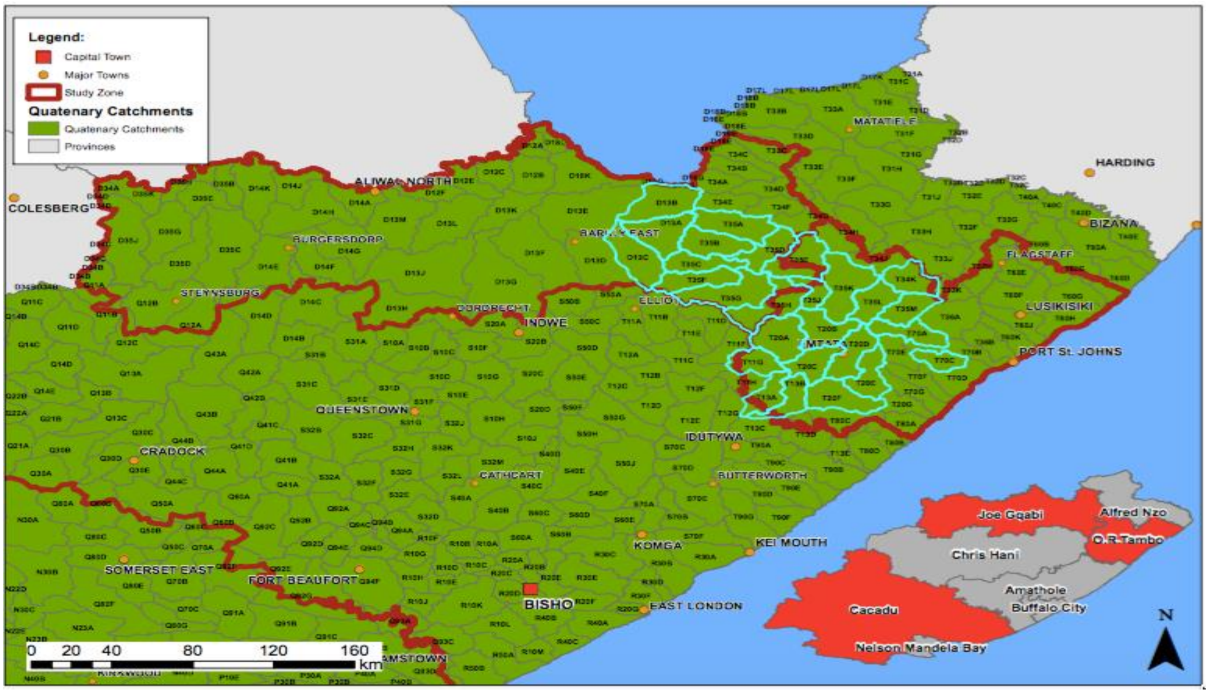

Fig. 8.4: Selected quaternary catchments for SAPWAT calculations

The results obtained with the SAPWAT modelling (Table 8.7) supported production potential for maize as illustrated by Schulze (2006) in Figure 8.5. We therefore expected to make minor adjustments to the current model. Important, however, is to develop the SAPWAT model as a decision support tool that considers expected seasonal trends and rainfall patterns.

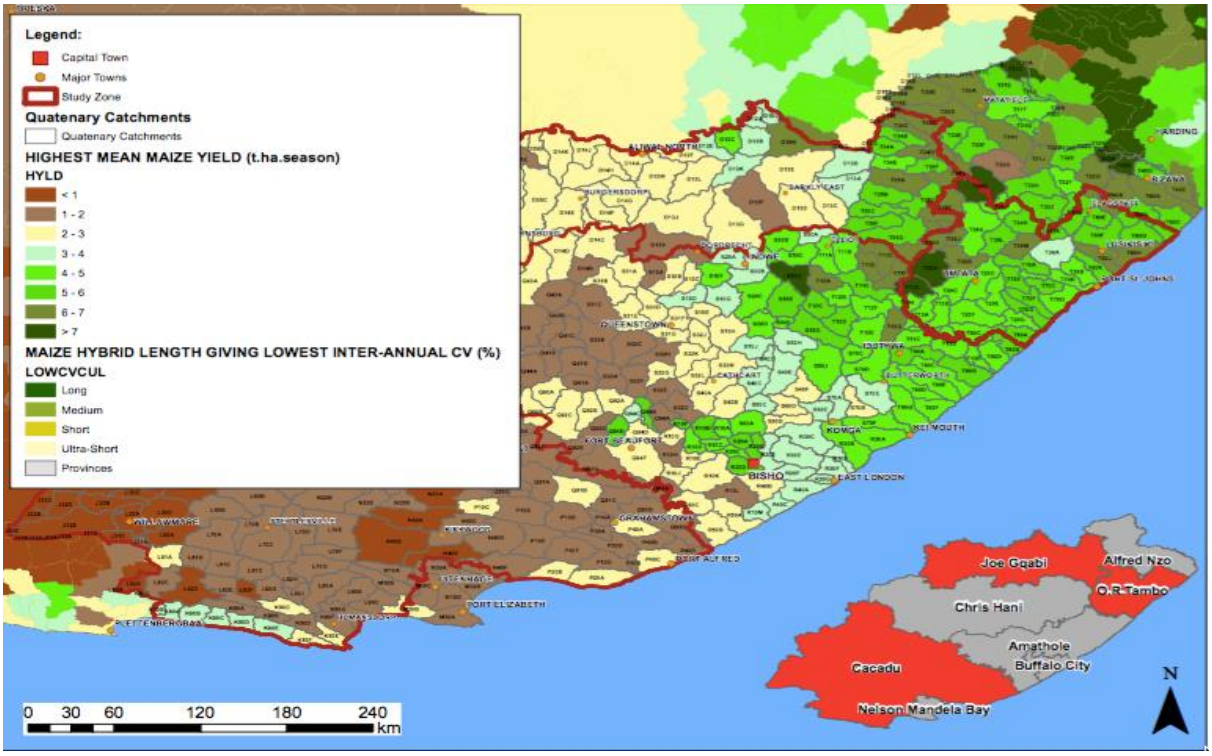

Fig 8.5: Expected maize yield potential
Source: Schulze, R.E. 2006.

Based on the modelled results from SAPWAT3, tests for correlation were done for precipitation and maize yield. Result shows a PEARSON correlation of 0,66, which was indicative of a strong positive correlation between precipitation and yield. Regression analysis was also done with yield being the dependent variable and seasonal precipitation as the independent variable. The result, in kg/ha, was:

$$Y = 1091{,}6\ln(x) + 4912{,}4$$

with $R^2 = 0{,}4742$

A loss function graph of the two variables is illustrated in Figure 8.6.

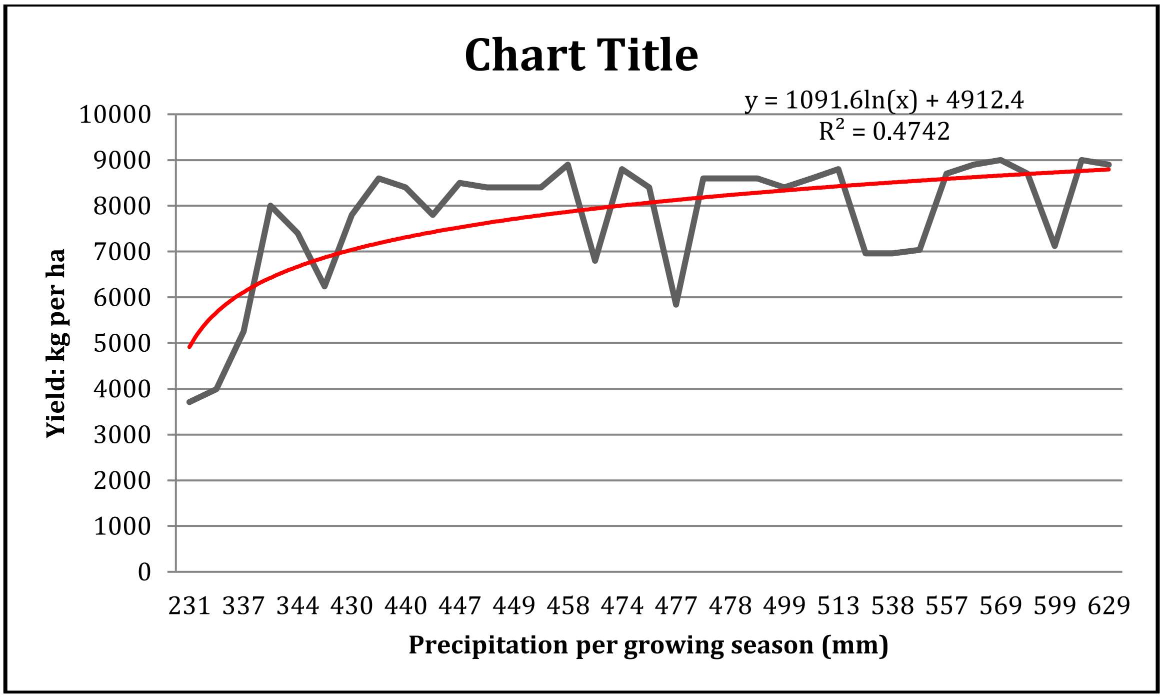

Fig. 8.6: Regression analysis yield vs. seasonal precipitation

The results clearly showed a dramatic drop in yield with seasonal precipitation of less than 400 mm. Table 8.7 shows results of SAPWAT modelled results for different catchments.

Table 8.8 is a summary of potential yields and yield losses per catchment as modelled by the SAPWAT3 programme. According to the model the catchments with the highest potential are D13B, D13E, D13K, D13F, D13C, D13G, D13D, D13H, T33C, T35A, T35D, T34J, T35C, T20B, T20A, T20D, T70E, T20C, T11G, T11H, T13A, T13B and T20F at 10 ton/ha. The catchment with the highest yield per ha after modelling of moisture stress and sensitivity analysis is T35D with only a 10% loss and a yield of 9,45 ton/ha. Other catchments with high yields are D13B, T35A, T20A and T11G with net yield after potential losses of 9,345 ton/ha. The catchment with the highest potential loss in tons/ha is T35B where the modelled loss is 47% or 3,105 ton/ha. The catchment with the lowest yield loss is T70F with only 0,524 ton/ha.

Table 8.7: SAPWAT modelling of dry land maize production for selected quaternary catchments

QUAT	Hectares	Moist RAW	Pot yield (tons)	%Loss	Yield/ha	Total yield	Crop evap (mm)	Transpir (mm)	Evapor (mm)	Rainfall (mm)	Effective rainfall (mm)	Rainfall use efficiency (%)	Change in soil water content (mm)
D12A	37830,49	75%	8	22%	6,24	0	402	356	46	363	331	91%	-88
D13B	53589,81	75%	10	11%	8,9	0	444	393	51	458	405	88%	-98
D13E	105075,73	75%	10	14%	8,6	0	464	412	52	478	411	67%	-75
D13M	64161,98	75%	7	25%	5,25	0	393	355	38	337	314	93%	-76
D13K	41352,75	75%	10	16%	8,4	0	445	392	53	449	388	86%	-61
D13F	95510,79	75%	10	16%	8,4	0	445	392	53	449	388	61%	-61
D13C	51151,81	75%	10	16%	8,4	0	429	384	45	440	375	85%	-98
D13G	112139,96	75%	10	22%	7,8	0	457	409	48	430	377	88%	-98
D13D	62185,23	75%	10	22%	7,8	0	443	395	48	440	377	88%	-98
D13J	115148,68	75%	10	26%	7,4	0	396	356	40	344	315	92%	-98
D13H	113968,06	75%	10	20%	8	0	375	337	38	340	316	93%	-66
T33C	37078,16	75%	10	13%	8,7	0	522	467	55	557	466	81%	-83
T35A	47076,91	75	10	11%	8,9	0	540	476	64	629	492	78%	-68
T35B	45670,35	75%	7	47%	3,71	0	352	328	24	231	221	96%	-95
T35D	17905,8	75%	10	10%	9	0	552	466	56	569	479	84%	-98
T35E	49072,45	75%	7	43%	3,99	0	355	328	37	241	232	96%	-97
T32H	45544,21	75%	8	13%	6,96	0	504	437	67	519	451	87%	-47
T34J	29774,62	75%	10	14%	8,6	0	482	430	52	479	428	51%	-72
T35C	42456,9	75%	10	13%	8,7	0	522	467	55	570	466	81%	-83
T20B	40883,31	75%	10	12%	8,8	0	496	437	59	513	448	81%	-50
T20A	47887,44	75%	10	10%	9	0	542	473	69	620	500	81%	-47
T70A	31511,01	75%	10	16%	8,4	0	461	403	58	499	404	81%	-98
T20D	35453,78	75%	10	16%	8,4	0	448	389	50	450	395	55%	-97
T70E	23066,75	75%	10	12%	8,8	0	447	390	57	474	403	85%	-98
T70B	27406,8	75%	8	27%	5,84	0	401	335	66	477	314	68%	-90
T20E	34701,49	75%	8	15%	6,8	0	453	398	55	466	400	86%	-35

T20C	34809,74	75	10	14%	8,6	0	437	388	49	430	389	41%	-97
T11G	28967,97	75%	10	11%	8,9	0	537	472	65	568	491	86%	-88
T70C	29240,68	75	8	13%	6,96	0	480	421	59	538	430	80%	-98
T70F	26076,71	75%	8	11%	7,12	0	514	448	68	599	470	78%	-97
T70G	27217,8	75	8	12%	7,04	0	476	416	60	553	432	78%	-97
T11H	15257,01	75%	10	14%	8,6	0	462	409	53	477	409	86%	-92
T13A	26898,8	75%	10	14%	8,6	0	472	419	53	501	491	84%	-91
T13B	29504,01	75%	10	16%	8,4	0	457	404	53	475	399	84%	-92
T20F	44791,55	75	10	15%	8,5	0	453	399	54	447	399	89%	-97

Table 8.8: Expected yield loss per ha and per catchment

QUAT	Hectares	Moist RAW	Pot yield (tons)	% Loss	Yield/ha	5% (sensitivity analysis)	Yield/ha/sensitivity	Total yield	Yield loss (tones)	Total yield after sensitivity
D12A	37830,49	75%	8	22%	6,2	0,31	6,51	234549,038	1,49	246276,4899
D13B	53589,81	75%	10	11%	8,9	0,445	9,345	476949,309	0,655	500796,7745
D13E	105075,73	75%	10	14%	8,6	0,43	9,03	903651,278	0,97	948833,8419
D13M	64161,98	75%	7	25%	5,25	0,2625	5,5125	336850,395	1,4875	353692,9148
D13K	41352,75	75%	10	16%	8,4	0,42	8,82	347363,1	1,18	364731,255
D13F	95510,79	75%	10	16%	8,4	0,42	8,82	802290,636	1,18	842405,1678
D13C	51151,81	75%	10	16%	8,4	0,42	8,82	429675,204	1,18	451158,9642
D13G	112139,96	75%	10	22%	7,8	0,39	8,19	874691,688	1,81	918426,2724
D13D	62185,23	75%	10	22%	7,8	0,39	8,19	485044,794	1,81	509297,0337
D13J	115148,68	75%	10	26%	7,4	0,37	7,77	852100,232	2,23	894705,2436
D13H	113968,06	75%	10	20%	8	0,4	8,4	911744,48	1,6	957331,704
T33C	37078,16	75%	10	13%	8,7	0,435	9,135	322579,992	0,865	338708,9916
T35A	47076,91	75	10	11%	8,9	0,445	9,345	418984,499	0,655	439933,724

T35B	45670,35	75%	7	47%	3,71	0,1855	3,8955	169436,9985	3,1045	177908,8484
T35D	17905,8	75%	10	10%	9	0,45	9,45	161152,2	0,55	169209,81
T35E	49072,45	75%	7	43%	3,99	0,1995	4,1895	195799,0755	2,8105	205589,0293
T32H	45544,21	75%	8	13%	6,96	0,348	7,308	316987,7016	0,692	332837,0867
T34J	29774,62	75%	10	14%	8,6	0,43	9,03	256061,732	0,97	268864,8186
T35C	42456,9	75%	10	13%	8,7	0,435	9,135	369375,03	0,865	387843,7815
T20B	40883,31	75%	10	12%	8,8	0,44	9,24	359773,128	0,76	377761,7844
T20A	47887,44	75%	10	10%	9	0,45	9,45	430986,96	0,55	452536,308
T70A	31511,01	75%	10	16%	8,4	0,42	8,82	264692,484	1,18	277927,1082
T20D	35453,78	75%	10	16%	8,4	0,42	8,82	297811,752	1,18	312702,3396
T70E	23066,75	75%	10	12%	8,8	0,44	9,24	202987,4	0,76	213136,77
T70B	27406,8	75%	8	27%	5,84	0,292	6,132	160055,712	1,868	168058,4976
T20E	34701,49	75%	8	15%	6,8	0,34	7,14	235970,132	0,86	247768,6386
T20C	34809,74	75	10	14%	8,6	0,43	9,03	299363,764	0,97	314331,9522
T11G	28967,97	75%	10	11%	8,9	0,445	9,345	257814,933	0,655	270705,6797
T70C	29240,68	75	8	13%	6,96	0,348	7,308	203515,1328	0,692	213690,8894
T70F	26076,71	75%	8	11%	7,12	0,356	7,476	185666,1752	0,524	194949,484
T70G	27217,8	75	8	12%	7,04	0,352	7,392	191613,312	0,608	201193,9776
T11H	15257,01	75%	10	14%	8,6	0,43	9,03	131210,286	0,97	137770,8003
T13A	26898,8	75%	10	14%	8,60	0,43	9,03	231329,68	0,97	242896,164
T13B	29504,01	75%	10	16%	8,4	0,42	8,82	247833,684	1,18	260225,3682
T20F	44791,55	75	10	15%	8,5	0,425	8,925	380728,175	1,075	399764,5838

8.1.6 About SAPWAT

The SAPWAT model has immense potential for application under dry land conditions. Application of precision agriculture provided more accurate data and one can link SAPWAT to precision agriculture systems. SAPWAT could provide much more than just drought loss functions. SAPWAT has the potential as a decision support tool with consideration of climate variability. A few adjustments are required to the software and one should ground-truth the results. Precision agriculture is applied by only a handful of farmers in the study area, but their records did not cover more than one drought, which is too little for time series analysis.

We propose more research on the SAPWAT model for application under dry land conditions.

Conclusion

Development of drought loss functions for the livestock sector remains a challenge considering the large number of variables to be accounted for. Owing to limitations on data availability the research team decided to use wool production as the dependent variable for production output and rainfall as the independent variable. Data at farm level and at district level were analysed, with the same result in that no correlation was found between the two variables. The result was surprising and was in contrast to the perception of most farmers of lower wool production during dry years. In fact the results showed a higher than average production during the driest years with SPI <-1. The *"unexpected result"* was significant in that it was an indication of a well-adapted production system to dry conditions. Considering climate change projections of drier climate and possibly longer dry periods, the wool production system should be supported as a well-adapted system for both smallscale communal farmers and commercial farmers.

In order to develop loss functions for the livestock sector, one needs to consider the additional inputs as well. The increased spending on additional feed and fodder during dry periods must be considered. Analysis of income and expenditure is therefore the best way to develop loss functions. Data availability will remain the biggest challenge.

Development of loss functions for maize production was equally challenging in the absence of reliable historical data. We 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 SAPWAT3 programme was adjusted for use for dry land conditions. The research team realised the potential of the SAPWAT3 model as a decision support tool for dry land crop production. After a few adjustments to the software we could calculate and demonstrate the use of the SAPWAT model. More work is still required to ground truth the results and to adapt the model fully for dry land applications.

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9 Drought Indicators for South Africa

Jordaan, A.J, Makate, D., Mashego, T., Ligthelm, M., Malherbe, J., Mwaka, B., Olivier, W., Symington, W. & van Zyl, K [11].

Executive Summary

Drought classification and the application of drought indicators are essential elements in drought management and drought monitoring. Drought classification is based on certain indicator thresholds and provides a framework for drought management. The drought classification, indicator selection and indicator thresholds discussed in this report are the result of research completed as part of this project as well as inputs from the expert committee on drought indicators – a sub-committee tasked by the National Drought Task Team to develop and finalize the drought categories and indicators for South Africa.

Drought is 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 are classified as primary indicators, which are easy to monitor on a daily basis, and secondary indicators, which focus more on drought impacts. Primary indicators are categorized as meteorological indicators, agricultural indicators, which are remotely sensed, and hydrological indicators. Thresholds are proposed for all the indicators, but the differences between different sectors such as small-scale communal farmers and commercial farmers are highlighted.

This chapter provides a guide for drought indicators for 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, utilise 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 as a result of this research. This can be expanded in future. The National Drought Task Team of South Africa accepted the proposed indicators as a good start and we expect the Department of Agriculture, Forestry and Fisheries (DAFF) to formalize the use of these indicators for all of South Africa.

[11] With inputs from the DAFF specialist working group on drought indicators. National Drought Task Team.

Introduction

When to declare a drought a disaster remains one of the most debated issues in the field of disaster management. The 2015/2016 drought in South Africa is another example that illustrates the need for quantifiable indicators for drought classification and declaration. Five out of the nine provinces in South Africa declared the drought as provincial disasters, yet it was never declared a national disaster in spite of the fact that the Disaster Management Act (Act 57 of 2002 and amended Act 16 of 2015) stipulates that a national disaster can be declared once more than one province is affected by drought or a disaster. The reasons provided by the National Disaster Management Centre (NDMC) for the non-declaration of a national drought disaster is not convincing and does not consider the impact of the drought on the South African economy. Our supposition is that the NDMC does not have the capacity to manage a drought disaster of the magnitude of the 2015/2016 drought; responsibilities were therefore delegated to the provinces.

The declaration of drought disasters and the way in which government responded to droughts is amongst the most important contributors to increased resiliency if it is handled correctly, but the lack of efficient relief causes increased vulnerability. Both the commercial and communal farming sectors are highly susceptible to the negative impacts of drought and so is the economy at large. The outcomes of this research clearly highlighted the importance for drought indicators that are quantifiable, easy to measure and understand, transparent and all-inclusive; implying that one should be able to measure the hazard as well as the impact of a drought.

Indicators for Drought Classification and Disaster Declaration

Drought disaster declaration is linked to drought classification, yet this research, as well as previous research done by Jordaan (2011), highlighted the difference in disaster thresholds for the different agricultural sectors. Communal farmers, for example, experienced normal dry periods as disaster droughts because of land degradation and overgrazing, the lack of alternative resources, poor management and numerous other reasons. The threshold for a disaster drought in the case of communal farmers is therefore not the same as thresholds for the commercial farming sector. Different agricultural systems also require different thresholds and different indicators. Dry periods during the months September to February can have a disastrous effect on the maize industry while the livestock sector might experience the same dry period as a mild drought; therefore the need for different thresholds and different indices for different systems. A “*one-fit-all*” indicator and threshold selection is not possible.

9.1.1 Drought Classification

The different types of drought are linked to the different indicators, with the primary indicators as follows:

- **Meteorological drought:** Meteorological indicators such as percentage of rainfall and the Standard Precipitation Index (SPI) or the Standard Precipitation Evaporation Index (SPEI).
- **Agricultural drought:** Remote sensing satellite indices such as the Vegetation Condition Index (VCI) and the percentage of Average Seasonal Greenness (PASG). Measurement of agricultural droughts is also done through secondary indicators such as actual veld condition, grazing reserves, drinking water, and animal and crop condition.
- **Hydrological drought:** Actual measurements of dam levels, streamflow and groundwater levels are used to measure hydrological drought.
- **Socio-economic drought** is only measureable through secondary indicators such as impacts on individual farmers and the regional and larger economy.

The drought classification and drought declaration system proposed in this chapter is based on best practice from leading countries with drought management plans such as the USA, Mexico and Australia. For the purpose of drought classification the proposed classification is aligned with the United States and Mexico classifications. Together with Australia, these are currently amongst the countries with formal drought plans. The proposed drought classification is illustrated in Table 3.1. The different drought categories are:

- D0 Dry:
- D1 Moderate drought
- D2 Severe drought
- D3 Extreme drought
- D4 Exceptional drought

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 sections (economic, social, environment) needs to be linked to the *"hazard"* or the lack of sufficient amounts of water, which are indicated through the different indices (Wilhite *et al.,* 1997; Du Pisani *et al*., 1998; Wilhite, 2000; Wisner *et al.,* 2004, Jordaan, 2011). 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.

The description of the drought categories with potential impacts is discussed in Table 9.1

Table 9.1: Drought categories

Category	Description	Potential impacts

D0	Dry	Going into drought:
		• Short term dryness
		  ○ Limiting planting conditions
		  ○ Limiting growth of crops or pastures
		  ○ Smaller farm dam levels lower than usual
		  ○ Some springs stop flowing
		Coming out of drought:
		• Some lingering water deficits
		• Pastures and crops not fully recovered
		• *"Green drought"* with young vegetation growth on pastures
		•

D1	Moderate drought	• Some damage to crops • Streams, reservoirs or wells low • Some water shortages developing or imminent • Voluntary water restrictions requested • Soil moisture deficit for planting crops • Grazing conditions start deteriorating • Animals start showing feeding stress
D2	Severe drought	• Crop and pasture losses likely • Water shortages are common • Water restrictions imposed • Grazing conditions deteriorated • Animals show serious feeding stress • Groundwater levels going down at selected places • Disaster drought declaration imminent and required for certain sections of society
D3	Extreme drought	• Major crop and pasture losses • Severe shortages in natural grazing • Some sales of productive assets • Widespread water shortages • Groundwater levels very low • Negative impact on regional economy • Disaster drought declaration required • Not enough feed and fodder for animals • Animals lose condition
D4	Exceptional drought	• Exceptional and widespread crop and pasture losses • Major sales of productive assets • Forced liquidation of farming enterprises • Shortages of water in reservoirs, streams and wells creating water emergencies • Boreholes dried up with extremely low groundwater levels • Rivers dried up • Potential food insecurity • Widespread economic impact - Impact on national economy • Disaster drought declaration required with extreme response and recovery actions

The United States Drought Monitor is probably the most developed drought monitor system in the world and they made the following statement: *"This is what makes the U.S. Drought Monitor unique. It is not a model. The USDM relies on experts to synthesize the best available data from multiple sources and work with local observers to localize the information as much as possible. Numeric inputs are many: the Palmer Drought Severity Index, the Standardized Precipitation Index, and other climatological inputs; the Keech-Byram Drought Index for fire, satellite-based assessments of vegetation health, and various indicators of soil moisture from data assimilation systems and other* *models; and hydrologic data, particularly in the West, such as the Surface Water Supply Index and snowpack"* (USNDMC, 2016).

The different drought types are illustrated in Figure 9.1 as follows:

- **Meteorological drought** is characterized by below normal rainfall and high temperatures and is the main initiator of drought, starting from D0 up to D4, with the end of the meteorological drought characterized by normal or above normal rainfall.
- **Hydrological drought** is represented by streamflow, reservoir levels and groundwater levels and is normally associated during drought categories D1 to D4, but the end of the hydrological drought coincides with the onset of good rainfall when drought categories changed from D3 to D2 and lower, and when reservoir levels and streamflow are on the rise.
- **Agricultural drought** is characterized by vegetation and crop stress. The onset of vegetation stress is already visible during D1 and it becomes worse as drought conditions develop to D4. Agricultural drought, however, continues to prevail long after the onset of first rains since vegetation and crops do not recover immediately. In many cases agricultural drought is characterized by a *"green drought";* that is when natural grazing is visibly green, but plant growth is not sufficient to provide sufficient grazing for animals. This is also the period when natural vegetation is at its most sensitive and livestock owners should limit grazing of such vegetation.
- **Socio-economic drought** is the final and most severe type of drought. That is the phase when dry conditions impact on the social and economic well-being of individuals, institutions and the government at large. The onset of socio-economic drought is normally during the transition from D2 to D3, but the impact is visible long after the end of a dry period and is measurable up to 4 and 5 years after D4 or exceptional droughts.

Drought is a slow onset disaster with long term consequences. The first rain during a D3 and D4 drought might end the meteorological drought, but not the agricultural drought and especially not the socio-economic drought. The end of the hydrological drought also only occurs during the fill-up of the reservoirs and increased streamflow. The de-classification of droughts therefore need to consider the lag effect of a particular drought. For example, grass can take 2 months to recover after the first rains and the socio-economic impact of drought are normally felt two years after the drought and in the case of D3 and D4 drought the impact can still be seen on average five years after the drought. Livestock farmers reported that in the case of D4 drought most farmers do not recover fully, especially when they have to sell breeding stock and when they lack the necessary resilience to withstand such a drought. In such cases government safety nets must be activated to support the agricultural sector. The 1992/93 drought is such an example where the South African Government supported the agricultural sector and Agricultural Cooperatives on a large scale.

The different drought categories and durations of different types of drought is illustrated in Figure 9.1.

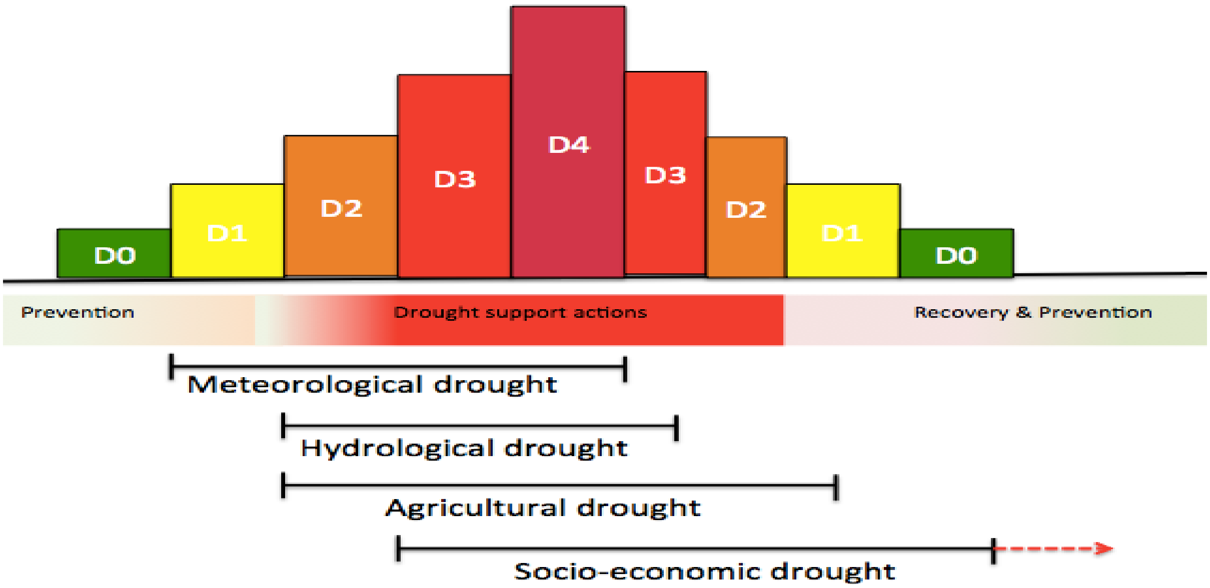


Fig. 9.1: Illustration of drought classifications

Disaster drought declaration is imminent during drought phase D2. During D2 the communal agricultural sector might already require external assistance. Disaster drought declaration is required for phases D3 and D4. Drought phase D4 might require extreme response and recovery measures in order to secure long term sustainability of the agricultural sector. Towns and some communities might be without drinking water and government at all levels should impose extreme water restriction measures and initiate activities to supply daily water requirements.

Important for the determination of different drought categories are the indicators and thresholds to measure the different droughts. The following section deals with drought indicators and also highlights the indicators and thresholds proposed for South Africa drought monitoring.

Drought Indicators

Drought indicators are classified as primary and secondary drought indicators. The primary indicators are those indicators that are easy to monitor using meteorological data, satellite images and gauging stations, while the secondary indicators require actual field visits to the affected area. It became clear from the literature that not one single drought index fitted all needs to determine the different types of droughts.

The finalization of the drought indicators discussed in this report followed a process of consultative meetings between Agri SA, the Department of Water and Sanitation (DWAS) and the Agricultural Research Council (ARC) under the chairmanship of DAFF. All parties involved in the development of the drought indicator document agreed that it was work in progress and the guidelines and indicators for drought declaration would be adjusted as we obtain more insight into especially the different thresholds. One of the major gaps identified are the thresholds for different types of drought and when a dry period becomes a drought, since these thresholds are not the same for all sectors due to the inherent differences in vulnerability and/or resiliency to drought.

The following section is, in some parts, a direct duplication of the DAFF document: "*Drought Hazard Indicators"* and explains also different thresholds. For the purpose of drought management in South Africa, the drought hazard indicators are classified as primary and secondary indicators. The primary indicators are mostly linked to *meteorological data, hydrological data through gauging* and *remote sensing*. These indicators are quantitative and it is possible to monitor drought hazard in real time. The idea with primary indicators is that continuous monitoring will take place and once certain thresholds are reached, drought classification can take place based on the thresholds, and evaluation of secondary indicators are then activated. The secondary indicators serve to *"ground-truth"* the impact of the dry period.

Primary Drought Hazard Indicators

Meteorologists and other specialists have developed numerous indicators for drought, yet none of these satisfied the need under all conditions. Examples of these, in no specific order, are (i) 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) PUTU suite of plant models (Fouche *et al*., 1985; Fouche, 1992), (vi) Rainfall Anomaly Index (Van Rooy, 1966), (vii) relative drought resistance method (Roux, 1993), (viii) rainfall deciles method (Erasmus, 1991), (ix) Roux expert system (Roux, 1991), (x) surface water supply index, SWSI (Shafer & Dezman, 1982), (xi) reclamation drought index, (xii) deciles (Gibbs & Mather, 1967), (xiii) Standard Precipitation Index, SPI (McKee *et al.,* 1993), (xiv) Standard Precipitation Evapotranspiration Index, SPEI (Vicente-Serrano *et al.,* 2010), (xv) ZA shrubland model (Venter, 1992), (xvi) Zucchini-Adamson models (Zucchini *et al*., 1991), and others which are not relevant in the context of this study (for example, Du Pisanie *et al*., 1998; 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 U.S. Department of Agriculture to determine when to grant emergency drought assistance, and can be used when working over large areas of uniform topography such as the Karoo. Areas with mountainous terrain and the resulting complex regional microclimates, find it 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 though, 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 play an important role in moisture deficit, and the newly developed SPEI used in this research provides an even better indicator for drought than the SPI (Vicente-Serrano *et al*., 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 the SPI and SPEI.

A detailed discussion of the above-mentioned indices has been given in Chapter 4 *"Drought Hazard Assessment".* As one of the outcomes of this research, the Department of Agriculture, Forestry and Fisheries (DAFF) finalized drought hazard indicators to be used in the future (DAFF, 2015). Tables 9.1 to 9.5 provide a summary of available indicators that are easy to use and that are used regularly by different countries. Indicator classification is done according to meteorological, remotely sensed, hydrological and composite indicators.

Table 9.2: Most common meteorological indicators

Index	Input parameters	Additional information
Aridity Anomaly Index	P, T, PET, ET	
Deciles	P	Easy to calculate
Keetch-Byram Drought INDEX (KBDI)	P, T	Specific climate in an area is basis for calculation.
Percent of Normal Precipitation	P	Simple calculations
Standard Precipitation Index (SPI)	P	Recommended by WMO for use internationally. Possible to compare different climate zones.
Standard Precipitation Evaporation Index (SPEI)	P, PET	Same as SPI, but evaporation also included. If all data is available a more accurate indicator than SPI>
Z-score	P	Simple to calculate, but shorter time scale with large difference in mean and median might not be accurate.
Aridity Index	P, T	Can also be used for climate classification
China Z Index	P	Easier to calculate than the SPI and provides similar results
Crop Moisture Index	P, T	Weekly temp and precipitation data are required
Drought Reconnaissance Index (DRI)	P, T	Monthly temp and precipitation data are required. Identify the onset and end of water deficit periods.
Effective Drought Index (EDI)	P	Requires daily precipitation data
NOAA Drought Index	P	Best used for application in agriculture
Palmer Drought Severity Index (PDMI)	P, T, AWC	Complex calculations and require serially complete data.
Rainfall Anomaly Index	P	Require serially complete data
Standardized Anomaly Index	P	Point data used to calculate regional conditions
Reclamation Drought Index (RDI)	P, T, S, RD, SF	Similar to surface water supply index, but also requires temperature data
Crop Specific Drought Index (CSDI)	P, T, S, RD, SF	Quality data of many variables needed, making it challenging to use.
Soil Moisture Indicators		
Soil Moisture Anomaly (SMA)	P, T, AWC	Intended to improve upon the water balance of PDSI
Evapotranspiration Deficit Index (ETDI)	Mod	Complex calculations with multiple inputs required
Soil Moisture Deficit Index (SMDI)	Mod	Weekly calculations at different soil depths and complicated to calculate.
Soil Water Storage Index	AWC, RD, ST, SWD	Owing to variations in both soil and crop types, interpolation over large areas is challenging

Table 9.3: Most common hydrological indicators

Index	Input parameters	Additional information
Palmer Hydrological Drought Severity Index (PHDI)	P, T, AWC	Serially complete data is required
Standardized Reservoir Index (SRSI)	RD	Similar calculations to SPI using reservoir data
Standardized Streamflow Index (SSFI) or Streamflow Drought Index (SDI)	SF	Uses the SPI methodology, but with streamflow data instead of precipitation
Standardized Water Level Index (SWI)	GW	Uses SPI methodology, but with groundwater or well level data instead of precipitation
Surface Water Supply Index	P, RD, SF, S	Many methodologies and derivative products are available, but comparisons between catchments are subject to the method chosen.
Aggregate Dryness Index (ADI)	P, ET, SF, RD, AWC, S	No code, but mathematics explained in the literature

Table 9.4: Most common remotely sensed indicators

Index	Input parameters	Additional information
Enhanced Vegetation index (EVI)	Sat	Does not separate drought stress from other stress
Evaporative Stress Index (ESI)	Sat, PET	Does not have a long history as an operational product
Normalized Difference Vegetation Index (NDVI)	Sat	Calculated for most locations. Difference in drought stress and overgrazing not always clear.
Temperature Condition Index (TCI)	Sat	Usually found along with NDVI calculations
Vegetation Condition Index (VCI)	Sat	Usually found along with NDVI calculations
Vegetation Drought Response Index (VegDRI)	Sat, P, T, AWC, LC, ER	Takes into account many variables to separate drought stress from other vegetation stress
Vegetation Health Index (VHI)		One of the first attempts to monitor drought using remote sensing data
Water Requirement Satisfaction Index (WRSI)	Sat, Mod, CC	
Normalized Difference Water Index (NDWI) and Land Surface Water Index (LSWI)	Sat	Produced operationally using Moderate Resolution Imaging Spectroradiometer data

Table 9.5: Most common composite indicators

Index	Input parameters	Additional information
Combined Drought indicator (CDI)	Mod, P, Sat	Uses both remotely sensed and surface data
Global Integrated Drought Monitoring and Prediction System (GIDMaPS)	Multiple mod	An operational product with global output for three drought indices: Standardized Soil Moisture Index, SPI and multivariate Standardized Drought Index.
Global Land Assimilation System (GLDAS)	Multiple, Mod, Sat	Useful in data poor regions due to global extent
Multivariate Standardized Drought Index (MSDI)	Multiple, Mod	Available, but interpretation is required
United States Drought Monitor (USDM)	Multiple	Available, but interpretation is required

Table 9.6: Key to variables used in Tables 9.1 to 9.5

AWC	*Available water content*	*Rad*	*Solar radiation*
CC	*Crop coefficient*	*RD*	*Reservoir*
CD	*Crop data*	*S*	*Snowpack*
ER	*Eco region*	*Sat*	*Satellite*
ET	*Evapotranspiration*	*SF*	*Streamflow*
GW	*Groundwater*	*ST*	*Soil type*
LC	*Land cover*	*SWD*	*Soil water deficit*
Mod	*Modelled*	*T*	*Temperature*
Multiple	*Multiple indicators used*	*Td*	*Dew point temperature*
P	*Precipitation*	*W*	*Wind data*
PET	*Potential evapotranspiration*		

Drought Indicators Selected for South Africa

Table 9.7 summarizes the thresholds for the different indicators and for different drought classifications. Streamflow and dam level indicators are not finalized as yet and there is still a knowledge gap in South Africa in this regard. Obviously critical river levels will differ according to watershed characteristics as well as the time of the year. Low streamflow levels just before the rainy season might not be critical if compared to after the rainy season; the same applies for dam levels and groundwater levels. The measurement for streamflow, dam levels and groundwater levels should be translated to an index, which represents the percentage of normal long term flow during a specific time of the season. One possible method is the use of the same calculations used for SPI or the Z score. The Z score is calculated as follows:

$$Z = \frac{X - \hat{X}}{\sigma}$$

where X= streamflow value (observed or simulated)

X^= mean streamflow for the same period of measurement (observed)

δ = Standard deviation

One single indicator on its own is not sufficient to measure drought and a combination of indicators is required; for example, the six-month SPI of -1,3 might indicate a D2 drought classified as a severe drought, but the soil moisture content and the NDVI results remains within the D1 classification due to good rains prior to the six month period in which the SPI was measured. That will put the specific drought in a D1 category in spite of the low SPI values. In order to classify a dry period into a specific drought category, at least three of the indicator thresholds must concur. Composite indicators such as the (i) Combined Drought Indicator (CDI), (ii) Global Integrated Drought Monitoring and Prediction System (GIDMaPS), (iii) Multivariate Standardized Drought Index (MSDI) and (iv) United States Drought Monitor (USDM) should be implemented to monitor drought accurately. The National Drought Task Team (NDTT) specialist working group on drought indicators however, proposed the indicators as shown in Table 9.1 as primary use for South Africa until the establishment of a drought monitor platform that should monitor drought in SA.

Disaster droughts depend on the different sectors. Internationally it is accepted to declare the D3 and D4 droughts as disaster droughts, during which time government safety nets should be activated. An analysis by Jordaan *et al*. (2010) in the Northern Cape and by Jordaan & Sakulski (2014) in the Eastern Cape shows that SPI -1,2 is already disastrous for smallholder and communal farmers due to their high vulnerability and low resilience.

The primary indicators shown in Table 9.7 should be supplemented with secondary indicators, which are more an indication of the impact of the drought. The following is a discussion on the indicators proposed for South Africa. Indicators are grouped as meteorological, remotely sensed and hydrological.

Meteorological Indicators

Precipitation is defined as any form of water particles, whether liquid or solid, that falls from the atmosphere and reaches the ground. A negative deviation from the normal (climatological mean) precipitation, required to maintain adequate soil moisture water content for normal plant growth, supply of reservoirs, streamflow and groundwater level, may result in drought. Precipitation is the main source of water for soil moisture, reservoirs, streamflows and groundwater; the lack thereof affects all these indicators. South Africa does not have significant snowfall and snow as an additional source of water for rivers and dams is not considered. The Palmer Drought Severity Index (PDSI), for example, is an indicator used in the USA in areas where snow is a source of water.

The effect of abnormally high temperatures increases evapotranspiration as well as stress in plants whilst further depleting surface water reserves through evaporation. High temperatures coupled with low relative humidity and desiccating or continental winds result in large water demands by vegetation. When the condition prevails over long periods it may lead to drought. The percentage of normal precipitation and SPI are recommended as meteorological indices for SA.

Table 9.7: Drought classification and index thresholds

				Meteorological		Remote sensing				Hydrological			
Cat	Description	Potential impacts	Freq.	% of Normal Preciptn.	SPI	NDVI	PASG	1-month VCI	St Veg Health Index	CPC Soil Moisture %	Dam levels zone Z score	Str. Flow Z score	Ground water level % Z score
D0	Dry	Dry period: Short term dryness slowing plant growth of crops and pastures; fire risk above average: some lingering water deficiencies: pastures and crops not fully recovered	1 : 3yr	< 75% for 30 days	-0,5 to -0,7		3month PASG < 90%	< 90%	36-45	21-30	In the moderately low zone	21-30	60- 100
D1	Moderate drought	Some damage to crops & pastures: fire risk is high: Levels of streams, reservoirs or wells are low: Some water shortages are imminent and developing: voluntary water restrictions requested: early warning	1: 5yr	< 70% for 30 days	-0,8 to -1,2		6-month PASG < 90%	<80%	26-35	11-20	In the low zone Z= -0,8 to -1,2	11-20 Z= -0,8 to -1,2	40- 60 Z= -0,8 to -1,2
D2	Severe drought	Crop and pasture losses likely: Fire risk very high: Water shortages common: Water restrictions imposed: drought warning messages: Institutions to prepare for response mechanisms.	1 : 10yr	< 65% for 180 days	-1,3 to -1,5		12-month PASG < 90%	<70%	16-25	6-10	In the very low zone Z= -1,3 to -1,5	6-10 Z= -1,3 to -1,5	30- 40 Z= -1,3 to -1,5
D3	Extreme drought	Major crop and pasture losses: Extreme fire danger: Widespread water shortages and restrictions compulsory: Extended duration with critical impact: Warning messages must be adhered to: disaster drought declaration: Institutions to implement active response actions.	1 : 20yr	<60 % for 180 days	-1,6 to -1,9		12/24-month PASG < 80/90%	<60%	6-15	3-5	Water below the absolute minimum Z= -1,6 to -2	3-5 Z= -1,6 to -2	15- 30 Z = -1,6 to -2
D4	Exceptional drought	Exceptional and widespread crop & pasture losses: Exceptional high fire risk: shortages of water in reservoirs, streams and wells creating water emergencies. Water restrictions compulsory: Warning messages must be adhered to: Active response mechanisms: Impacts critical		< 65% for 360 days	-2 or less		12/24-month PASG < 80%	<60%	1-5	0-2	Dams dry Z<-2	0-2 Z<-2	0- 15 Z<-2

9.1.2 Precipitation Expressed as Percentage of the Long Term Mean

Total precipitation for any period is expressed as a percentage of the long term average. Below the threshold of 75% for a certain period, the index may indicate meteorological drought. Depending on the period for which the deviation is calculated, it may serve as an indicator for both agricultural (12 months and less) and hydrological (24 months and more) droughts. Important, however, for especially crop farmers is the timing of the deviation. A low percentage of normal precipitation combined with high temperatures during the growing season of specific crops might have disastrous results. On the other hand, a low percentage of normal precipitation outside the growing season might not be as damaging.

9.1.3 Standardized Precipitation Index (SPI)

The SPI quantifies precipitation deficits at variable time scales and provides an indication of drought intensity and duration, based on the historical distribution of rainfall. It has been applied with success in various parts of the world. Its simplicity and application over a wide range of climatic regions and all seasons makes it an attractive tool for delineation of drought conditions. The SPI has been used to track the evolution of drought at time scales ranging from 1-24 months or longer. Depending on the relevant period, the index can be used to identify both agricultural and hydrological droughts.

Important, however, is the time scale of measurement and during which season it is applied. The three-month and six-month SPI during the growing season is very important for crop farmers since a low three- and six-month SPI from November to March in the summer rainfall area can result in total crop losses. The 12-month and 24-month SPI is more relevant to livestock farmers, but a low six-month SPI during the growing season might also impact negatively on livestock farmers.

The SPI and SPEI are, globally, the preferred index to be used for drought risk assessment (WMO, 2009), henceforth the use of the SPI and SPEI as the preferred indicators for drought classification. The SPI and SPEI are therefore discussed in detail in the following two sections. In order to understand the meaning of 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 Centre, 2011):

- ***Accumulated Precipitation*** *- the total precipitation that has fallen during the indicated number of months, through to the end of the month displayed.*
- ***Accumulated Precipitation Departure*** *- 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 Per Cent of Average*** *- the observed accumulated precipitation, over the time period 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-Exceedence"*** *- this quantity indicates how often a value of the magnitude observed is seen, its degree of "unusualness". A value of 0 means that zero per cent of the other values in the record do not exceed 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.*

Tom McKee, Nolan Doesken and John Kleist of the Colorado Climate Centre formulated the SPI in 1993 to give 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 at 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 *et al*., 2003; Paulo & Perreira, 2005; 2007; 2008, Moreira *et al.,* 2008). Drought early warning and measurement of the onset of drought using drought indices has received much research attention from scientists. Candelliere & Salas (2007), for example, developed a stochastic approach to forecast monthly SPI values for different time scales. Mishra & Desai (2006) and Thyer *et al*. (2006) also developed neural networks and stochastic models applied to precipitation time series data. 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 class drought 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):

- SPI is uniquely related to probability.

- The SPI is normally distributed and is therefore useful to monitor dry and wet periods.
- Because of the normal distribution of SPI, the 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 precipitation 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):

$$Z = \frac{X - \hat{X}}{\sigma}$$

where X = precipitation (observed or simulated)

X^= precipitation mean (observed)

δ = standard deviation

A typical frequency distribution of precipitation for a given time scale is skewed, with the mean precipitation larger than the median. In other words, it is 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 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-month and 48-month time scales 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 two parameters 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 (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 be used to optimally estimate parameters alpha and beta:

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$\beta = \frac{x}{\alpha}$$

where: $A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$

and 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, the Gamma transform = GAMMADIST($x, \beta, \alpha, true$)

The Gamma function is not defined for the value of *x=0*, and if 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. The *Standardized Precipitation Index (SPI)* is then calculated by transforming the cumulative probability, *H(x),* to the standard normal random variable *Z* with mean zero and variance one.

Abramovic & Stegun (1965), as cited by Sakulski (2002), proposed an easy way to calculate 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 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 zero and a variance of one 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)

Fig. 9.2 shows the standard normal distribution for SPI and it illustrates that about 16% of the time SPI will be below -1.0, which indicates *dry* conditions, with 6.7% of the time below -1.5, which indicates *severe* and *extreme droughts* for values below -2. Also, 16% of the time 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.

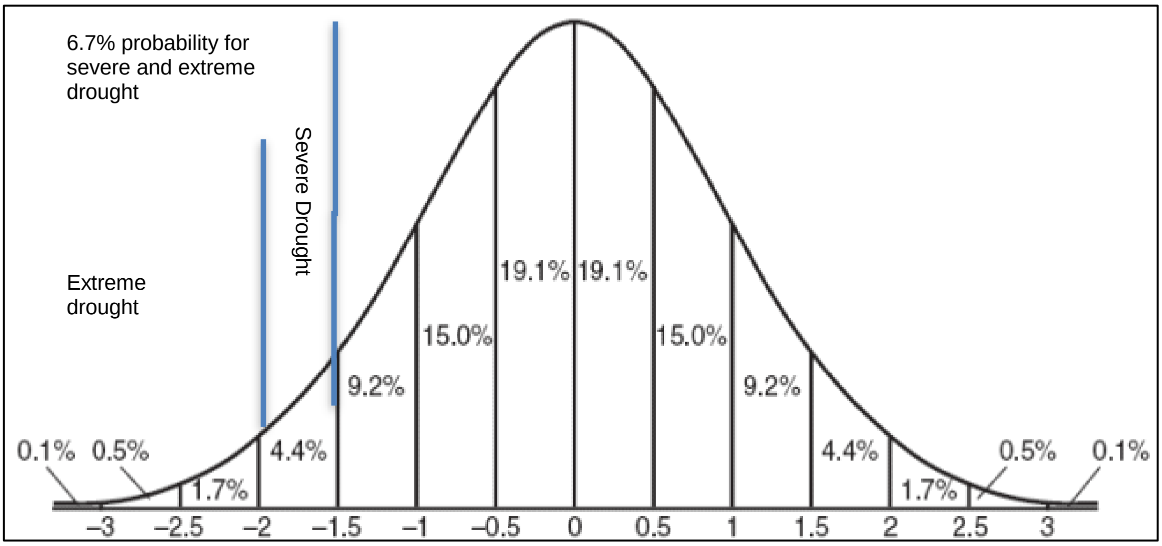


Fig. 9.2: Standard normal distribution with SPI and SPEI

As explained earlier, the algorithm for 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 the study area. (See 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 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 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 distinguishes drought from "*desiccation"*[12]. Warren & Khogali (1992) distinguish drought from desiccation by arguing that (i) drought occurs when moisture supply is abnormally below 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 based on 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:

• higher 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 (2000) proposes modifications to Agnew's categories by using 5%, 10% and 20% probabilities of 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

[12] Aridness or aridity

The classification proposed by McKee (1993), Hayes (1999) as well as Agnew (2000) is considered and we propose the following for use in South Africa:

- > 2 exceptionally wet – floods
- 1.5 to1.99 extremely wet
- 0.5 to 1.49 wet
- -0.5 t0 0.49 normal
- -0,8 to -0,69 moderate dry
- -1,2 to -0,99 dry
- -1.5 to -1,39 severe drought
- -2 to -1.69 extreme drought
- < -2 exceptional drought

The proposed thresholds consider the communal agricultural sector with a classification of >-1.2 for disaster droughts and >-1.5 for the commercial farming sector.

9.1.4 Standard Precipitation Evapotranspiration Index (SPEI)

The most recently developed indicator for drought is the Standard Precipitation Evapotranspiration Index (SPEI) developed by Vicente Serrano, Beguiria & Lopez-Moreno (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 evaporative demand that are caused by fluctuation 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 SPEI calculation one should understand the principles of 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, 1994; Allen *et al.,* 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 surface. 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 evaporation, or potential evapotranspiration (PET), is defined as the amount of evaporation that would occur if a sufficient water source were available. 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, which in places in South Africa is by a factor of 5 to 10 times.

The SPEI is based on the same calculation methodology for SPI, but the calculation of potential evapotranspiration (PET) is also included since the SPEI uses the monthly or weekly difference between precipitation and PET as basis for calculation. Calculation of PET is the most difficult because of numerous parameters such as surface temperature, atmospheric humidity, incoming solar radiation, water vapour pressure and ground-atmosphere latent and sensible heat fluxes (Allen *et al.,* 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 of 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):

$$\vartheta = 0.4093 sen\left(\frac{2\pi J}{365} - 1.405\right)$$

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:

$$D_i = P_i - PET_i$$

This provides a simple measure of the water surplus or deficit for the month under analysis. The calculated D_i values are aggregated at 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 occurrence in 200 to 500 years. 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 ($\gamma > D < \infty$). Parameters of the Log-logistic distribution can be obtained following different procedures. Among them, Vicente Serrano *et al.* (2010) followed Ahmed *et al.* (1988) who found the L-moment procedure as the most robust and easy approach. Vicente Serrano *et al.* (2010) further followed Singh *et al.* (1993) who reported that when L-moments are calculated, the parameters of the Pearson III distribution could 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:

$$SPEI = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3}$$

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 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 acceptable, 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 vegetation water content, which has a direct effect on agricultural droughts commonly recorded by short time-scale indices. Narasimhan & Srinivasan (2005) and Vicente-Serrano *et al.* (2010) conclude that evapotranspiration-based indices show better results than solely 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 where temporal trends in temperature do not exist. 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 Gqabi district municipality. The maximum annual precipitation for catchment D13F is 1050,7 mm (1988), the minimum 240 mm (1954), with a median of 653,7 mm and a mean of 644,3 mm. Basic input data for the 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 a 3-month SPEI); then, define a new set of data as 3-months-sum, for each year[13]. The histogram and PDF plot is shown in Fig. 9.3.

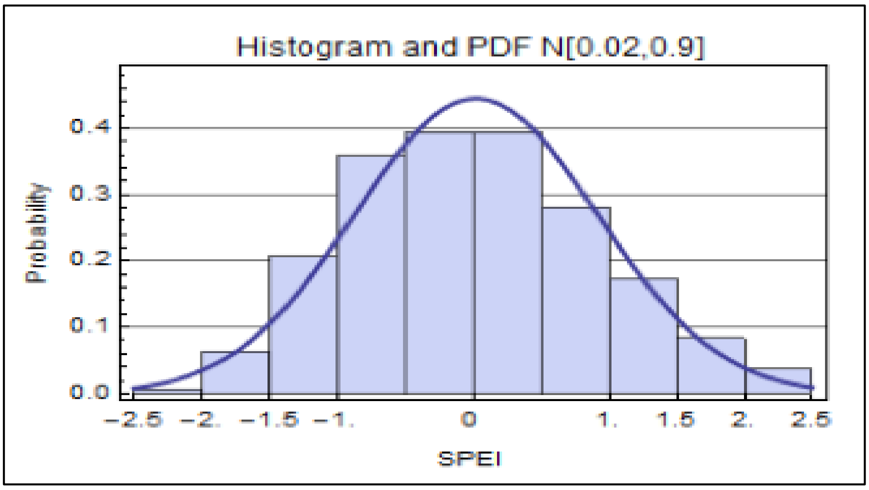


Fig. 9.3: Histogram and PDF plot of 3-month precipitation data with April month-end

Step 2: Calculate the empirical cumulative probability by using frequency analysis. Sakulski (2002) found empirical probability to be optimal where precipitation data were ranked in increasing order of magnitude, so that the k^{th} value was K-1 values from the lowest and where n was the sample size.

Empirical cumulative probability = $\frac{k}{n+1}$ and is shown in Fig 9.4.

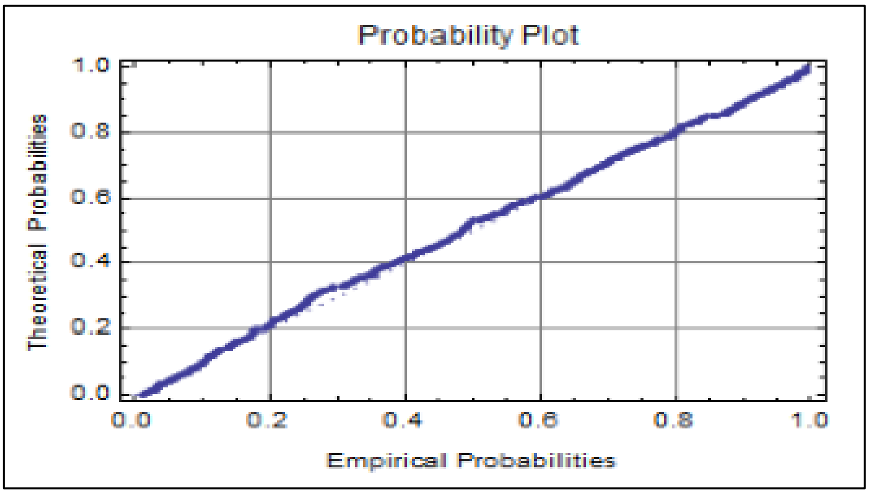


Fig. 9.4: Empirical cumulative probability

[13] Depending on the SPI period to be calculated it could be 6-month-sum or 12-months-sum

Step 3: The smooth curve as shown in left graph of Figure 9.5 (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 9.5 (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 (Fig 9.5 (a))

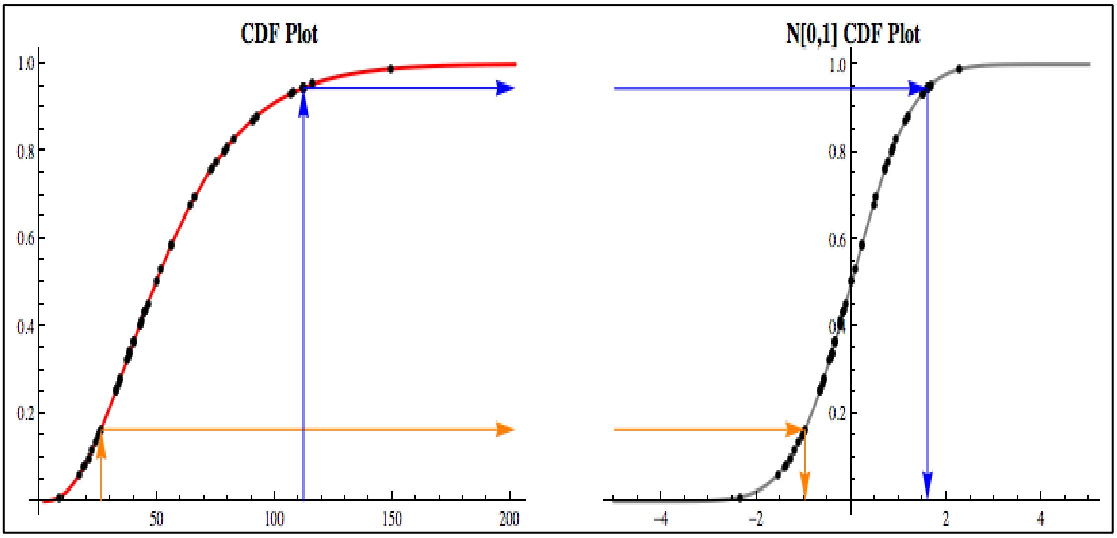


Fig. 9.5 (a) and (b): Gamma to Standardised Normal distribution.

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 9.5 (a) until the fitted Gamma cumulative probability curve is intersected. Then go horizontally (maintaining an equal cumulative probability) to the right (Figure 9.5 (b)) until the curve of the Standard Normal cumulative distribution is intersected. Then proceed vertically down to the x-axis of Figure 9.5 (b) in order to determine the SPEI value. In this case, the SPEI is approximately -1. The histograms, probabilities and Gamma standardized normal distribution for different SPEI values are illustrated in Figures 9.6 to 9.8.

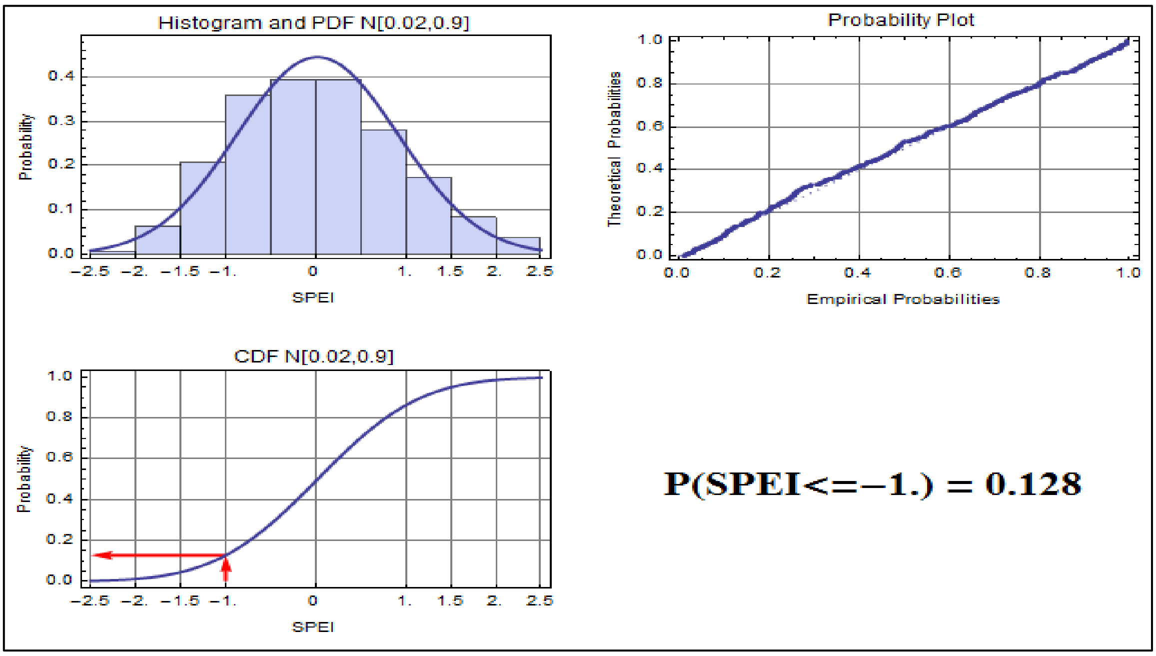


Fig. 9.6: Histogram, probability and normal distribution for SPEI <=-1 in quaternary catchment N14B.

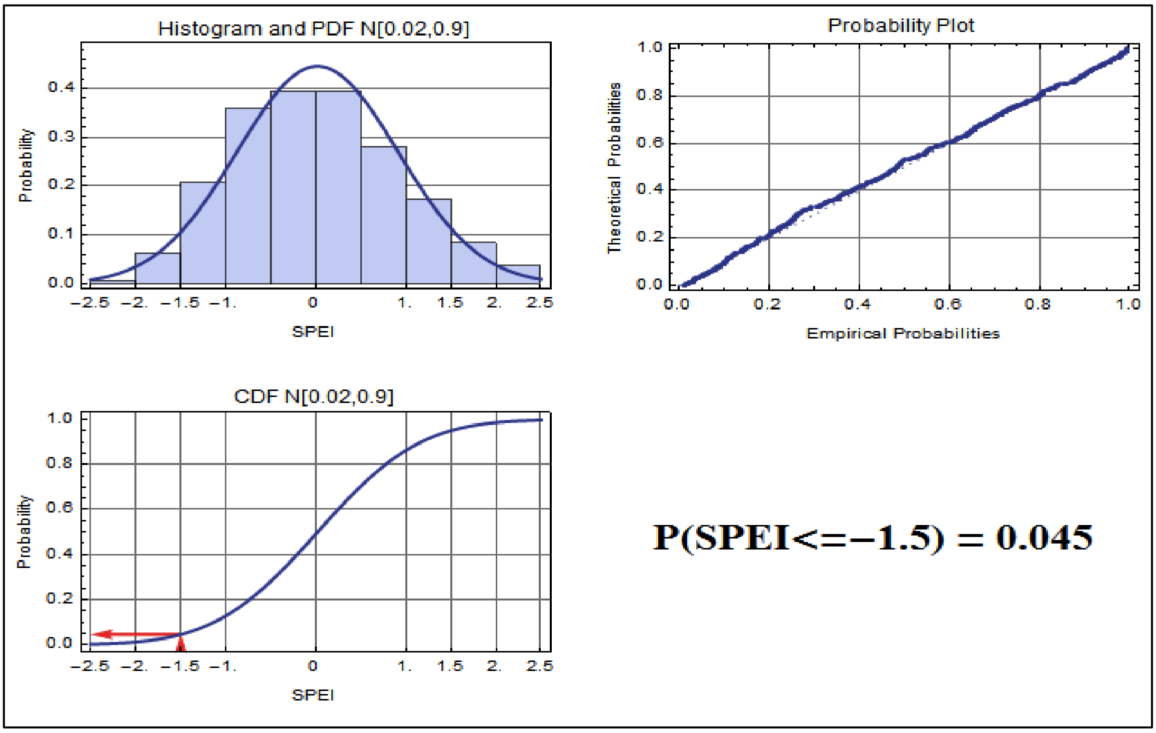


Fig. 9.7: Histogram, probability and normal distribution for SPEI <=-1,5 in quaternary catchment N14B.

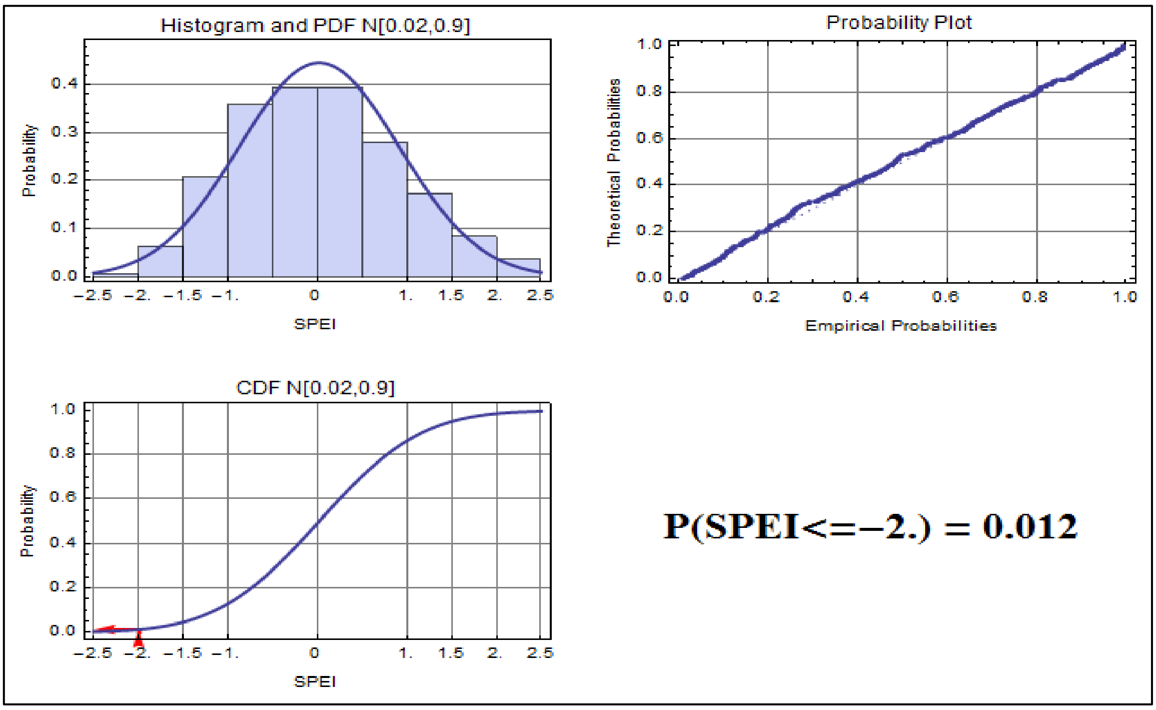
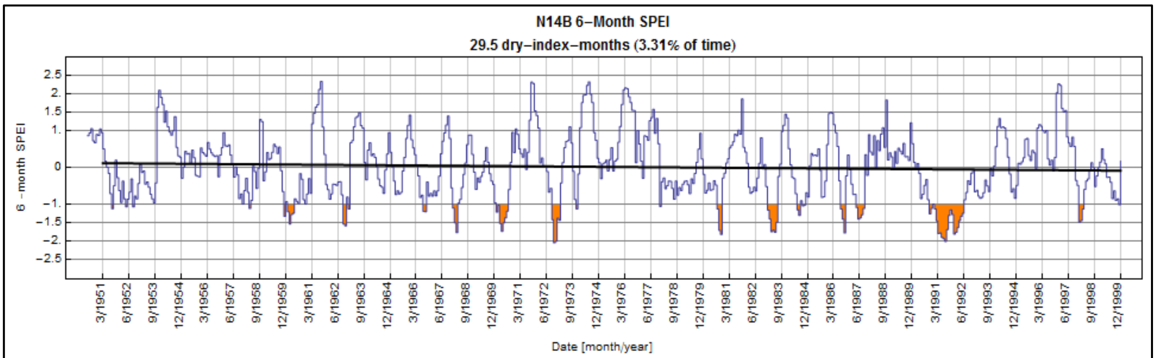


Fig 9.8: histogram, probability and normal distribution for SPEI <=-2 in quaternary catchment N14B.

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 9.9. The same methodology applies to the calculation of different time scales of SPEIs.



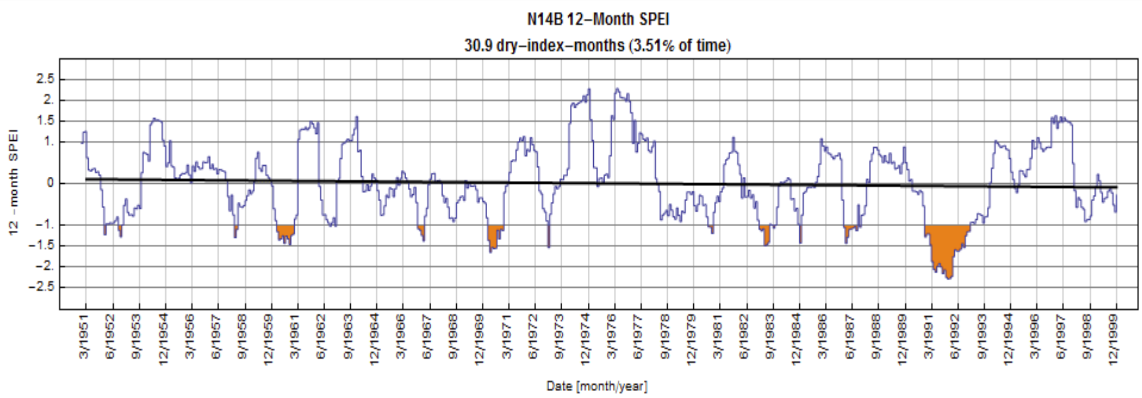
Indicative linear trend: 0.117878 - 0.000338354 x , p-Value=0.1161

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. 9.9: Six-months 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[14] was the most effective for monitoring drought impact on vegetation, especially when the 3-month period coincided with the peak growing season. They compared NDVI and SPI 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 co-variation 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 at Figures 9.9 and 9.10.



Indicative linear trend: 0.110244 - 0.000335401 x , p-Value=0.1266

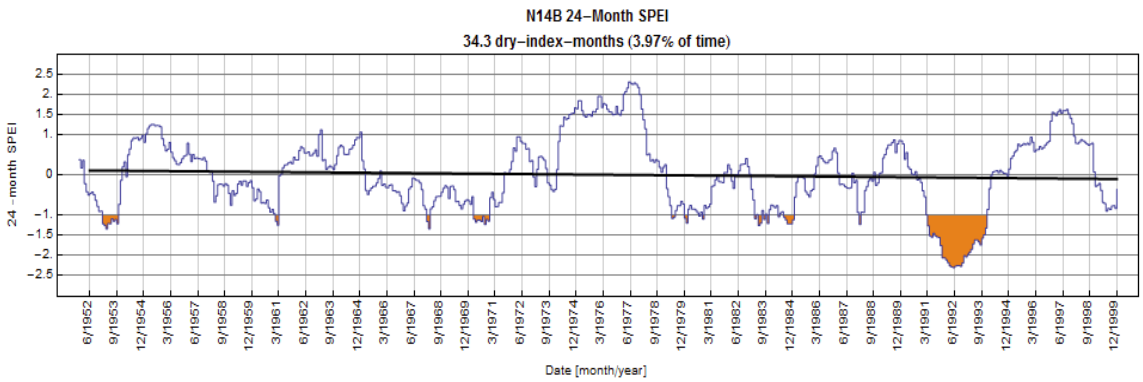
Dates	{Apr 1970, Jul 1970}	{Mar 1991, Jul 1992}
Duration	4	17
Intensity	1.56	1.96
Severity	6.24	33.32

Fig. 9.10: 12-month SPEI graph for tertiary catchment N14B
(Sakulski & Jordaan, 2014).

Khan, Gabriel & Rana (2008) found 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-priory* 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 9.10 clearly shows one extreme dry period with SPEI <-2 during the drought of 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 Fig 9.9).

[14] SPI and SPEI results are similar in cotext of this study since no statistical change could be found on climate change

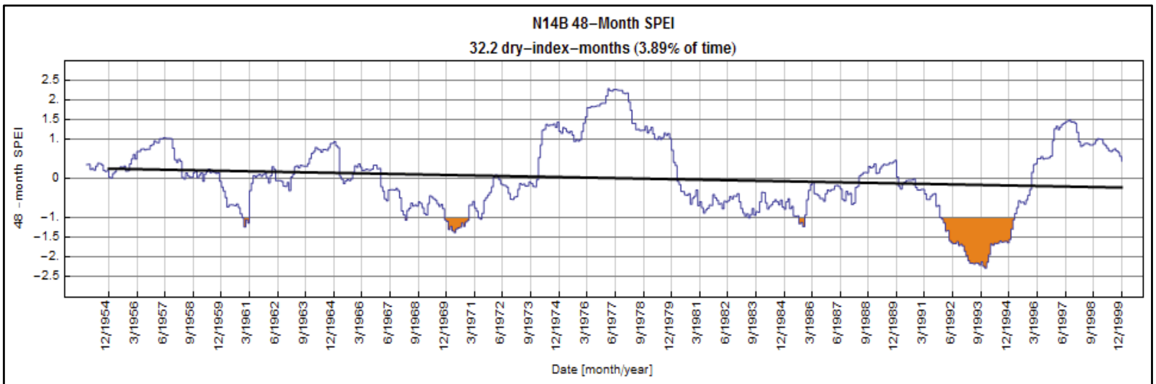


Indicative linear trend: 0.111666 - 0.000366687 x , p-Value=0.1094

Dates	{Apr 1991, May 1991}	{Jul 1991, Sep 1993}
Duration	2	27
Intensity	1.52	1.94
Severity	3.04	52.38

Fig. 9.11: 24-month SPI graph for tertiary catchment N14B
(Sakulski & Jordaan, 2014)

The longer time-span (24-month in Figure 9.11 and 48-month in Figure 9.12) 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 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. 9.12: 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 transforms the data as a normal distribution, one should expect probabilities for severe droughts to be < 0.67 and for 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 the 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 7 out of 50 years.

Figure 9.13 shows the exceedence probability for the example catchment D13F. The strength of the SPI and SPEI technique is illustrated here in that one can clearly see how easy it is to calculate probability for dry and wet periods with positive values from 1 to 2,5 at the top of the graph (McKee *et al,* 1993; Guttman, 1999; Hayes *et al.,* 1999; Wilhite, 2000 (a); Hayes, 2011).

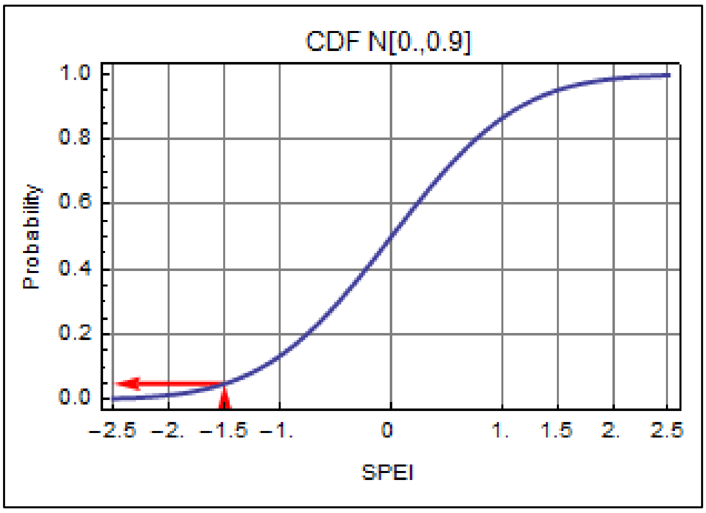


Fig. 9.13: Twelve-month exceedence probability for SPEI -1,5 for quaternary catchment D13F ***(Sakulski & Jordaan, 2014)***

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)? These are some of the questions to being answered in this report.

Agricultural Drought Indicators Through Remote Sensing

Earth Observation (EO) data can be employed to provide information on the abundance and condition of vegetation. The data are remotely sensed and unlike several other climate products, which are interpolated from point values, they are comprised of contiguous pixels representing conditions on the ground. Various bands in the visible through near infrared and short wave infrared are sensitive to, amongst others, various characteristics of vegetation.

9.1.5 Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) expresses vegetation health in terms of the amount of reflectance/radiation in the red and near-infrared bands. The index is used to analyse remote sensing measurements and assess whether the target being observed contains live green vegetation or not. The NDVI is often directly related to other ground parameters such as percentage of ground cover, photosynthetic activity of the plant, surface water, leaf area index and the amount of biomass. Several derivatives of this index, based on cumulative and historical data, may provide information on the duration and intensity of drought, while the contiguous nature of the data is an excellent indicator of the spatial extent of such a drought.

9.1.6 The Vegetation Condition Index (VCI)

The VCI compares the current NDVI to the range of values observed in the same period in previous years. The VCI is expressed as a % and gives an idea where the observed value is situated between the extreme values (minimum and maximum) in the previous years. Lower and higher values indicate poor and good vegetation state conditions, respectively.

One of the challenges for the use of VCI is the fact that the satellite data do not distinguish between man-made droughts as a result of overgrazing and actual drought. Therefore, one should consider different indicators in combination with each other.

9.1.7 The Percentage of Average Seasonal Greenness (PASG)

The PASG provides an indication of the cumulative vegetation activity over a specified period (i.e. a growing season) relative to the long term average for the period. The index expresses the current cumulative vegetation activity determined by the cumulative NDVI as a percentage of the long term average cumulative NDVI value for the specified period. Over a shorter time span, such as a 3-month to 6-month period, the PASG provides an overview of conditions relating to possible drought stress during a growing period, and is therefore relevant for the monitoring of agricultural drought. At a 24-month time scale, the index may be more applicable as an indicator for hydrological drought.

9.1.8 Soil Moisture Index

Drought occurs when the balance between rainfall, evapotranspiration and discharge leaves less available water in the soil storages than necessary for plant growth and for support of animals. The key role of available soil moisture in the root zone is providing food for people and animals. This feature places accurate monitoring and effective responses as central issues in food security. In this regard, drought can be considered as a combination of moisture deficit and land use due to this idealized cause–effect relationship which assumes that a shortage of rainfall (the cause) leads to a soil moisture deficit that results in a reduction of vegetation production (the effect). This relationship gives an opportunity to provide an early warning system for drought by monitoring soil moisture. Remote sensing of soil moisture is a new development with good potential for drought monitoring.

Hydrological Indicators

Hydrological indicators are important for the irrigation sector and these are an indication of the amount of water available for irrigation. Livestock farmers also depend mostly on groundwater and potable water for livestock drinking water and are, as such, also threatened by hydrological drought.

9.1.9 Reservoirs / Dams

Generally, a reservoir is a storage system created by a wall across a river and its purpose is for harvesting water during the rainy season when streamflow rates are more than the required water supply abstraction rates. Therefore, during dry and/or drought periods water supply is sustained by appropriate releases from the reservoir.

The reservoir storage level is therefore a function of the season's runoff amounts - meaning that during drought little water is harvested and the reservoir level will be low. Based on previous records, the Department of Water and Sanitation (DWS) has prepared graphs that indicate zones/ranges of water levels in the different reservoir during the year. See an example for a specific reservoir in Figure 9.14.

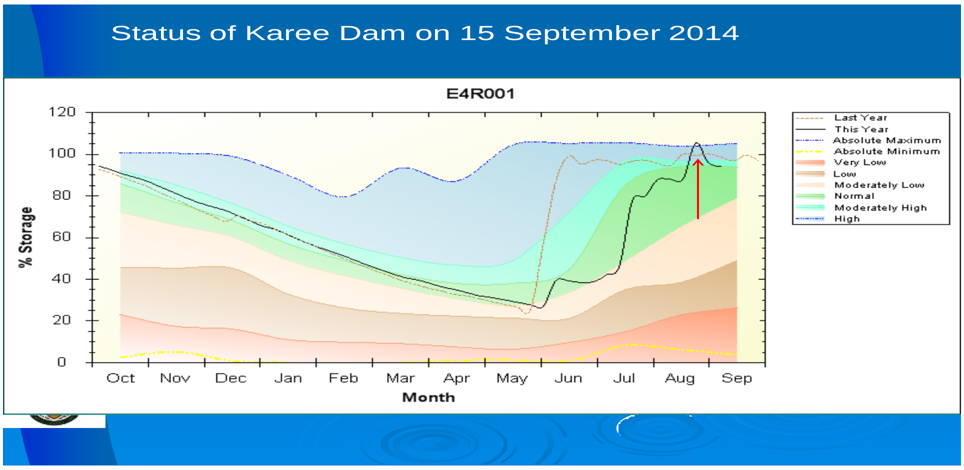


Fig. 9.14: Classification of water levels for the Karee dam.

Water levels falling in and below the *"Low"* zone/range would signal drought conditions (www.dws.gov.za/hydrology/State of Dams/WMA/Indicators- for dams across the country). These tools (graphs) for dams across the country are available on the DWS's website – It is important to mention here that the characteristics of the storage zones are different for different dams depending on the hydrology and general water supply and water use pattern of the system.   Also important is the time of measurement. An empty dam at the end of the rainy season might be an indication of extreme drought while the same dam level at the beginning of the rainy season might reflect a normal dry period.

A simple method of calculating drought based on dam levels is the application of the same methodology used for calculating SPI. In this case one would use the current dam levels and compare them with the historical mean dam levels during the corresponding time in the past. Again one would require at least 30 years of historical data for accurate calculations. The Z score also provides an alternative way of calculation.

9.1.10 Streamflow Levels

Streamflow levels are a direct or indirect function of precipitation in the catchment area of a specific river. Some of the precipitation water (runoff) also enters the ground and is released into the stream after weeks, months or even years. In certain areas, water directly from streams is used in various agricultural activities such as irrigation and water for livestock.

Depending on the size of the catchment, drought stress can cause serious impacts on streamflow. As for reservoirs, indicators should be prepared to indicate zones/ranges of water levels in the river over the year – but only for sites that are not under the influence of releases from upstream reservoirs. However, because most critical streamflow sites are influenced by artificial reservoir releases and/or other human activities, such graphs are not readily available for streamflows, but can be easily generated by a professional hydrologist/engineer where necessary. This is currently a gap in the drought monitoring system and should be calculated to quaternary catchment level.

A simple method of calculating drought based on streamflow is the application of the same methodology used for calculating the SPI. In this case one would use the current streamflow levels and compare them with the historical mean streamflow for the corresponding date. Again one would require at least 30 years of historical data for accurate calculations. The Z score also provides an alternative way of calculation.

9.1.11 Groundwater

Drought is exacerbated by lack of precipitation and excess evapotranspiration. Groundwater is affected in various ways by a drought and the components and characteristics of groundwater that are affected are:

- Groundwater recharge (water that infiltrates and replenishes the aquifer)
- Groundwater discharge (into surface water bodies, springs or the ocean)
- Groundwater storage (total volume of water withheld within the aquifer)
- Groundwater levels (level of the water table in the aquifer).

Groundwater availability fluctuates less seasonally, making groundwater a good buffer against drought. Groundwater is often available during earlier parts of a drought when surface water has run out and only in later stages of a drought will groundwater storage and hence availability diminish as a result of a continued drought. Hence, groundwater can be used as a drought mitigation strategy, but only to a certain degree, because the available groundwater may not represent the present day recharge. It should be noted that during drought it is often boreholes that fail and not the aquifers.

After a drought event, groundwater may be in short supply even after rainfalls start and therefore it tends to react with a time lag relative to rainfall and surface waters, both at the onset of a drought and in the end of a drought. This is illustrated in Figure 9.15.

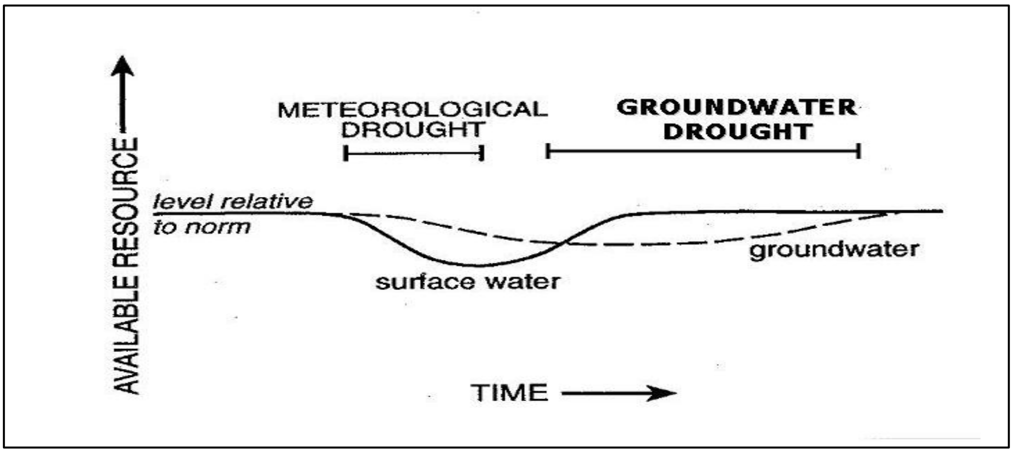


Fig. 9.15: Sequential response and recovery functions of groundwater and surface water to drought.

A potential method of calculating drought based on the groundwater level is the application of the same methodology used for calculating the SPI. In this case one would use the current groundwater level and compare it with the mean groundwater level during the corresponding time in the past. Again one would require at least 30 years of historical data for accurate calculation. The Z score also provides an alternative way of calculation. Further research is required to determine the Z score and the SPI equation as an alternative.

Secondary Indicators

Secondary indicators are the indicators that should be used to *"ground-truth"* and support the primary indicators. The United States Drought Monitor sometimes utilises up to 30 or more drought indicators as a composite indicator for drought monitoring and drought impact (US Drought Monitor, 2015). The secondary indicators to be utilised in conjunction with the primary indicators include, but are not limited to, the following:

- Crop condition and damage
- Grazing condition and availability
- Animal conditions
- Actual soil moisture content

9.1.12 Reference Farms

Quantitative measurement of the secondary indicators is a challenge and drought declaration in the past was heavily influenced by political pressure and pressure from the affected communities themselves. In order to ensure proper drought monitoring at farm level a system of reference farms should be implemented. At least one reference farm should be selected for each quaternary catchment. The objective with reference farms is to formalize and implement a system on the selected farms based on practical experience and research over a long period of drought management. Reference farms are those particular farms chosen in a catchment area on the basis where a farmer is prepared to collect and supply data on rainfall, carrying capacity, veld condition and other scientific information according certain terms and conditions, in collaboration with DAFF, the provincial departments of agriculture, the disaster management centres and organized agriculture. Data should be submitted on a regular basis via the Internet on a web-based system. These data should be analysed, processed and used as a source for drought monitoring and early warning.

Furthermore, the system of reference farms can contribute to the calculation of carrying capacity for the different catchment areas. Reference farms must have typical characteristics of the selected catchment. One acknowledges the fact that rainfall is not always the same on all farms in a specific catchment and cognizance should be taken of thunderstorms and localized showers.

The natural resources on the reference farm must be representative of the specific catchment. The most notable natural resources are veld type, water supply, soil type, geographical features as well as the farming system. The farmer (owner or lessee), called the participant, must be willing and able to keep records and provide data on at least a weekly basis. The participant must apply good agricultural practices according to the norms and climate conditions of the specific region. In addition the participant must be connected or have access to the Internet in order to provide and upload data on a regular basis.

Participants in the drought monitoring and early warning project must adhere to the following:

- Supply daily meteorological data on at least a weekly basis: The possibility of automatic meteorological data capturing mechanisms should be discussed with SAWS or the ARC.
- Supply an inventory of all animals and movement of animals in terms of progeny, sales and purchases on the farm: This applies to sheep, cattle, horses, donkeys, ostriches and game (Values according to the present Meisner tables or as reviewed).
- Adhere to the carrying capacity according to the norms of DAFF over a twelve-month cycle: As a farmer who applies good agricultural practices he/she will under-graze in some years and overgraze other years, depending the condition of the veld and climate conditions. Therefore the carrying capacity will be exceeded some years etc. The baseline veld condition on a specific farm differs from others and not all farms have the same carrying capacity, but good agricultural principles apply.

- Comply with good farming practice (veld management system)
- Comply with the protocols provided by the drought monitor unit.

The secondary indicators on the reference farms (crop condition, grazing and animal condition) can now be used as a basis for drought classification in conjunction with the primary indicators.

9.1.13 Other Sources of Secondary Indicators

Other Departments responsible for the monitoring and provision of data on secondary indicators are the National Department of Agriculture, Forestry and Fisheries (DAFF), the Department of Water and Sanitation (DWS) and the Department of Environmental Affairs and Rural Development. Municipalities and traditional leaders as custodians of agricultural land should also be included as sources of secondary data for drought classification.

Drought Indicator Thresholds

Not all dry periods are droughts and the impact of dry periods is different between different sectors. The use of the prescribed indicators without the consideration of the sector specific characteristics will be foolish. Factors to consider before drought declaration are the following:

Primary indicators: At least three of the indicators must have a threshold for at least a D2 drought, at which stage one can expect secondary indicators also to indicate a drought.

Secondary indicators: Grazing on the reference farm should display definite dry conditions and the farmer should reduce animal numbers by 30%. Crops should reveal definite signs of water stress with potential crop losses of at least 40%.

Time of monitoring: The three-month SPI during the growing season can lead to a disaster drought for crop farmers whereas the same SPI value outside the growing season might only be regarded as a dry period with little impact. Reservoir levels are also linked to seasonality; for example, reservoirs with low water levels at the beginning of the rainy season are not a problem compared to empty reservoirs at the end of the rainy season, which then could lead to water shortages. One needs to consider the seasonality and growing season of different crops and grazing on livestock farms with the classification of drought; therefore the use of secondary indicators to ground-truth the impact of a dry period becomes vital.

Sector differences: The difference between the communal farming sector and the commercial farmers in terms of drought vulnerability and resilience is significant (Jordaan, 2011). Communal farmers and the smallholder farming sector are extremely vulnerable to drought because of (i) overgrazing, (ii) land degradation, (iii) poor infrastructure on their land, (iv) a lack of grazing management systems, (v) poor quality animals, (vi) lack of reserves, (vii) imperfect markets, (viii) lack of knowledge, and (ix) cultural beliefs (Jordaan, 2011). Communal farmers experience normal dry periods as droughts and they report significant drought losses every one in three years. A D0 and a D1 drought could be disastrous for them while, on the other hand, most commercial farmers are able to manage a D2 drought. Figure 9.15 illustrates the dilemma by way of drought loss functions.

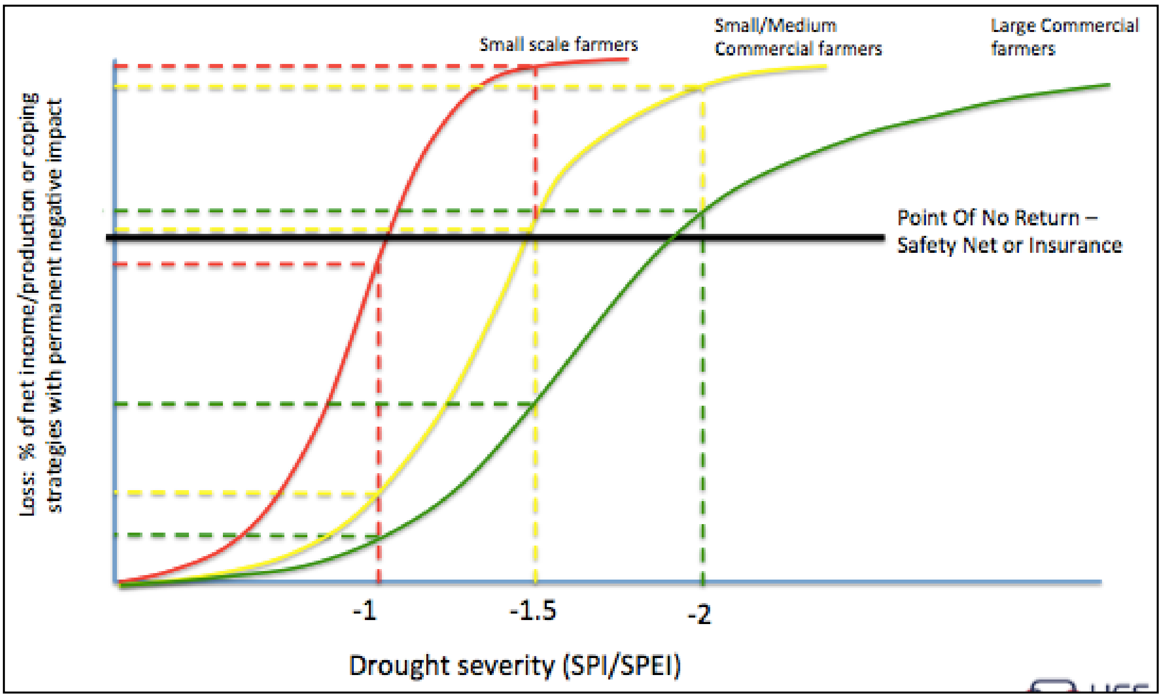


Fig. 9.16: Drought loss functions for different agricultural farmer categories

Figure 9.16 illustrates typical drought loss functions for smallholder or communal livestock farmers, medium scale farmers and large commercial farmers. SPI values are illustrated on the x-axis and production loss as a % of normal production on the y-axis. Smallholder communal farmers already lose more than 50% of normal production at a 12-month SPI value of -1,2 and require safety net activation long before the larger and more resilient farmers. More than 2 million people are classified as smallholder farmers in South Africa and 40% of domestic livestock in South Africa is owned by this sector (DAFF, 2014). These farmers produce mostly only enough for subsistence, but that in itself is significant in that they contribute to the total food production in South Africa. Each one of these farmers, who migrates out of agriculture because of drought, becomes an additional burden on the social security system in South Africa. It is therefore strategically important to provide safety nets in order to support smallholder and communal farmers with continued production.

Indications are that drought safety nets should be activated for communal farmers already at drought stage 2, which is characterized by a SPI -1,2. Drought declaration and activation for commercial farmers is at drought D3 with SPI <1,5. For livestock farmers one should use the 12- and 24-month SPI while the 6-month SPI during the growing season becomes relevant for crop farmers. Obviously one should also consider other indicators in conjunction with the SPI.

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 (roads, large urban centres), nearby forests, water sources and tourism all have an influence on the resiliency and coping strategies of 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).

Figure 9.16 illustrates the comparison of the different thresholds of households with different levels of own resources. It is clearly illustrated in Figure 9.17 that households with different resource levels reach the different thresholds at different times.

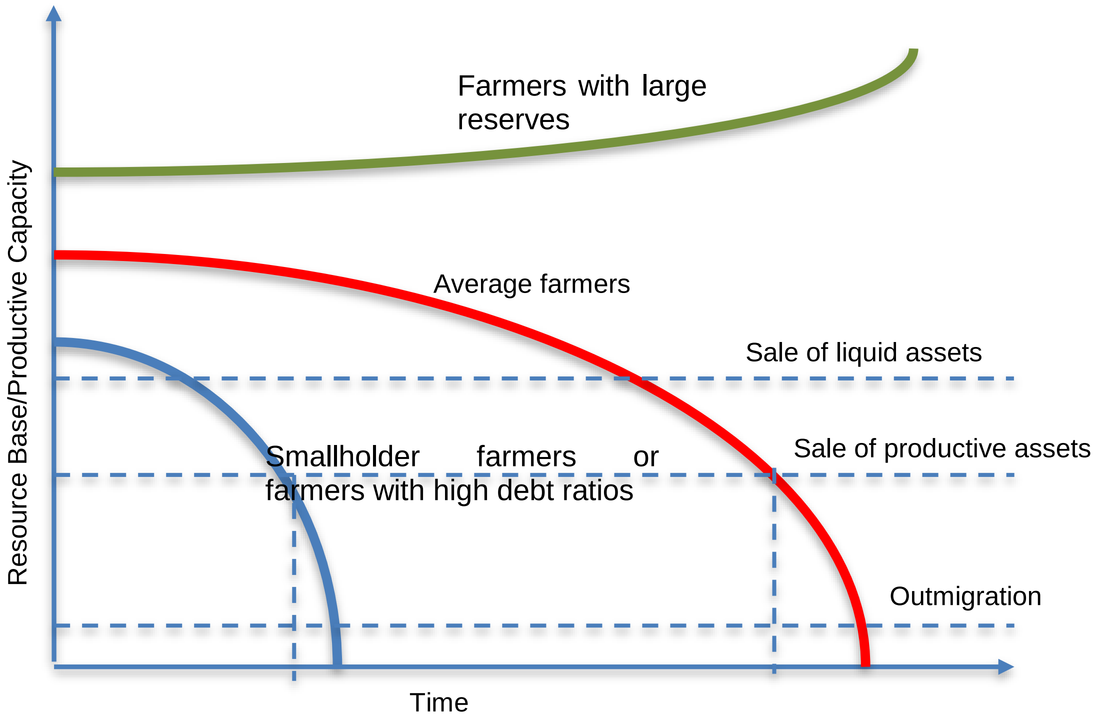


Fig. 9.17 Response of farmers as a function of resource base
Source: Author after FEWS (1999).

Clearly illustrated is that 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 meagre 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.

Drought Disaster Declaration

Both the Disaster Management Act (Act 57 0f 2002) and the Disaster Management Amendment Act (Act 16 of 2015) are clear on the declaration of local, provincial and national disasters. The proposed indicators discussed in this report provide the necessary guidelines for disaster declaration or not. The indicators and different thresholds for drought classes also provide a guideline for decision makers to be careful in classifying drought according to single indicators. Drought is a complex phenomenon and the impact on different sectors need to me considered. The report, for example, explained the difference between communal farmers and commercial farmers.

An important contribution of this report is the provision of quantitative indicators for drought classification and that should limit political interference or pressure from interest groups to declare dry periods as droughts when it is not the case. Details of the process for disaster declaration are covered in the proposed template for a provincial and district drought plan.

Conclusion

The contents of this chapter provides important guidelines for indicator selection and indicator thresholds for South Africa. All thresholds are currently selected based on literature and on their use in leading countries with drought management plans. The unique circumstances of the communal farming sector in South Africa are considered. The implementation of an official drought classification that is based on quantitative indicators should limit the possibility of political interference and pressure groups on drought disaster declaration.

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10 Framework for Provincial Drought Management Plan

Jordaan, A.J.

Executive Summary

Drought is a recurring hazard event that causes hardship to many livelihoods and economic sectors in southern Africa. Climate change projections of a warmer climate might result in increased dry periods of higher intensity. In spite of the large number of people affected on the African continent, we still do no not have the capacity to accurately predict when the next drought will happen and how severe it will be.

South Africa has a well-developed economy with a strong agricultural sector and the citizens in South Africa 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 droughts in the past, we can expect densely populated urban areas also to suffer water shortages in future droughts if South Africa does not plan properly for the next drought.

Decision makers in all institutions and enterprises that depend on water need to prepare for dry periods and droughts. These would include:

- *Government – All Departments*
- *Agricultural sector*
- *Wildfire managers (Disaster Management)*
- *Municipal water suppliers, including water boards*
- *Tourism and recreation*
- *Electrical power producers (ESKOM)*
- *Industry*

The drought plan template proposed in this chapter is based on the National Disaster Management Framework and consist of the four Key Performance Areas (KPA's) 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 three enablers of the drought plan 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 government, namely, district, provincial and national. The development of a drought plan 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 standardized for all government levels.

According to Wilhite et al. (2005) at the National Drought Monitor Centre in the USA, the implementation of a drought strategy should follow 10 steps, as follows:

- *Appoint a drought Task Team*
- *State the purpose and objectives of the drought plan*
- *Seek stakeholder participation and resolve areas of conflict or duplication*
- *Inventorise resources and identify groups at risk (risk assessment)*
- *Establish and write the drought plan*
- *Identify research needs and fill institutional gaps*
- *Integrate science and policy*
- *Publicise the drought plan*
- *Develop education and awareness programmes*
- *Evaluate and revise the drought plan*

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

Introduction

The vision for agriculture, as stated in the Agricultural Sector Plan, is a united, non-racial and prosperous agricultural sector. Climate and weather conditions are some of the main determinants of agricultural production and ultimately a prosperous agricultural sector as described in the Vision for the South African Agriculture.

The Disaster Management Act (Act 57 of 2002) and the National Disaster Management Framework (NDMF, 2005) provide the legislative and policy frameworks for the provincial drought management framework.

Drought has no universal definition as droughts are region specific reflecting differences in climatic characteristics with different socio-economic and physical variables. Some of the most common definitions are the following:

- 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".*
- Knutson *et al.* (1998) define drought as "*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 Director of Commonwealth Bureau of Meteorology during 1965 suggested a broad definition for drought as *"severe water shortage".*
- Palmer (1965) states that *"Drought is an interval of time, generally of the order of months of years in duration, during which the actual moisture supply at a given place rather consistently falls short of the climatically expected or climatically appropriate moisture supply".*
- Chopra (2006) defines drought as *"a period of rainfall deficiency, extending over months or years of such nature that crops and pastures for stock are seriously affected, if not completely burnt up and destroyed, water supplies are seriously depleted or dried up and sheep and cattle perish"*
- McMohan and Diaz Arena (1982) define drought as *"a period of abnormally dry weather sufficiently for the lack of precipitation to cause serious hydrological imbalance and carries connotations of a moisture deficiency with a mass usage to water".*

All the above definitions only consider meteorological influences and have little reference to the socio-economic and environmental impact of drought and dry periods. Wilhite & Glantz (1985), Wilhite (2000) and Castillo (2009) recognized the challenge for a universally accepted definition and categorized drought into four different categories with specific definitions. The four most common definitions describing the different types of drought are (i) meteorological drought, (ii) agricultural drought, (iii) hydrological drought and (iv) socio-economic drought. These are illustrated in Figure 10.1.

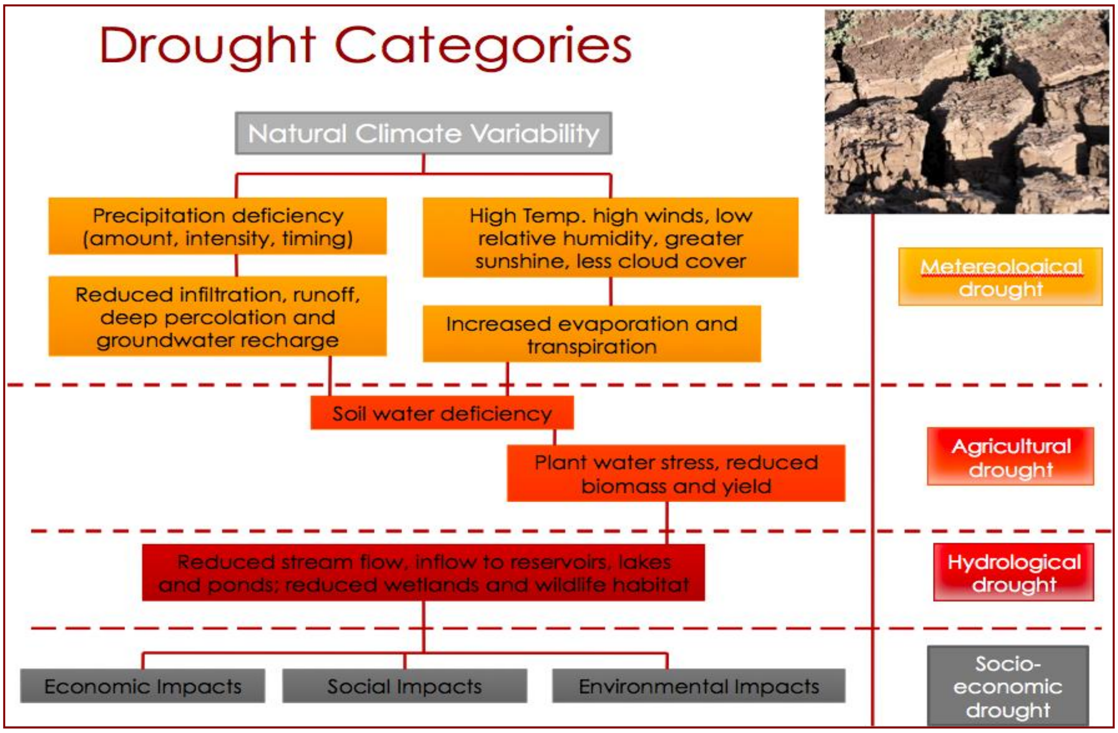

Fig. 10.1: Drought categories
(Wilhite and Glantz 1985; Wilhite, 2000; Castillo, 2009)

- ***A precipitation deficiency threshold usually defines meteorological drought*** over a predetermined period of time. This is a reduction in rainfall supply compared with a specified average condition over a specified period of time. Different indexes and methodologies are used to define the meteorological drought such as Standard Precipitation Index (SPI), the Standard Precipitation Evapotranspiration Index (SPEI), percentage of normal rainfall, etc. The SPI is currently the most sophisticated index used worldwide to measure meteorological droughts.
- ***Agricultural drought*** is commonly defined by the availability of soil water to support crop and forage growth. It is a reduction in water availability below the optimal level required by a crop during each different growth stage, resulting in impaired growth and reduced yields. Agricultural drought relates to an imbalance in the water content of the soil during the growing season which, although influenced by other variables such as the crop water requirement, the water-holding capacity and degree of evaporation, is also largely dependent upon rainfall amount and distribution.
- ***Hydrological drought*** is normally determined by a departure of surface and subsurface water supplies from some average condition at various points in time. It occurs when there is substantial deficit in surface runoff below normal conditions, or when there is a depletion of groundwater supplies. Hydrological drought reduces the supply of water for irrigation, hydro-electrical power generation, and other household and industrial uses.
- ***Socio-economic drought*** differs markedly from the other types of drought. It concerns the relationship between the supply and demand for some commodity or economic good that is dependent on precipitation. It represents the impact of drought on human activities, including both

indirect and direct impacts. This relates to a meteorological anomaly or extreme event of intensity and/or duration outside the normal range of events taken into account by enterprises and public regulatory bodies in economic decision-making, thereby affecting production and the wider economy.

Van Zyl (2006) also provides some alternative and practical definitions for drought types usually experienced in South Africa. This terminology is commonly used by farmers:

- ***False drought:*** This type of *"drought"* occurs when rainfall is normally below the long term average, but as a result of overgrazing the veld and fodder supply becomes prematurely depleted, giving the impression of a prevailing drought. In some instances false droughts have been wrongly declared as disaster droughts.
- ***Premature drought:*** This type of drought occurs when a chronic dry situation is so aggravated by overgrazing that a disaster drought is prematurely declared. In many instances, adjoining farms may differ widely as the intensity of a drought is, in this case, a result of veld management practices and the exploitation of grazing capacity.
- ***Prolonged drought:*** A drought situation can be prolonged for months when high stock numbers are maintained. This results in a more or less chronic food shortage even after rains have fallen. Plants become severely damaged. It is also possible that areas which have been declared drought stricken, do not recover after moderate rainfall. After a few months the drought could be even worse.
- ***Green drought:*** Green drought occurs when excessive grazing pressure is maintained in semi-dry periods. This causes food shortages even though the vegetation appears green and soil moisture reserves are favourable, or where natural causes such as rain showers during a drought promote a short spell of green growth, but not enough for breaking the drought. A green drought can also occur where insects severely attack plants and deplete the fodder to such a degree that it takes on the appearance of a drought situation. There is thus a shortage of fodder in spite of favourable climatic circumstances. The most common pests are locusts, Karoo caterpillar and the commando caterpillar.
- ***Financial drought:*** Farmers exert pressure to obtain financial assistance in order to improve cash flow. Therefore a region is sometimes declared drought stricken even though a drought does not prevail. The declaration of such a region as a disaster drought area has a negative effect on the interpretation of rainfall records because a drought is indicated when it does not exist

Drought Management

Climate variability is a given fact and the vegetation in a region is the result of a specific climate profile. It is important to remember that drought is a temporary anomaly, unlike normal arid and semi-arid climatic conditions, and one needs to distinguish between drought and aridity. Understanding the difference between these two concepts is important for the development of drought risk reduction plans, which are based on the assessment of drought risks (WMO, 2006). Farmers should be conscious of the fact that weather fluctuates from wet periods to dry periods and they therefore must adapt their agricultural practices to fit within the two extremes.

Figure 10.2 illustrates the interaction between long term production potential and climate profile in the agricultural sector. Within this climate profile certain years might receive above normal rainfall with potentially above normal production, whereas below normal precipitation in other years might result in lower than normal or below average production outputs (IPCC, 2001). However, this is not always the case since some farmers reported that with good agricultural practices, it is possible to receive the same profits during dry years as well (Olivier, 2010).

Market forces (supply and demand) more often than not complement below average production outputs during dry years. The ideal production situation though, is located between the two extremes since farmers can then plan accordingly (See Figure 10.2). The international environment also has a large impact on local economy and global forces can become very important.

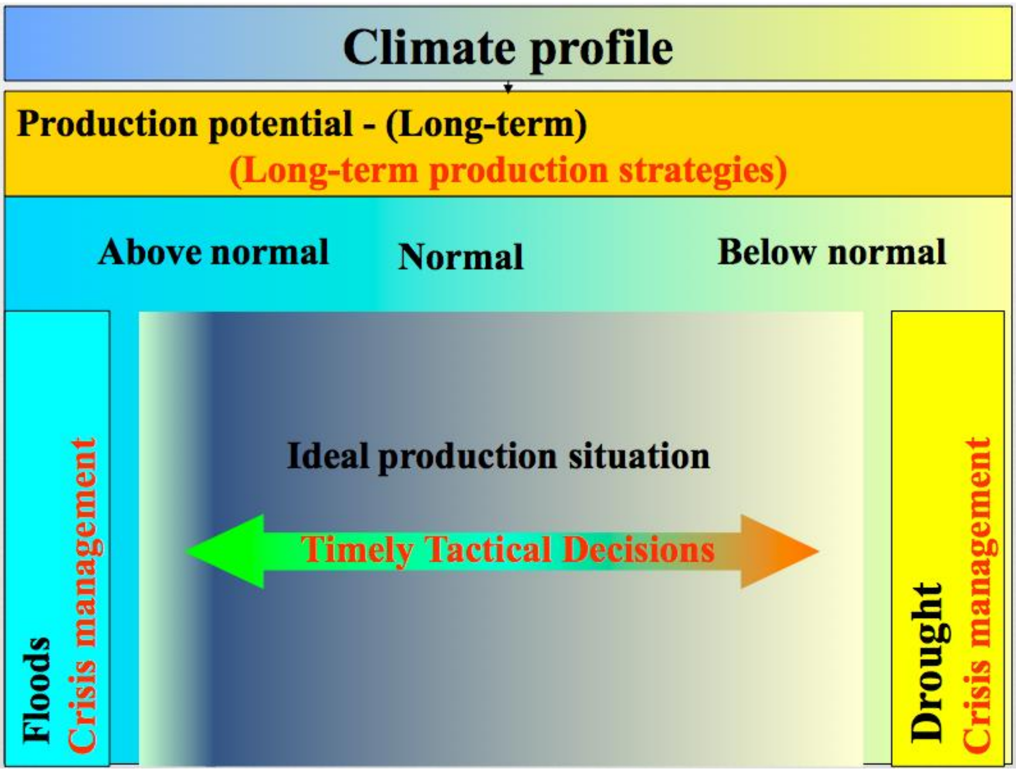

Fig. 10.2: Illustration of the relation between the climate profile, production levels and management decisions.
(Source: IPCC, 2001)

The purpose of drought risk assessment and drought early warning is to allow farmers to make timely tactical decisions instead of reverting to crisis management during the extreme climatic situations (See illustration in Figure 10.2). Farmers, the private sector and government should therefore include drought planning as part of the normal management process. Budgeting for drought according to the calculated drought mean annual loss, insurance schemes and fodder banks are some of the risk reduction measures to be included in planning.

Acts and Regulations

The South African National Drought Plan should consider the principles and guidelines contained in the following regulations, policies and acts:

- The Constitution;
- The White Paper on Agriculture, 1995;
- The White Paper on Disaster Management, 1999;
- The Disaster Management Act (57 of 2002);
- The Strategic Plan for Agriculture;
- The Conservation of Agricultural Resources Act (43 of 1983);
- National Disaster Management Framework (NDMF, 1995)
- National Drought Management Framework (2008)

Drought Plan Framework

The National Disaster Management Framework and the National Drought Management Framework consist of four key performance areas and three enablers. These provide the framework and structure for the provincial drought management plan and are addressed in the following two sections.

The four KPAs are:

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

10.1.1 KPA 1: Integrated Institutional and Organisational [15] Capacity for Drought Management

KPA 1 deals with the different institutions responsible for drought management at all levels and also how to ensure coordinated action and implementation. This section provides guidelines for joint action and implementation for all stakeholders, inclusive of government, the private sector and individuals.

10.1.1.1 Objective

Establish integrated institutional capacity within the province to enable the effective implementation of drought management that includes drought risk reduction and drought response and relief

The primary responsibility for the implementation of the Disaster Management Act (Act 57 of 2002) lies with the Department of Provincial Government and Traditional Affairs (COGTA). The respective Provincial Disaster Management Centres (PDMC) together with the District Disaster Management Centres are therefore pivotal in the coordination and implementation of the Act within the Province. The Provincial Department of Agriculture and Rural Development, on the other hand, is primarily responsible for agriculture and drought impacting on the agricultural sector.

Other role players involved in drought management include the commercial farming sector as well as the small-scale and communal farming sector. That therefore includes the different farmers' organizations, commodity organizations and local municipalities as landowners of communal land.

The term drought governance is used instead of drought management, which is more focused at the operational or farm level. The farmer and land owner must manage dry conditions in order to prevent disaster droughts on the farm while government has the responsibility to provide policy guidelines and to govern dry conditions and drought in order to prevent permanent economic loss and ensure sustainable resource use in the agricultural sector and the province.

10.1.1.2 National intergovernmental drought management structures

The national structures should be described in the National Drought Plan. Important, however, is for the EC Province to understand the role of the NDMC, DAFF and other government departments. The province is also obliged to participate in the National Disaster Management Forum and in the National Drought Task Team chaired by DAFF. The NDMC is responsible for all-sector drought declaration,

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[15] Institutional refers to the rules, regulations, agreements etc. Organisational refer to the organisations such as Departments, NGO's etc. Heading in national framework refer only to institutional. Should read "*Integrated institutonal and organisational capacity".*

impact assessment and drought monitoring. DAFF on the other hand is the lead department insofar the drought has impacted on the agricultural sector, while the Department of Water and Sanitation focuses drinking water and water for industries. The different water boards and municipalities are also important role players. The content and focus of this plan, however, is on agriculture, and industry, tourism and urban water supply is excluded from this proposed template.

10.1.1.3 Provincial intergovernmental drought management structures

This section deals with drought governance at provincial level. The proposed institutional organization and framework is illustrated in Figure 10.3. A Provincial drought strategy and plan is imperative for efficient drought governance in all Provinces. The Provincial Departments of Agriculture and the PDMC are the two key institutions responsible for drought governance and management in the province. In order to assist them with drought related issues and to ensure coordination of all sectors, *ad hoc* structures should be developed with the primary role of assisting the responsible departments with drought management in the province. The following are proposed:

- Provincial Drought Task Team at provincial level
- District Drought Task Team at district municipality level
- Reference farms in each of the quaternary catchments
- Drought Early Warning and Monitor Unit responsible for data capturing, analysis and early warning. Such a unit can be located within the Department of Agriculture or it can be outsourced to an institution with the capacity to maintain such a unit.

The proposed structure is illustrated in Figure 10.3.

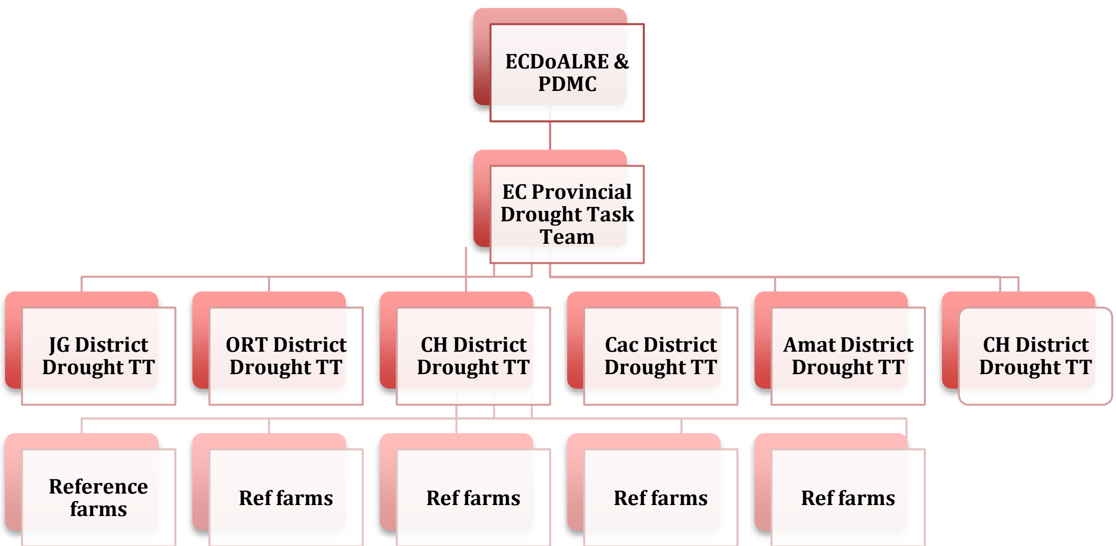

Fig. 10.3: Proposed structure for drought governance

10.1.1.4 Interdepartmental Working Group on Drought (Provincial Drought Task Team)

The provincial department of agriculture is responsible for the establishment and support to a drought committee or an interdepartmental working group on drought (Provincial Drought Task Team). This group should be multi-disciplinary and should consist of the following representatives:

- Provincial Department of Agriculture (Chair)
- Provincial Disaster Management Centre, PDMC (Co-Chair)
- DWS
- Organized Agriculture (EC Agri, NAFU and AFASA)
- Water User Associations
- SAWS
- Specialists co-opted from Industry, Higher Education, and Research Institutes etc.

The role of the EC Provincial Drought Task Force is as follows:

- Oversee the development and implementation of a detailed drought plan
- Oversee the updating and roll down of drought risk assessments at municipal level
- Provide guidance and advise to the HOD of PDoARD and HOD of COGHSTA with regards to drought declaration
- Provide guidance and advice to the HOD of PDoARD and HOD of COGHSTA with the application and approval of relief schemes
- Provide guidance and advise to the PDoARD and the HOD of COGHSTA with regards to mitigation and prevention programmes
- Review and recommend on the effectiveness of early warning systems
- Recommend on the improvement of drought plans
- Assist the PDoARD with drought impact assessments
- Provide guidance and assistance to the PDoARD during drought relief and response

10.1.1.5 District Drought Task Team

- Representatives
    - District Disaster Manager (Chair)
    - DoA District Manager (Co- Chair)
    - Extension Officer
    - Organized Agriculture
    - DFA
    - NAFU & AFASA
    - Chiefs where applicable
    - Local Catchment Management Agency

    - Local Business
    - Experts as required
- Tasks
    - Support and advice to extension officer
    - Local identification of reference farms
    - Local coordination of reference farms
    - Support to the PDoARD and the PDMC during the process of drought declaration
    - Support the PDoARD and the PDMC with drought relief actions
    - Reporting to representing structures, e.g. to DFA
    - Monitoring of local conditions
    - Validating local conditions
    - Assist with coordination of drought relief actions (e.g. fodder distribution etc.)

10.1.1.6 Provincial Disaster Management Centre

The role of the PDMC is mainly coordination and support to all provincial departments, district municipalities and local municipalities and the private sector in disaster management issues. The role of the PDMC in the context of droughts is as follows:

- Coordinate and maintain drought early warning systems in collaboration with SAWS, DAFF and PDoARD
- Coordinate drought relief and response in collaboration with municipalities and PDoARD
- Ensure inter-institutional collaboration and coordination
- Develop and maintain an all-inclusive provincial drought management framework and plan
- Conduct an all-inclusive drought risk assessment for the province
- Coordinate, maintain and implement drought risk reduction awareness, training and education programmes in collaboration with other role players
- Include drought issues (drought early warnings, drought risk reduction, awareness, monitoring and drought relief) as a standing point on the agenda of the provincial disaster management forum
- Execute administrative responsibilities for disaster declaration and relief activities

10.1.1.7 Provincial Departments of Agriculture and Rural Development (PDoARD)

The PDoARD deals primarily with agriculturally related droughts[16] and is the leading agent for agricultural related drought issues. The PDoARD is responsible for the following:

- Development and maintenance of an agricultural drought management plan that includes:

[16] Note the difference between agricultural related droughts and agricultural droughts according to the definition.

    - Drought risk assessment
    - Drought risk reduction plan
    - Drought response plan
    - Drought relief and recovery plan
- Establish and Co-Chair the provincial interdepartmental working group on agricultural droughts (Drought Task Team)
- Develop and oversee a research programme on drought related issues
- Assist district municipalities and the farming sector with drought risk assessments
- Develop and execute extension programmes with a focus on drought risk reduction and agriculture best practice in given climate zones
- Promote conservation farming principles
- Lead education and awareness programmes for drought risk reduction in collaboration with the PDMC and other role players
- Provide additional extension services with focus on conservation farming and good agricultural practices to small-scale and communal farmers
- Provide additional support to communal farmers in terms of markets and timely marketing of animals during dry periods
- Participate actively in disaster management forums at provincial and district levels
- Develop and implement a system for drought monitoring and evaluation
- Develop and implement an information management system
- Develop and maintain a drought early warning system in collaboration with the DAFF, SAWS, DWA and the PDMC
- Compile vegetation indicator maps by using technology available at national and provincial level as well as other research institutions
- Disseminate timely information amongst all clients
- Provide provincial guidelines for drought classification in line with national guidelines
- Apply and monitor dry periods according to agreed upon national guidelines
- Ensure and monitor timely destocking of animals during dry periods
- Compile drought impact assessments and source funding for drought relief and response in collaboration with the PDMC. The following should be adhered to:
    - Coordinate drought relief applications
    - Evaluate and verify drought relief applications
    - Conduct the damage costs and a cost benefit analysis
    - Prepare reports
    - Maintain records
    - Verify impact assessments and prepare final reports for drought relief assistance at national level in collaboration with the PDMC
- Coordinate and manage drought relief in collaboration with the relevant DDMC and the PDMC. The following should be adhered to:

    - Management and control of funds according to guidelines from Treasury and the Auditor General
    - Record keeping
    - Timely and efficient support to farmers according to drought relief guidelines
    - Appoint and pay service providers to deliver services to affected farming communities
- Ensure sufficient capacity for drought management
- Provide the necessary funding to develop and maintain an online facility for the capturing of farmer data
- Provide funding for the development of a departmental or outside facility for the monitoring and maintaining of meteorological and on-farm data from reference farms

10.1.1.8 District municipalities

District municipalities are mandated according to the NDM Act (Act 57 of 2002) to coordinate disaster management at district and local level. They should play a pivotal role in drought management as follows:

- Provide information concerning drought in the municipal area
- Conduct detailed drought risk assessments at district level
- Assist the PDoARD and PDMC with dissemination of information
- Assist local municipalities with local drought management plans
- Coordinate and collaborate with the PDoARD and PDMC on drought relief and response actions within district
- Participate in the district drought task team
- Assists the PDoARD and PDMC with data gathering and data storage

10.1.1.9 Local municipalities

Local municipalities in most cases own the communal land within its boundaries and as landowners they are responsible for the sustainable use of its resources. Local municipalities should contribute to drought risk reduction as follows:

- Ensure the existence of lease and usage contracts for the use of commonages (land belonging to municipality)
- Maintain infrastructure such as fences and water provision on commonages (land belonging to municipality)
- Ensure the sustainable use of resources by applying grazing capacity guidelines as provided by the PDoARD
- Prevent overgrazing of commonages

- Ensure the application of good agricultural practices on all commonages
- Provide support to extension officers in extension programmes directed at communal farmers
- Develop drought management plans for commonages. These plans include:
    - Drought risk assessment of commonages
    - Drought risk reduction plan
    - Drought relief plan
    - Drought recovery and rehabilitation plan
- Assist the PDoARD in the control and distribution of emergency feed and fodder supplies
- Assist communal farmers with marketing channels for animals

10.1.1.10 Commercial farming sector

Commercial agriculture is well organized with farmers associations, regional representative structures and Provincial Agricultural Unions at provincial level. The different commodity organizations are part of the commercial farming sector. Assistance to this sector is in accordance to the Disaster Management Framework.

Organized agriculture already plays an important role in drought planning and they are responsible for the following:

- Maintain and expand the reference farm scheme to ensure representatives from at least all quaternary catchments
- Motivate all farmers to support the reference farm scheme
- In collaboration with the PDoARD and PDMC, computerize the reference farm information system for easy analysis and as an early warning and drought monitor mechanism. The PDoARD and or the PDMC should provide the necessary funding to develop and maintain an online facility for farmers to submit the necessary meteorological and on-farm data.
- Provide advice to government with drought declaration through the provincial and district drought task teams
- Provide support to government with administration of relief schemes. Data capturing regarding drought impacts remains a challenge and organized agriculture should assist the PDoARD with the capturing and verifying processes.

In order for the sector to be considered for drought relief and assistance, they should have:

- Adapted agricultural practices to climatic conditions with sustainable resources use in mind
- Applied drought prevention and -mitigation strategies
- Followed good agricultural production practices
- Utilised early warning in their planning

The commercial farming sector in the EC is divided mainly into three agricultural systems, namely irrigation farming, which is highly intensive and depends largely on water from reservoirs, rivers or groundwater, the extensive livestock farming sector, which consists of small-stock, large-stock and game farming, and rain fed agriculture which is mostly characterized by crop production. All sectors should treat water as a scarce resource and should adhere to the following:

- Introduce technology that introduces the efficient use of water such as drip irrigation, where possible
- Maintain own water reticulation infrastructure to prevent unnecessary leakages and water wastages
- Adhere to allocated water quantities according to DWS allocations
- Adhere to the prescriptions of the National Water Act (Act 36 of 1998)

Extensive stock farmers should adhere to the following in order to be considered for drought relief and support:

- Updated and valid stock counts should be kept at all times
- A register of all stock including purchases, sales, progeny and mortalities should be kept for at least 12 months prior to a drought application
- Fences and water reticulation systems, whether privately owned and erected or erected with government subsidy, must be maintained and secured at all times
- Good agricultural, including grazing, principles should be applied and adhered to. Overgrazing will lead to forfeiture of assistance
- Farmers must adhere to the grazing capacity guidelines prescribed by the PDoARD
- Farmers must reduce animal numbers according to guidelines provided by PDoARD after drought early warnings issued by the PDoARD. Current guideline are a 30% reduction in animal numbers, but this should be phased in according to veld conditions of individual farms
- The purpose of drought relief schemes must consider the sustainable use of natural resources
- The maximum number of livestock to be considered for governmental drought relief schemes is 200 LSU. Drought relief and drought support is regarded as a safety net for farmers to maintain a minimum production capacity. Government recognizes the limitations of drought support in that not all farmers will be able to recover fully to the same state as before from the impacts of drought.

10.1.1.11 Reference Farms

10.1.1.11.1 Objectives

The objective is to formalize and implement a system of reference farms based on practical experience and research over a long period of drought management. Reference farms are those particular farms chosen in a catchment area, on the basis that a farmer is prepared to collect and supply data on rainfall, carrying capacity, veld condition and other scientific information according certain terms and conditions, in collaboration with the PDoARD. Data will be submitted on a regular basis via the Internet on a web-based system. This data will be analysed, processed and used as a source for drought early warning.

A service provider from a reliable research institution to be appointed will be responsible for the capturing, processing and analysing of the data and to advise decision makers as an early warning message on the deterioration of veld and drought conditions, and the declaring of drought as disasters as part of the Disaster Management Act, 2002.

Furthermore, the system of reference farms can contribute to an effective determination of carrying capacity for the different catchment areas, and could act as a stimulus for farmers to farm on a sustainable basis and to use risk mitigation measure.

10.1.1.11.2 Geographic selection

Reference farms must be as representative to a specific climate zone as possible. One acknowledges the fact that rainfall is not always the same on all farms within a specific region. In order to ensure proper provincial coverage the quaternary catchments should be used as the preferred region for sampling reference farms. At least one reference farm should be sampled from each quaternary

Profile of Reference farms

The natural resources on the reference farm must be representative of the specific catchment. The most notable natural resources are veld type, water supply, soil type, geographical features as well as the farming system.

The farmer (owner or lessee), called the participant, must be willing and able to keep records and provide data on at least a weekly basis. The participant must apply good agricultural practices according to the norms and climate conditions of the specific region. In addition, the participant must be connected or have access to the Internet in order to provide and upload data on a regular basis.

10.1.1.11.3 Responsibility of participants

Participants in the drought monitor and early warning project must:

- Supply daily meteorological data on at least a weekly basis. The possibility of automatic meteorological data capturing mechanisms should be discussed with SAWS.

- Supply an inventory of all animals and movement of animals in terms of progeny, sales and purchases on the farm, i.e. sheep, cattle, horses, donkeys, ostriches and game (Values according to the present Meisner tables or as reviewed).
- Adhere to the carrying capacity according to the norms of the PDoARD and DAFF over a twelve-month cycle. As a farmer who applies good agricultural practices he/she will under-graze some years and overgraze other years, depending the condition of the veld and climate conditions. Therefore the carrying capacity will be exceeded some years etc. The baseline veld condition on a specific farm differs from others and not all farms have the same carrying capacity, but good agricultural principles apply.
- Comply with good farming practice (e.g. veld management system) as approved by the PDoARD.
- Comply with the protocols provided by the service provider and the PDoARD.

Extension Officers and the Soil Conservation Committees will play a vital role in the role-out of the scheme and overseeing measures.

10.1.1.11.4 Functioning

Participants will have to upload the prescribed information to the early warning research unit through a prescribed web based programme. By default the system will automatically remind participants of any non-compliance. This could have a detrimental effect on those farms coupled to the particular reference farm, as they are also dependent on the results obtained through the scheme and it might jeopardize the outcome of the advice to the decision makers as far as financial assistance is concerned in case of required drought assistance.

10.1.1.12 Provincial Drought Mitigation Centre

- Research and propose the most relevant spatial and temporal drought monitor indicators
- Continually monitor spatial and temporal drought related indicators
  - Design and develop software for data submission, data analysis and reporting
    - Develop e-based data submission system from reference farms to research unit
    - Obtain inputs from other research stakeholders
    - Process and analysis of data
    - Report to different stakeholders
  - Integration of existing drought related indicators
  - Analysis of all drought related indicators
  - Compilation of integrated report
- Advice to relevant stakeholders (PDoARD, PDMC, DWA, organized agriculture and others) regarding drought early warning and other related issues.

The early warning research unit should provide the necessary early warning to the PDoARD and farmers in case of a pending drought, based on the SPEI and feedback from reference farms. Once feedback from reference farms and an SPEI of -1,5 is evident, the NDVI and soil moisture content should be evaluated and ground-truthed within the affected catchment.

The early warning research unit can be based as a unit within the Department, but services can also be contracted to an organization with relevant experts and capacity.

10.1.2 KPA 2: Drought Risk Assessment

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 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). Questions arise as to 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?

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, the spatial extent of damage caused by drought (i.e., the area affected by drought) and the 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 (Rowan *et al*., 1994), researchers described lower preference for such tools by livestock producers compared to crop producers (Guyer, 1986; Lawrence & Wang 1998; Schroeder *et al*., 1998; Ward *et al*., 1999). One possible reason is differing levels of risk across livestock and crop enterprises. Alternately, a 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.
- Undertake a vulnerability assessment (socio-economic and institutional analysis)
- Estimate time of exposure (climate forecast)
- Define capacities and measures to be taken.

The disaster risk assessment methodology as stipulated in the National Disaster Management Framework (NDMF, 2005) is shown in Figure 10.4. This model was used as a framework for calculating drought risks. Stage one provided valuable information for the Phase 1 assessment and included a drought hazard and vulnerability assessment, a literature study and a desktop review.

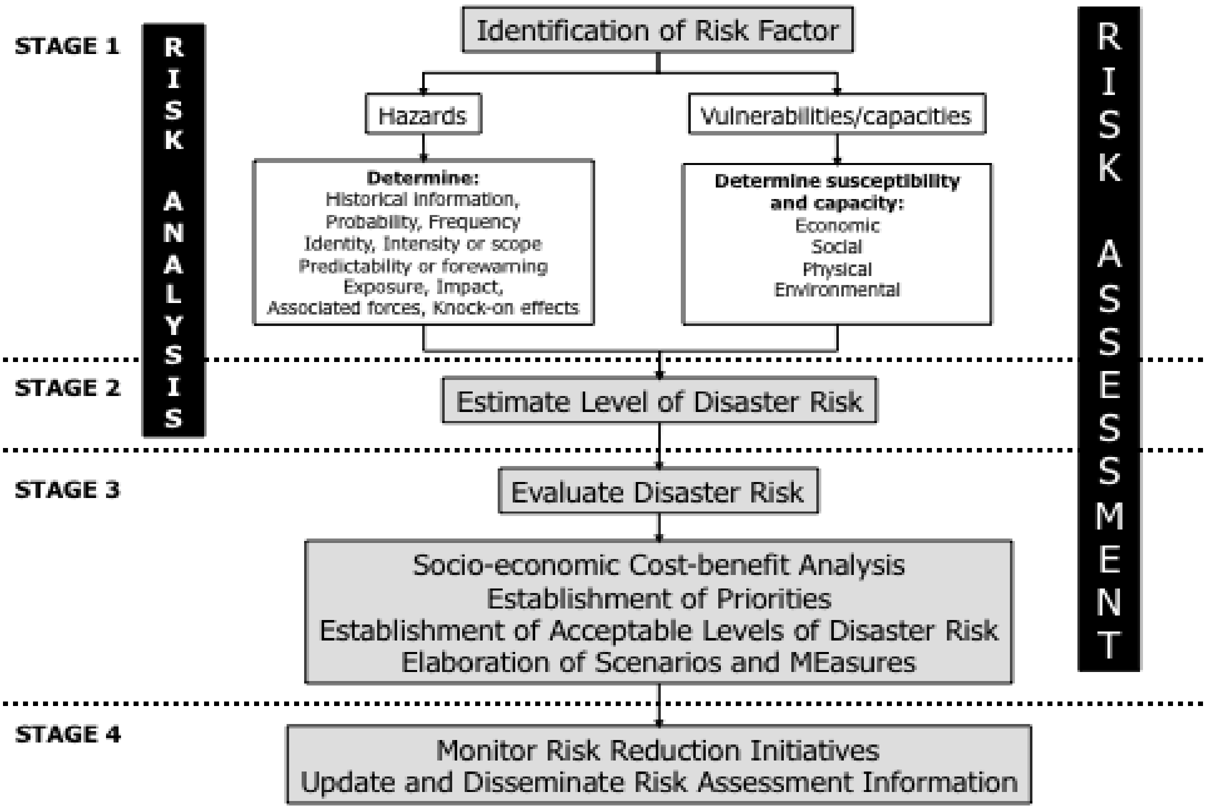

Fig. 10.4: Disaster Risk Assessment Methodology

(Source: NDMF, 2005)

In the case of drought, the main determinant for hazard assessment is a water deficit for normal production resulting from 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).

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, a geographically specific decline 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 to wetlands, increased incidence of wild 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 cost, the 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 sector 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 loss 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 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 possibly moving 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 may ultimately affect the local community due to the economic slowdown of a small town.

After generating a priority list of impacts, the bulk of the vulnerability assessment can be conducted. The vulnerability assessment's focus is identifying 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 is as important as vulnerability and is included as major indicators for drought risk reduction.

The main objective of KPA 2 is to establish a uniform approach to assessing and monitoring drought risks that will inform drought risk reduction and drought response management by provincial organs of state and other role players. The first step in the development of a drought management plan is the drought risk assessment. Scientific drought risk assessment should be conducted at provincial level, but also at micro level (District level at least)[17].

Drought risk assessment is not a once-off activity with the purpose of identifying priorities and sensitive indicators; it is a continuous process that includes monitoring and evaluation of drought risk indicators.

10.1.3 KPA 3: Drought Risk Reduction

Drought risk reduction encompasses all actions that reduce the risk of dry periods or droughts to farming enterprises, livelihoods or the economy at large. Strategies or activities could include (i) prevention, (ii) mitigation, (iii) adaptation, (iv) avoidance, (v) adjustment, or (vi) consumption smoothing through insurance etc.

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[17] The absence of a scientifically based risk assessment is not an excuse for non-compliance to the development of drought management plans.

Most effort and funding should be allocated to risk reduction strategies. As a general rule one can expect a seven- to ten-fold saving on capital expenditure on risk reduction instead on relief and recovery.

The main objective of KPA 3 is to ensure that all drought management stakeholders develop and implement integrated drought risk management plans and risk reduction programmes in accordance with approved guidelines.

The focus of drought risk reduction is the prevention and mitigation of the potentially devastating impacts of drought. This should be achieved mainly through the application of good agricultural practices in both the intensive irrigation sector as well as in the extensive livestock sector. Drought risk management is the responsibility of each individual land owner and farmer. The main roleplayers here are the farmers themselves, together with their supporting structures as well as the PDoARD and research institutions. Farmers should adapt to their local climatic conditions and ensure adequate adaptation and coping mechanisms. Resiliency should be enhanced through the timely application of risk reduction measures such as insurance, reserve feed and fodder banks and a grazing capacity suitable to the veld condition. Extension services play a critical role in the transfer of knowledge and during monitoring and evaluation.

The following should be addressed in the drought risk reduction plan

- Early warning systems
- Data gathering, analysis and dissemination needed for planning
- Adaptation, mitigation and prevention strategies
- Extension programmes
- Research programmes

10.1.3.1 Early Warning and Monitoring

Drought is a slow onset disaster and early warning is possible through several well developed indicators, which are monitored by the SAWS and should also be the responsibility of the Drought Mitigation Centre. The following indicators are important:

- Monitoring of indices such as the % of normal, SPI and SPEI
- NDVI
- Soil moisture content
- Reference farms data sent in at regular basis.
- Data being processed with weekly reports
- Using the SPI/SPEI are primary indicators
- Considering secondary indicators such as NDVI and soil moisture content satellite images

- Reporting and ground-truthing at monitor farms. If monitor farm show critical condition then drought disaster declaration for that quaternary catchment should be activated. Ground-truthing and final demarcation is the responsibility of the District Drought Task Team.

Drought indicators serve as a methodology to quantity the onset and severity of dry conditions and droughts. Considering the different types of drought and the complexity of drought, a single indicator cannot be used to determine when a drought has occurred and/or when a drought should be declared a drought. The set of indicators easily monitored and available at present are soil moisture, NDVI, satellite vegetation index, groundwater levels, streamflows, dam levels, per cent of normal precipitation and the SPI or preferably the SPEI. Different sets of indicators are required for the crop producing areas during and outside the growing season. Important indices for the growing season are topsoil moisture index, the Keetch-Byran Drought Index, 3-month SPI and SPEI and the satellite vegetation health index. The timing of heat waves and dry periods are also significant indicators for specific crops. The different categories of drought and the corresponding indicators are discussed in Chapter 3 of this report.

10.1.3.2 Data management

Data management and data sharing are key in the effective management of drought risk reduction and drought relief and support. All stakeholders are responsible for data capturing and data management according to their own mandates, but data sharing must be controlled by means of inter-governmental and inter-organizational MOUs. Drought early warning, drought risk reduction and drought relief management is only possible when all potential sources of data are considered and combined. Coordination and processing of data is the responsibility of the Drought Mitigation Centre, which is responsible for daily updates, processing and dissemination of results.

10.1.3.3 Adaptation mitigation and prevention strategies

These include:

- Macro level impacts on adaptive capacity
- Culture, ethics, knowledge, perceptions
- Farm level adaptation
- Adjustment strategies
- Drought avoidance strategies
- Alternative livelihood activities (casual labour and informal trade)
- Food management strategies
- Sale of non-productive items and productive items
- Social networks
- Animal feeding strategies

- Drought insurance
- Coping strategies

10.1.3.4 Extension programmes

Extension is the frontline for any drought mitigation and drought risk reduction programme. The drought risk assessment highlighted the importance of extension programmes especially amongst communal and small-scale farmers that cannot access the services of the private sector.

10.1.3.5 Research

The PDoARD is primarily responsible for prioritizing drought research needs and programmes. Research projects can be undertaken within the Department or contracted to organizations with capacity to execute research projects.

10.1.4 KPA 4: Response and Relief

Response and relief is required during dry periods and droughts. The most significant critique against government relief actions is that it is always too late. Planning and development of contingency plans are essential for timely and efficient relief actions. Pre-approved contingency plans are a pre-requisite for efficient relief actions. All role players must pre-approve contingency plans; that includes Treasury at all levels.

The different indicators and thresholds will play an important role in the activation of contingency plans. Plans must be designed in such a way that the plan can be activated with immediate effect once a certain threshold is reached for specific indicators; that includes activation of funding for pre-arranged activities as agreed upon in the contingency plan.

The main objectives of KPA 4 are to ensure effective and appropriate drought response and relief by:

- Implementing a uniform approach to the dissemination of early warnings,
- Providing an economic safety net for the agricultural sector to avert or reduce the potential negative drought impacts on the regional economy and prevent the out-migration of farmers from the agricultural sector,
- Implementing immediate integrated and appropriate response and relief measures when significant drought occurs or is threatening to occur, and
- Implementing differentiating indicator thresholds that consider the unique circumstances of the different agricultural systems.

Government has a responsibility to provide safety nets in the form of relief and recovery support after exogenous shocks such as disasters, and particularly drought, in the context of this plan. Most of South Africa is a semi-arid to arid area with relatively low rainfall coupled with regular dry periods. The farming sector and communities should therefore adapt agricultural practices to climatic conditions and should take pro-active measures themselves to mitigate the impacts of drought. Regular dry periods with a probability of more than 1 in 10 years or a 12-month SPI > minus 1.5 should be dealt with by the respective farming sectors themselves. The agricultural sector can apply for drought support once the 12-month SPI in a specific region reaches the value of -1.5 (severe drought) or when water restrictions reached the 50% benchmark. In the case of subsistence and communal farmers the 12-month SPI < minus 1.2 could already be regarded as a severe drought because of their limited resources, low coping capacity and degraded land.

Governmental assistance schemes are not designed to replace drought losses; they are designed to enable farmers to continue farming and recover sufficiently to continue with food production despite the negative impacts of drought. In many cases the drought relief schemes are the only livelihood survival mechanism for subsistence and communal farmers; therefore the need for specific tailor-made schemes for these communities.

10.1.4.1 Drought declaration

The Disaster Management Act (Act 57 of 2002) provides for the declaration of disasters through national, provincial and local government. When a dry period develops into a drought and the farming sector, the PDoARD, municipalities or other stakeholder's highlight the need for a drought declaration, the Provincial Interdepartmental Drought Committee (PDTT) should be activated and they should adhere to the following:

- Initiate efforts to assess the current and potential magnitude and severity of the drought
- Inform all relevant departments of the findings and potential impact
- Alert all disaster management role-players in the province who might be of assistance and affected
- Ensure, in collaboration with PDoARD and the PDMC through the structures of organized agriculture, that affected farmers have reduced stock numbers in time.

The involvement of advisory or extension services and local government in a province's assessment is crucial so as to advise the DAFF and the NDMC on the scale and extent of the losses caused by drought. Provincial departments will then be informed about the financial assistance required to normalize the situation. Key determinants will be considered during the assessment, such as veld, livestock, fodder and crops, weather and climatic conditions, and water supply systems so as to ascertain whether the disaster was beyond the farmers' control or not.

10.1.4.2 Drought indicators

The SPI or the SPEI should form the main meteorological indicators for dry periods and droughts. The lack of reliable meteorological data might impede on the usefulness of the said indicators and therefore the need for all farmers to keep at least rainfall records and provide the data to a provincial database. Calculation of the SPI is only possible with at least 30 years of historical rainfall data. The Department should therefore endeavour to obtain historical records from farmers and maintain the necessary database. Weather data obtained and captured by the SAWS and the Institute for Soil, Climate and Water of the ARC must be made available to the respective role players such as agriculture and disaster management at different levels.

The NDVI is an important indicator to determine veld deterioration as a result of drought. One of the main challenges with the NDVI, however, is that it is difficult to distinguish between overgrazing and poor veld condition because of drought. Additional measures are therefore required to ensure that farmers who overgraze are not favoured for drought support in relation to farmers who apply good agricultural practices. The inputs of extension officer and the contribution of reference farms in each quaternary catchment should provide the necessary monitoring mechanism.

For detailed guidelines on drought indicators refer to Chapter 3 of this report or the DAFF document *"Drought Indicators"* (DAFF, 2016)

10.1.4.3 Drought Relief

Drought relief is the joint responsibility of the DAFF, provincial departments of agriculture and the NDMC, PDMC and district disaster managers. The DAFF and provincial departments of agriculture are the lead agents for drought relief and the extension officers will monitor the relief actions at grassroots level jointly with the district disaster managers. That includes monitoring, record keeping and evaluation of the relief action. Detailed documentation should be prepared for drought relief, taking cognisance of the following:.

- Drought relief should follow a process as stipulated in a *Drought Contingency Plan.*
- The drought report template should be used.
- Guidelines for the implementation of drought relief template should be followed.

The enablers are in support of the key performance areas and are similar to those prescribed in the National Disaster Management Framework.

Enablers

The enablers as described in the National Disaster Management Framework are in support of the four KPAs. The three enablers are:

- Enabler 1 Information management and communication
- Enabler 2 Education, training, public awareness and research
- Enabler 3 Funding

The three enablers are discussed in the next section.

10.1.5 Enabler 1: Information Management and Communication

Disaster risk reduction and disaster relief requires up-to-date and reliable information in a format ready for decision-making. Information systems could involve remotely sensed information, GIS, early warnings, demographic information, market information, hazard information, information about coping capacity and many more. Enabler 1 seeks to address the information needs as well as the processing and storage of data. In addition, communication is equally important and this enabler also deals with communication systems.

The main objective of Enabler 1 is to guide the development of a comprehensive information management and communication system and to establish integrated communication links with all drought management role-players.

Information and the analysis and dissemination of information are key elements in drought management. Information in most cases is based on data gathering and analysis. All role-players should contribute to the process of data gathering and the following guidelines are applicable:

10.1.5.1 Weather related data

The SAWS is primarily responsible for weather related data and information and it should make these available as needed by the DAFF, Provincial Departments of Agriculture, the NDMC, PDMC, municipalities or the farming and private sector. DAFF and NDMC should enter into an agreement with the SAWS to ensure their support to the drought management framework and plan.

The Agricultural Research Council also has valuable climate and weather related data and information. The Elundini report is a good example of drought related information and should be distributed to all role-players and farmers. Again the Provincial Department of Agriculture should ensure the continuation of the agreement with the ARC for the availability of data and information for the purpose of research and early warning.

The need for rainfall data in each catchment is imperative for future drought declarations and land owners should participate in the provision of rainfall and other climate data. The reference farm system implemented in the Northern Cape is a good example of farmers participating in data gathering.

Modern-day drought early warnings are fairly accurate and are communicated well on most of the national media. The interpretation and implications of dry periods and pending droughts, however, are not well communicated.

10.1.5.2 On-farm data

On-farm data are data such as animal numbers, farm sizes, grazing capacity and veld condition. The extension services and the PDoARD should work jointly to gather, store and analyse the data. The monitor farm systems should be computerized in order to ensure up-to-date analysis. Provincial agricultural structures can also assist to ensure that all quaternary catchments are represented by at least one monitor or reference farm. Data obtained from the reference farms should be updated regularly in order to ensure up-to-date calculations of SPIs and other indicators.

10.1.5.3 Data storage and analysis

The NDMC and DAFF are primarily responsible for drought related data gathering and analysis and should provide systems for data storage and analysis. Research institutions and Higher Education Institutions can assist with the analysis of data and the development of systems that automate data analysis.

Data regarding the monitor farms should be computerised and automated at provincial level in order to have timely feedback.

Meteorological data from the SAWS and the ARC should be made available for research and early warning.

10.1.5.4 Information dissemination and communication

Extension services are primarily responsible for the dissemination of information regarding agricultural related droughts and that should be coupled to a communication strategy. The private sector and organised agriculture should cooperate and provide own resources for increased communication and information dissemination.

10.1.6 Enabler 2: Education, Training, Public Awareness and Research

The main objective of Enabler 2 is to promote a culture of drought adaptation and drought risk avoidance among stakeholders by capacitating role-players through integrated education, training and public awareness programmes that is informed by scientific research.

The DAFF and the extension services of the respective PDoARD together with the NDMC, PDMC and the DDMC are primarily responsible for education, training and public awareness. Extension officers are the *"foot soldiers"* with direct contact with farmers and should be well trained and equipped to provide training and information to the farming community. Proper extension programming and planning is necessary in order to educate and train farmers. It is acknowledged that extension programmes for commercial farmers differ from programmes to emerging, small-scale, subsistence and communal farmers. Programmes with a focus on the specific needs of the different farming sectors should be designed and implemented.

10.1.6.1 Education and training to all farmers

The commercial farming sector in general uses sophisticated technology and successful farmers apply sound agricultural practices, yet a large group of these farmers experiences droughts regularly. The over-exploitation of the natural resource base is of concern and the PDoARD together with organised agriculture should identify areas of overgrazing and land degradation and institute measures to stop the continued degradation of the land.

The private sector, through agricultural businesses, is currently the primary source of information dissemination to commercial farmers and they should also be sensitized to the importance of drought management as an integral part of the management system on all farms.

Special emphasis should be placed on support to communal farmers who currently tend to over-exploit the natural resources. The land owners (municipalities and the state) should collaborate with extension services to educate land users and, if necessary, to enforce the application of sound agricultural practices. Extension programmes with an emphasis on drought risk reduction should be developed and implemented by the PDoARD.

10.1.6.2 Research

A large number of drought related research gaps exist. Continued research should be coordinated and the DAFF, NDMC, PDoARD and organised agriculture should mobilize funds and task research institutions such as the ARC, Universities, the Water Research Commission (WRC) and others to conduct drought related research with an emphasis on climate resilience, adaptation, mitigation, prevention and coping capacity.

10.1.7 Enabler 3: Funding Arrangements for Drought Management

The main objective of Enabler 3 is to establish mechanisms for the funding of drought risk reduction and drought response and relief.

Funding for each of the KPAs are discussed separately:

10.1.7.1 Funding for institutional arrangements

Government departments responsible for drought management should cover own costs while the DAFF, PDoARD and the NDMC and PDMC are jointly responsible for the direct costs and per diems of non-governmental individuals contributing to the different drought task teams.

10.1.7.2 Funding for drought risk assessment

The PDMC is primarily responsible for the funding and development of an all-inclusive provincial disaster risk assessment (Act 57, 2002) while district municipalities have the responsibility for district disaster risk assessments. The fact that the PDoARD contributes toward provincial agricultural related drought risk assessments does not exclude the PDMC from the responsibility of funding risk assessments that includes all sectors. The DAFF and NDMC are responsible for national risk assessments that also consider food security.

10.1.7.3 Funding for disaster risk reduction

Farmers themselves best support drought risk reduction through the application of good agricultural practices. The primary role of extension services is the transfer of technology and knowledge that should empower farmers to apply sound agricultural practices. The PDoARD is therefore instrumental in the achievement of increased drought resiliency. Apart from the role of extension, specific targeted programmes and projects also serve as mechanisms to increase awareness and resiliency against droughts. These projects are funded on a project-to-project basis through the Mitigation and Prevention fund from DAFF called the Conditional Grants scheme.

The NDMC and PDMC are mandated and obliged by the Disaster Management Act (Act 57, 2002) to implement and fund disaster risk reduction efforts. Drought being the most prominent disaster in South Africa, the NDMC and PDMC must also provide funding for drought risk reduction programmes and projects.

10.1.7.4 Funding for disaster relief and response

See Chapter 6 on the Disaster Management Act (Act 57 of 2002):

The farming community must firstly be able to prove that they did everything within their own capacity to manage and cope with dry periods. Farmers should adapt to climate conditions and continally work with the relevant Departments and other research institutions to implement new drought mitigation and avoidance strategies. Under extreme drought conditions Government will provide relief as a safety net.

Districts should first explore own reserves to support especially the communal farmers farming on municipal land. If municipalities have no funding, the relevant Departments must first utilise own emergency funding to support farmers and only when they can prove that they have no resources of their own, are they allowed to apply for funding from the disaster management structures at provincial and national level.

Funding models should adhere to the following principles (From the *National Disaster Management Framework)*:

- ***Adequacy**.* Both the Agricultural Departments and disaster management structures and municipalities should have adequate resources to perform their functions effectively. In relation to drought management, all organs of state should have access to sufficient funding to be able to discharge their legislative responsibilities.
- ***Equity.*** Funding mechanisms should ensure that legislation is implemented equitably across municipalities and affected agricultural systems. This would help to avoid inter-jurisdictional spill-overs arising from uneven and inequitable implementation.
- ***Predictability.*** Any funding mechanism that includes intergovernmental transfers should ensure predictability by making allocations from national to provincial and local organs of state over the term of the Medium-Term Expenditure Framework (MTEF). Any allocations to municipalities should be disclosed timeously so that municipalities are able to take cognizance of these allocations in their annual budgets.
- ***Administrative efficiency*.** The cost of administering the funding mechanisms should be kept to a minimum. Ideally, the funding mechanisms should not impose new reporting obligations on any organ of state. Rather, the reporting process should be integrated into the existing reporting cycle.
- ***Incentive effects*.** Funding mechanisms should be designed in such a way that they provide incentives for sound fiscal management and reduce the likelihood of inefficient fiscal practices. In this way, perverse incentives in the system may be minimized and the risk of moral hazard behaviour by recipients of the funds is discouraged.
- ***Autonomy.*** The assignment of functions or the transfer of funds between spheres of government should not undermine the constitutionally mandated autonomy of provincial and municipal organs of state. The autonomy criterion should be viewed within the context of co-operative governance.

- ***Risk pooling*.** The cost of droughts can become so substantial that no single provincial and municipal organ of state is able to fund recovery efforts on its own. In such cases, funding mechanisms should make provision for post-disaster recovery costs to be shared across the widest possible population rather than being a burden on the affected population.
- ***Timely funding*.** Contingency plans and funding mechanisms should consider the timely drought relief to farmers. Emergency funding for drought relief should be made available immediately during the drought and not months after the funds are required.

Funding models depend on the amount of funds available as well as on national guidelines. In addition to funding guidelines, the following should also be considered:

- Feed and fodder suppliers must be carefully selected.
- Tender processes for the supply of feed and fodder must be controlled and the interest of the beneficiaries must always be considered
- Mark-up and profits to the middle man must be controlled
- Credit management through Coops must be responsible. Agricultural companies and the private sector should have pre-agreements with the Department with regards to drought relief schemes

Conclusion

The framework format proposed in this chapter can be used at national, provincial, district or metro and local municipal level. Standardisation of all disaster management plans according this framework will create a better understanding and implementation of disaster management plans. Most disaster managers are already familiar with the national and respective disaster management frameworks. Compiling hazard-specific plans according the same template is sensible.

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11 Recommendations for Drought Risk Reduction

Jordaan, A.J.

Executive Summary

The focus of this 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 land owners are also provided in separate tables.

The Community Capitals Framework (CCF7) serves as the basis on recommendations for resilience building. Factors contributing toward high vulnerability were identified and grouped under the CCF7 framework. Recommendations address the different spheres, namely (i) human, (ii) social, (iii) culture, (iv) financial, (v) infrastructure, (vi) environmental or ecological, and (vii) political.

Introduction

Drought remains one of the disasters impacting most people in the world. The 2015/2016 drought experienced in southern Africa again illustrates the importance of drought risk reduction through the development of drought resilience strategies. The Sendai Framework (2015) for Disaster Risk Reduction 2015-2030 plans to achieve the following:

> *"The substantial reduction of disaster risk and losses of lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries."*

Strong political leadership and commitment is required for this outcome, and countries agreed in Sendai on the following goal:

> *"Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery and thus strengthen resilience."*

In order to achieve higher levels of resilience against the increased number of hazard threats, countries decided to focus on the following four priorities for action:

- Priority 1: Understanding disaster risk

- Priority 2: Strengthening disaster risk governance to manage disaster risks
- Priority 3: Investing in disaster risk reduction for resilience
- Priority 4: Enhancing disaster preparedness for effective response and to *"Build Back Better"* in recovery, rehabilitation and reconstruction.

Also during 2015, the United Nations Secretary General (UNSG) proposed a climate resilience strategy during the COP 21 in Paris, France, named the A2R strategy. This strategy proposes a focus on the following three concepts:

- Anticipate
- Absorb
- Reshape

The shift in focus from climate change to climate resilience emphasizes the acknowledgement that we as humans might not be able to stop climate change and that we should focus on the resilience of society and systems to climate shocks. Droughts are expected to occur more regularly and might be more severe than previously, and the need to adapt and to build resilience is now greater than ever.

South Africa is not exempt from drought and its devastating effects. Recently South Africa has experienced recurring drought events associated with severe negative impacts, such as the 1982/83, 1991/92, 2003/04, 2009/10 droughts (FAO, 2004; IRIN, 2004; Gumenge, 2010; Makana, 2013). In 2004, for example, drought emergency was declared in six provinces, namely: Northern Cape, North-West, KwaZulu-Natal, Eastern Cape, Mpumalanga and Free State provinces, in which 4 million people were directly affected, whilst Limpopo had previously been declared a disaster area (IRIN, 2004). Ngaka (2012), FAO (2013) and the Department of Rural Development and Land Reform (DRDLR, 2013) concur that drought has been ranked a major concern in South Africa in terms of the total economic losses, as well as the number of people affected. Among a host of drought impacts, some of the most serious effects have been reduced water supplies, reduced staple crops such as maize, as well as commercial crops. Moreover, there was a considerable migration to urban areas, especially in the 1992/93 drought, and importation of maize into the country; farm closures, farm labourer lay-offs as well as increased indebtedness in the agricultural sector occurred (Ansie, 2010).

The 2015/2016 drought is regarded as one of the most severe droughts in history with five Provinces declared disaster drought regions. These were Kwa-Zulu-Natal, Free State, Limpopo, North West and Mpumalanga. More than 100 000 cattle were reported dead in Kwa-Zulu-Natal alone. Maize production dropped from more than 14 million tons in 2013/2014 to just over 7 million tons in 2015/2016 (Crops Estimates Committee, 2016). Staple foods such as maize meal went up in price by more than 20% and poor people suffered the most. This chapter builds on the research presented in previous chapters and provides solutions and recommendations to the identified challenges.

Global Drought Resilience

Global resilience to drought requires a concerted effort by all governments, the private sector and society to implement policies and plans targeting drought vulnerability and building capacity for drought resilience. The climate resilience strategy proposed by the UNSG at COP 21 in Paris, France, is a step in the right direction to build climate resilience globally. At the core of the A2R vision are three outcomes to be achieved by 2020. The UNSG proposes that this should be synchronized with the implementation of the 2015 Paris Climate Agreement, and the following are the core outcomes to be achieved:

- *Comprehensive early warning – early action systems are established in [XX number of] vulnerable countries in SIDS, LDCs and Africa;*
- *[XX number of] SIDS, LDC and African countries, and vulnerable people within these, have increased access to risk transfer pools as well as strengthened social protection packages;*
- *[XX number of] governments, multi-lateral agencies, PSOs, CSOs incorporate climate risks into financial decision-making and the design of physical and environmental infrastructure.*

The framework is illustrated in Figure 11.1.

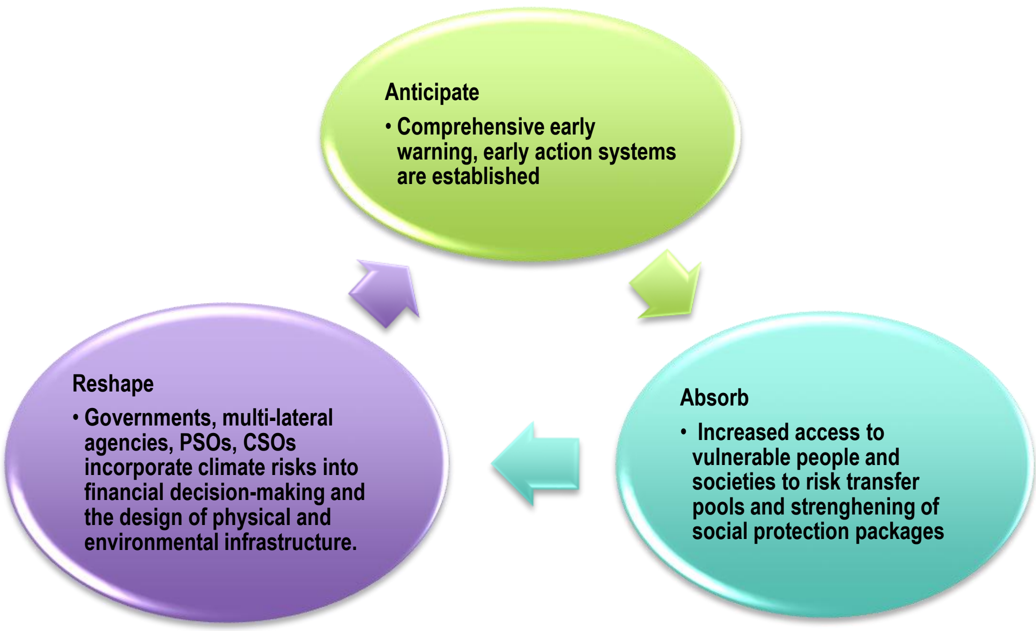

Fig. 11.1: A2R pillars

The A2R framework for action plans to achieve the following goals:

- ***Strengthen capacity*** *to anticipate climate related hazards, absorb shocks and reshape development pathways*

- ***Provide a global platform*** *to increase the impact of resilience action by coordinating activities around a collective ambition;*
- ***Mobilize financing*** *and other resources for resilience building;*
- ***Create and operationalize partnerships*** *between stakeholders, including the private sector;*
- ***Catalyze research,*** *development and testing of new tools for resilience.*

The key features of the A2R initiative are founded in the opportunity for governments, international organizations, the private sector and civil society to work in partnerships to strengthen climate resilience. The collective actions will focus on the A2R pillars that are fundamental to resilience. These are explained as follows:

- ***The capacity to anticipate climate-related hazards.*** *Early warning – early action systems must be strengthened. Risk information must be made available to communities. Their ability to take action must be enhanced through the creation of preparedness plans and provision of funding in advance of disasters and humanitarian crises.* Possible commitments and partnerships for the advancement of this anticipated pillar could include:
  - The CREWS initiative developed by the Global Framework for Climate Services (GFCS) establishes seamless multi-hazard early warning systems in all SIDS and LDCS. The GFCS provides climate information products and services that support countries and partner agencies working to enhance the resilience of the agriculture, food, disaster risk reduction, water, health and energy sectors among others, to anticipate and prepare for extreme climate events.
  - Mobile network operators commit to expand use of cell broadcast technology under the GSMA Humanitarian Connectivity Charter, ensuring warning messages can be sent to communities by SMS at no cost.
  - Google partners with countries to expand the use of the common alert protocol, effectively disseminating warnings using the Internet.
  - The Food and Agriculture Organization rolls out an early warning – early action system, working with national authorities in 30 countries to develop indicators, evidence-based early action triggers and pre-approved action plans.
  - Governments commit to develop flexible preparedness funds that can be used under standard operating procedures. In conjunction, the Red Cross Red Crescent Climate Centre tests forecast-based finance programmes for different sectors
- ***The capacity to absorb shocks:*** *Social protection measures must be strengthened at the same time as insurance coverage or risk transfer pools are made available at the individual, sub-national and national level.* Some commitments are the following:
  - The World Food Programme (WFP) expands the Rural Resilience Initiative, reaching an additional 500 000 farmers by 2020 and contributing to strengthened social protection in ten additional countries in Africa and SIDS.

    - The African Risk Capacity (ARC) assists 30 countries by 2020, providing nearly USD 1.5 billion of sovereign insurance coverage against drought, flood and cyclones. ARC scales up the Extreme Climate Facility to all LDCs, providing resources for adaptation if the frequency of extreme events changes.
    - Caribbean Catastrophe Risk Insurance Facility (CCRIF) offers parametric insurance to countries in the region and broadens the base of its products;
    - A viable and functional risk insurance pool akin to CCRIF and ARC, and building on the existing regional risk pools, is established for the Pacific SIDS.
    - Swiss Re, a global reinsurer, covers 20 sovereign or sub-sovereign public institutions against climate risk, offering over USD 10 billion protection by 2020.
    - Insurance companies, associations and regulators, in partnership with governments and international agencies, pilot climate risk insurance schemes for city governments— a new tool for resilience.
- ***The capacity to reshape development pathways:*** *Adaptive capacity must be strengthened. Effective resilience will hinge on developing an economy that reduces risks and supports climate-proof physical and natural infrastructure.*
    - Countries adopt national roadmaps for sustainable finance along with legislation to mandate disclosure of climate risk.
    - Double the number of countries and private sector organizations adopt a carbon price to facilitate decision-making that accounts for climate risk.
    - Private Sector Global Adaptation and Resilience Funds (PSGARF), each of USD 500 million to 1 billion, are created to invest in companies that produce technologies, products and services that enable adaptation and strengthen resilience.
    - Banking regulators develop climate and sustainability stress test methodologies, as piloted by the 1 in 100 Initiative.
    - UN-Habitat tests and expands the CityRAP tool (the City Resilience Action Plan tool) to enable the creation of urban resilience plans in countries.

Drought risk reduction strategies in the Eastern Cape and to a larger extend in the whole of South Africa will follow the same framework as proposed by the UNSG at COP 21. The focus of this research thus far is on the identification of drought vulnerability and drought resilience. The next section focuses on the main recommendations for drought resilience and drought risk reduction.

Resilience to Dry Periods and Droughts

The concepts of vulnerability and resilience to drought were discussed in detail in Chapters 3, 5, 6 and 7. The recommendations in this section for drought resilience building is structured according the different sectors and role players. The Community Capitals Framework, as utilised in the risk assessment, is used to guide the reporting structure. Community capitals are as following:

- Human capital
- Social capital
- Cultural capital
- Financial capital
- Infrastructure capital
- Environmental capital
- Political capital

The different sections or role players are the following:

- Table 11.1: Drought resilience strategies and plans for communal farmers
- Table 11.2: Drought resilience strategies and plans for land reform farmers
- Table 11.3: Drought resilience strategies and plans for commercial farmers
- Table 11.4: Recommendations to government
- Table 11.5: Recommendations to municipalities

The recommendations are summarised in table format and should be read together and not in isolation. What that means is that recommendations for communal farmers are also applicable to commercial and land reform farmers and *vice versa*. Government policy and projects are also discussed in different tables, but a recommendation for one sector is also applicable to another. Recommendations are made based on the outcomes of the research thus far and also with practical applications in mind.

11.1.1 Drought Resilience Strategies for Communal Farmers

Table 11.1: Drought resilience strategies and plans for communal farmers

Capitals	Vulnerability and resilience indicators	Actions for building resilience
Human	• Education • Age • Health • Management skills	• An effective mentorship programme should be instituted to benefit upcoming farmers of which the small-scale and land reform farmers would be key beneficiaries. Considering the adaptive resilient capacity of the commercial farming system, experienced and successful commercial farmers should be appointed as mentors. These mentors are not to duplicate extension officers' work, but to walk the farming journey with the mentees. Mentors should undergo a mentorship-training programme in order to be properly equipped to provide efficient mentorship. The current practice with inexperienced graduates is doomed to fail. • The Mncgunumbe Elundini mentorship programme is an example of an excellent programme that increases productivity and lowers mortalities amongst livestock. Similar programmes should be implemented in other communal areas. • The impact of psychological stress on farmers should be determined so that appropriate and effective programmes can be developed to help them cope with it. This will help reduce the negative impact on their health as well as reduce further vulnerability to drought impacts. • Schools should incorporate programmes that motivate the youth to take up farming seriously. Agricultural schools should be established and these schools can be linked to Agricultural Colleges or Faculties of Agriculture at Universities. Agricultural and farm level knowledge should be passed on to the younger generation. This will help the older farmers get relieved from much of the farming responsibilities. • Farmers should establish study groups and farm management training should form part of a training programme for farmers.
Social	• Formal networks • Information support • Safety and security	• The relationship between small-scale farmers and farmer's organizations should be improved so that the farmers benefit from the organization's representation to government as well as the interaction with other farmers. AFASO and NAFU are both poorly organized at grass roots level. Government supports both these organizations, but the fact that they compete with each other for the same clientele and are poorly organized at grass roots level increases the vulnerability of farmers. • AgriSA has vast experience in organizing farmers and establishing efficient farmers' organizations. AgriSA should consider a specific section dealing with and representing communal and small-scale farmers as a group. • Information access should be increased through the development of robust systems that are accessible in rural areas. The Red Cross implemented a system with large notice boards in rural towns in Kenya and Tanzania where information such as meteorological information, market information, information on diseases and other relevant information can be displayed. An information display can be erected at the entrances of rural towns and extension services and the district municipality can update these information boards. • Most people have cell phone access even in the most remote places in SA. Cell phones should be used as a source of information dissemination. • Internet based information systems such as the *Agripedia* platform should focus development on low technology production systems applicable for communal farmers. • Security is a challenge for all communal farmers. Stock theft is a big problem and communal land adjacent to the Lesotho border is particularly vulnerable. The SAPS stock theft units should be strengthened and communal farmers should participate and establish own Community Police Forums and *"land watches"*. Communication between local

		communal farmers and police must improve. The SAPS should be sensitized about the importance of communal farmers and their security threats.
Culture	• Dependency syndrome • Gender discrimination • Cultural beliefs	• Government, through extension programmes, should address the culture of dependency with a focus on personal development. Cultural and community leaders should take a leading role in such programmes. The perception that government will always help during droughts should be corrected. Farmers and extension officers should implement self-help programmes; for example, farmers should join with local municipalities as land owners, district municipalities and commercial farmers to build fodder banks during the good years. • Gender discrimination is still alive in remote rural areas where the role of women is limited to individual household decisions and caring for children. It is not easy to change cultural customs and practices. The true meaning of extension is to support the whole livelihood and that includes gender issues. Extension programmes should involve community workers from the Department of Social Development and jointly address the gender issue. • Cultural beliefs related to cattle numbers as an indication of wealth increases vulnerability. Farmers keep cattle for too long during the onset of droughts and eventually cattle die or are in poor condition and not marketable. Extension officers to provide intensive training on drought management and they should highlight the cultural barriers to resilience.
Financial	• Price sensitivity of products • Market access • Employment opportunities • Insurance	• Certain agricultural production systems are better adapted to dry conditions and droughts than others. Examples of well-adapted systems are wool production, goats, and ostriches. Cattle are more sensitive for droughts and farmers should consider farming with small stock as a drought adaptation strategy. • Market access by communal farmers must improve. In most cases they are far away from recognized markets and have to sell to the one or two buyers available. With little competition on the demand side they have to sell at the price offered to them. This is exacerbated during dry periods when buyers realize that farmers have to sell and prices can drop dramatically during dry periods with extremely high prices when they want to replace stock after the drought. Municipalities as landowners should motivate and assist farmers utilising their land to establish micro-cooperatives that ensures market access, transport and an information system that provides timely information to farmers. Livestock auctions are still in use by commercial farmers and communal farmers should utilise these for better prices, • Financial support from government should be directed not only towards drought relief; it should be channelled towards agricultural education, research and technological development in order to assure increased and more efficient outputs under changing market and climate conditions. • Imperfect market systems remain a challenge for small-scale farmers and should be addressed. Commercial farmers are using Internet marketing and direct sales with fewer auctions where small-scale and communal farmers traditionally sold their livestock. The new trend in marketing leaves the small-scale farmers more exposed to impacts of dry conditions.
Infrastructure	• Infrastructure poorly maintained on communal land • Boreholes and water reticulation not maintained causing lack of water during dry periods.	• See recommendations for municipalities. • Communal farmers should honour agreements with municipalities and ensure the security of infrastructure. In many cases non-farming community members steal infrastructure such as fences and borehole equipment. Communal farmers should work together and with the SAPS to stop this from happening. • Maintenance of infrastructure is the responsibility of the land owner, but a stalemate between communal farmers and municipalities is currently preventing proper maintenance. Farmers say that municipalities do not maintain infrastructure while municipalities claim that farmers are not paying any rent for the land.
Environmental	• Land degradation • Land use • Land ownership	• Overgrazing, soil erosion and land degradation should be addressed as a matter of urgency in the Eastern Cape. The soil conservation committees, which used to play an important role, should be reintroduced.

	• Predators	• Farmers must reach an agreement with each other in terms of stock numbers and reduce stock numbers to at least 70% of the Meisner guidelines until improvement in vegetation condition is evident. • Erosion is a big problem in most communal areas. The Land Care programme of Department of Agriculture is a good initiative, but it should be supported by all Departments and requires more funding. • In spite of its complexity, surface water should be managed to augment supply towards rain-fed agricultural production. OR Tambo District receives an average of 800 mm annually, but most of the water is not retained to benefit farming in the area. Responsible organizations should work together and develop a shared understanding of the most suitable solutions to surface water management to reduce drought risk. • Predators are causing the biggest loss especially amongst small stock. Some communal farmers reported up to 80% loss in progeny because of predators. Government should embark and implement a predator control programme. The Department of Environmental Affairs is probably the responsible Department.
Political	• Drought contingency plans • Government inefficiency • Land governance	• Drought contingency plans must be developed at all levels of governance. • Municipalities with communal land must prepare for dry periods by (i) building a fodder bank through fodder purchases during good years when fodder is available at low prices, (ii) produce own fodder banks when they have access to irrigation and land, or (iii) contract commercial farmers to produce fodder for them during normal and wet years. • Relevant authorities which promote rural development should address the discrepancy between provinces, especially with regard to the distribution of drought relief. National indicators and guidelines should be applied to all provinces. The SPI and proposed DAFF indicators for drought classification should be adopted nationally. • Communal land is poorly managed. Municipalities must develop and enforce land management plans. Currently these are not enforced. Overgrazing on communal land must stop. • Communal land should be available only to *bona-fide* small-scale farmers. Persons such as extension officers, government officials and business people should not compete for grazing land. Land owners to enforce and impose heavy penalties on infringements. • The province and district municipalities should develop a provincial and district drought management plan (Proposed template is part of this report chapter 10)

11.1.2 Drought Resilience Strategies for New Land Reform Beneficiaries

Table 11.2. Drought resilience strategies and plans for land reform farmers

Capitals	Vulnerability and resilience indicators	Actions for building resilience
Human	• Most farmers are not experienced in managing a complex business such as farming. Integrating production, financial management and marketing requires experience.	• New land reform beneficiaries should be better prepared for the managerial challenges of farming. The DoARD should design an introduction course to new farmer entrants and the following should be included on such a course o Strategic planning o Integrating challenges for managing a farming business o Financial management o Laws, regulations and responsibilities of land owners o Agricultural institutional structures including local structures and roles and responsibilities o Natural resource management

		○ The market ○ Who's who in agriculture ○ What do I need to know as a new land owner? ○ Commercial farming environment • The Department of Rural Development must improve selection of beneficiaries for farms. Only people with real aspirations to become a farmer and with some experience should be selected. Some communal farmers are already producing commercially with a few hundred and even more than a thousand animals and they should be selected as land reform beneficiaries.
Social	• New farmers are ignorant of local organizations and institutions in support of agriculture • The black farmers unions such as NAFU and AFASA are not well organized at grass roots level and do little to provide practical support to new farmer entrants. • New farmers do not trust commercial farmers as mentors; on the other hand commercial farmers confirm their willingness to mentor new entrants. • Mentors appointed by the Department of Rural Development are not mentors in the real sense of the word. They do not have intimate knowledge of local conditions and lack experience.	• Introduce new farmers to local structures as well as to commercial farmer leaders who can provide information. • The distrust between organized agriculture and new farm entrants is not founded on facts and is a perception, which is fuelled by politicians and government officials. ECAgri and the local structures, i.e. the farmer associations, must implement a programme where new farmer entrants are welcomed to their meetings. Neighbours can play an important role here. Extension officers should link better with commercial farmers. • Rural development must sort out the mentorship challenge and that is only achievable through building good relations amongst commercial farmers, new farmers and the government. These mentors are not to duplicate extension officers' work, but to "*walk the talk"* with the mentees. Mentors should undergo a mentorship training programme in order to be properly equipped to provide efficient mentorship. The current practice with inexperienced graduates with no practical farming experience is doomed to fail.
Culture	• In general new farmers expect government to do everything for them. • The culture of dependency and entitlement is evident amongst many land reform beneficiaries.	• It must be made clear to new farmers that farming is hard work and means taking responsibility. Government should not foster dependency by handing out and promising support with every dry period.
Financial	• Lack of production finance seems to be the biggest problem for new farmers. They do not have title for the land and cannot unlock production funding due to lack of collateral and, secondly, the fact that they have no credit history and farming experience.	• Government must revisit its policy of leasing farms to new entrants. New entrants must take ownership of land, but they must be better prepared and government must support them financially after taking ownership of the land. • Receiving a farm is only half of the costs. New farmers need production capital as well as capital for animals and implements in order to be successful. The smallest dry period results in low yields or animals that die and new farmers do not have the reserves to sustain themselves during dry periods. Government should therefore ensure sufficient start-up capital for new farmers.
Infrastructure	• Infrastructure on land reform farms is not maintained or is in bad shape. Commercial farmers stop maintaining infrastructure as soon as they realize that land claims are registered and in most cases it then takes years for farms to be transferred to new farmers. • Water reticulation to all camps seems to be a problem during dry periods. • Lack of irrigation infrastructure	• Infrastructure must be maintained after farms are identified for expropriation or for government purchase. The time it took to negotiate final purchase agreements must be shortened. • New farmers must inform themselves about local conditions during dry periods on a specific farm before taking responsibility of the land. Discussions with neighbours will assist in this regard. • Government as the land owner must provide the necessary infrastructure on a farm, but maintenance is the responsibility of the beneficiary.
Environmental	• In some cases poor quality farms are bought. There is a reason why commercial farmers sell land and in most cases it is linked to low potential land or lack of water.	• Government must make sure about the natural resources on farms before purchase and price negotiation. • Make sure new farmers farm with systems adapted to local conditions and a specific farm. • Business plans must consider farm specific challenges.

	• New farmers do not farm according to requirements on a specific farm • New farmers are not aware of the impact and large losses because of predators on their animals	• Business plans should not be based on a best scenario basis, but rather conservatively on a difficult scenario adapted to dry periods and the 1 in 10 year drought scenario.
Political	• Land reform policy does not allow land ownership to new farmers • Water rights are not secured and clarified during land purchase	• Government must revisit current policy and find ways to transfer titles and the responsibility of farmers to new farmers. The key is in the support after farmers are settled on farms. A combination of good extension and mentorship is required to ensure success. • The current system where government buys land and leases the land to beneficiaries is not successful. Such farmers do not have title of their land and will not invest and maintain the farm. In addition they cannot use the land as collateral. • Government must make sure about water rights on each farm before purchasing land.

11.1.3 Drought Resilience Strategies for Commercial Farmers

Table 11.3. Drought resilience strategies and plans for commercial farmers

Capitals	Vulnerability and resilience indicators	Actions for building resilience
Human	• Education • Age • Health • Management skills • Experience (Resilience) • Exposure to mentors (Resilience) • Management skills (Resilience)	• Managing a farm today requires a high level of management, leadership and decision-making skills. Most farmers today have tertiary qualifications. Technical and practical knowledge is traditionally taught at the Agricultural Colleges and these should be revived. The B.Agric degree seems to be a popular qualification amongst new farmers, but it still lacks sufficient practical exposure. Tertiary qualifications should include at least 1-year's practical work on a farm under mentorship of an experienced manager. • Agricultural schools could be an important system of preparing potential farmers already from school level. Each province should have at least 5 agricultural schools. These schools should be closely linked to the commercial agricultural sector in the province, agri-business sector, agricultural colleges and the faculties of agriculture at the closest University. • The impact of psychological stress on farmers as a result of drought and its effects are serious. Appropriate and effective programmes should be developed to help farmers cope with droughts. This will help reduce the negative impact on their health as well as reduce further vulnerability to drought impacts.
Social	• Formal networks • Information support • Safety and security • Private production advise • Marketing information • Access to information	• Eastern Cape Agri (ECAgri) represents most of the farmers and contributes to drought resilience within the commercial farming sector through their representation at AgriSA and continuous deliberations with government. The structure of farmers associations and district farmer unions is well established in the province and farmers should continue to participate and support these structures; therefore it should continue to be supported by all stakeholders, including new farmers. ECAgri and its affiliates, however, should increase efforts to register more black farmers in order to obtain better support from government and limit the wrong perception of a racially based organization. • The network of commodity organizations amongst commercial farmers enhances drought resilience. The RPO and WGA need mentioning. The work of the NWGA amongst communal and small-scale wool farmers in the OR Tambo district should be a case of good practice to be followed by other organizations. • Security for both farming families and their livestock has a negative impact on drought resilience since farmers have to invest additional funding in security, hence it should be addressed. Farmers living and working on farms are extremely vulnerable and the number of farm murders is evidence of their vulnerability. The former commando system provided an efficient safety and security network before the system was abandoned. A rural police safety network never replaced it. Farmers need to improve

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<tr><td></td><td></td><td>relationship with the local Police. A farm watch system is implemented in some areas, but this is currently not sufficient to provide a blanket protection for all farming communities against farm attacks and stock theft. Farm workers should also become more active in such a security system. It is important however, that farm watch organizations join community police forums and work with the police. District municipalities should also support the farm watch system financially, since farmers pay land tax to these municipalities. Farm watches should also have the responsibility of disaster management in that they are well structured, for example, to assist during wild fire responses and lend support to each other during floods and other calamities. Farm watches are typically organized according the farmers’ associations geographic areas, which is commendable.
• Most of the EC has cell phone signals, but data transfer is still extremely slow in many rural places. Internet access is key to information dissemination and the minority of farmers uses the Internet as a source of information. The importance and speed of information dissemination should be highlighted amongst farmers. Most farmers, however, do monitor market prices and trends through their cell phones.
• Dissemination of information and the use of technology to farm workers are inadequate. Farm workers are, in general, excluded from IT in that they have no access to IT and they are not at all exposed to IT. Farm schools have been closed and children of farm workers now have to stay in hostels or with others in order to attend school in the nearest town. Government should provide subsidies to farmers in order to support them to establish an IT centre on each farm where farm workers have the opportunity to be exposed to IT. One or two computers with Internet access, supported by some basic training, should suffice to unlock the web for farm workers.
• District municipalities must establish a rural development committee, which can assist with the planning and coordination of rural development issues. Organizations with representation on these committees should include (i) district municipality, (ii) local municipality, (iii) commercial agriculture, (iv) local businesses, (v) Department of Agriculture, (vi) Department of Rural Development, (vii) Department of Roads & Transport, (viii) ESKOM, (ix) TELKOM, (x) Department Environmental Affairs, (xi) Tourism and other role players responsible for rural development and rural infrastructure. Such a committee can assist in the identification and prioritization of development and infrastructure plans. Joe Gqabi district has successfully implemented such a committee.</td></tr>
<tr><td>Culture</td><td>• Dependency syndrome
• Gender discrimination
• Cultural beliefs
• Innovative planning
• Work ethic
• Perseverance (R)</td><td>• A culture of “ ‘n boer maak n plan” is one of the key success factors amongst commercial farmers. Farmers realized that they have to make own plans for drought risk reduction; there is therefore the realization that they should not depend on government for support.</td></tr>
<tr><td>Financial</td><td>• Price sensitivity of products
• Market access
• Employment opportunities
• Alternative farming income
• Alternative non-farm income
• Financial safety nets
• Fodder banks</td><td>• Financial resources should not just be directed towards drought relief, but should be channelled towards agricultural education, research and technological development in order to assure increased and more efficient outputs under changing market and climate conditions.
• On-farm diversification is an important strategy for drought resilience and, where possible, farmers should seek alternative on-farm income sources. Farm tourism is one example where farmers have managed to supplement farm income during dry periods.
• On-farm diversification through irrigation and fodder production is a key strategy to drought resilience. Even small areas of irrigation increases drought resiliency in that farmers can build fodder banks in preparation for dry periods. New water efficient irrigation methods such as pivots allow many farmers to increase areas under irrigation from groundwater sources. Drip irrigation uses water more efficiently and should be implemented on a larger scale.
• Some farmers expand horizontally during good years by obtaining additional land, which is a good strategy. Instead of stocking all land fully, farmers should apply a grazing capacity of about 60% in order to have sufficient reserve grazing during dry periods.</td></tr>
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		• It is a good strategy to invest in non-farm assets during good years. Farmers, however, should select non-farm investments carefully in that such investments should be available as a safety net during dry periods. • The need for climate risk insurance packages is larger than ever. Government should support the private sector in the development and implementation of climate risk insurance.
Infrastructure	• Irrigation • Fencing • Water reticulation	• Owing to the importance of agriculture to the nation, the government should invest in road maintenance so that farmers have access to markets. Good quality roads will help dairy farmers, for example, to access markets with greater ease. In many cases farmers had to stop with dairy production and the production of perishable products as a result of poor road infrastructure. This limits their options for diversification. The Department of Roads, district municipalities and farmers must work together in the planning of road maintenance. The establishment of a district agricultural committee is the first step in the right direction. • An infrastructure subsidy scheme, similar to the one that the Department of Agriculture, Forestry and Fisheries provided during the 1960s to 1980, should be provided as an initiative to build drought resilience. This could also help in the maintenance of old infrastructure such as fences, which at the time of this study, were estimated to be older than 50 years in many cases. • Infrastructure is an important drought risk reduction factor and farmers should continue to invest in water reticulation and good fencing. • Communication infrastructure is key to information dissemination as well as for safety and security in rural areas. Government and the private sector should jointly invest in telephone communication infrastructure that ensures Internet and telephone access to all rural areas. • Farmers maintain own radio communication systems in many areas. The purpose of this radio communication is mostly for security reasons as well as being a communication system during disaster response, such as veld fires and floods. District municipalities should provide funding and support to the farming community in order to ensure a proper radio communication system.
Environmental	• Land degradation • Land use • Land ownership • Predators • Soil quality • Groundwater risk • Surface water risk	• To combat soil erosion and land degradation, which is a serious environmental vulnerability factor in the Eastern Cape, soil conservation committees, which used to play an important role, should be institutionalized again. • Government recently institutionalized district land reform committees, but the mandate of these committees is limited to land reform. The mandate of these committees should be extended to environmental conservation as well. • Fracking in certain parts of Cacadu is a possibility and farmers should stand together to prevent implementation of fracking due to the potential of groundwater pollution and use.
Political	• Drought contingency plans • Government efficiency • Land governance • Drought relief schemes • Extension support	• The relationship between the commercial farmers and the local and provincial government is one of mistrust from both sides and should be addressed. This lack of trust is counter-productive to resilient building and increases the vulnerability of the agricultural sector, not only to drought but also to all exogenous shocks. • The discrepancy between provinces, especially with regard to the distribution of drought relief, should be addressed. National guidelines on drought declaration and drought relief should be developed. • Whilst commercial farmers support the land reform programme, their role as mentors is limited.

11.1.4 Drought Resilience Strategies Required from Government

Table 11.4. Government extension support

	Problem areas	**Actions for building resilience**
	• The Department of Rural Development mirrors the work of extension officers by the appointment of so-called mentors. This is a waste of funds and a duplication of the responsibilities of extension officers. • Land reform farmers require experienced mentors, but most mentors appointed by the Department of Rural Development are employed by private companies and those so-called mentors have little to no practical farming experience. • Extension officers in general are poorly trained and do not have the required knowledge to advise farmers on drought risk reduction strategies. • Extension officers do not focus on extension. They are project managers implementing projects and do not uplift the living standard of rural people through increased and efficient agricultural production and marketing. • Extension officers have limited to zero knowledge about drought risk reduction strategies and never considered drought risk as part of their extension work. They are involved in drought relief programmes, but little knowledge transfer is done during drought relief actions. These actions are mostly administrative with commercial farmers and monitoring of feed and fodder distribution to communal farmers. The opportunity for knowledge transfer with the objective of future drought risk reduction is not utilised during drought relief.	• The idea of mentorship is a positive development in support of new farmers and specifically land reform farmers. A mentor is not the same as an extension officer or an agricultural advisor. Mentorship is the assistance to new farmers from a person with local knowledge and experience. The best mentors, in most cases, are your neighbours. The local structures of ECAgri, namely the farmers' associations, can play an important role in this regard. A local farmers' association should identify new farmer entrants in their region and implement a mentorship programme for these farmers. It might be the case then that more than one experienced farmer will mentor a new farmer. • The Department of Agriculture should appoint extension officers with sufficient knowledge and training. Appointment of extension officers with agricultural diplomas only should be stopped. Extension officers should at least be qualified with a B degree in agriculture and a post-graduate qualification in extension. After qualifying, a young extension officer should be mentored by a senior for at least two years. Diploma graduates can assist extension officers or programme managers. • The Department of Agriculture should stop the practice of utilising extension officers as project managers and return to the philosophy of extension work by uplifting the living standard of all people in rural areas through agricultural development. Implementation of study groups that meet regularly should be explored. • Programmed extension with a focus on natural resource management was highly successful in the past and extension programmes must be adjusted to focus on natural resource management and climate resilience. Commercial farmers acknowledge the important role of extension and study groups in preparing them for dry periods. If Government is serious about land reform, it must improve the extension services by doing the following: o Re-structure the ranking system for extension officers as follows: ▪ Extension officers have a B degree plus Honours in extension plus three years' experience under supervision of a mentor – a senior and experienced extension officer ▪ Persons with lesser qualifications and experience should be ranked assistant extension officers ▪ Project managers are those who manage specific projects ▪ Technical experts are those responsible for technical planning ▪ Specialists are scientists with specialist knowledge such as agricultural economists, agronomists, specialists in animal husbandry etc. and they are responsible to assist the extension officers with specialist knowledge o Develop an extension programme especially for land reform farmers and communal farmers. Such a programme should include the following: ▪ Natural resource management with specific reference to drought risk reduction ▪ Financial management o Make use of study groups to transfer knowledge and information

		o The Mncgunumbe livestock improvement programme has been highly successful amongst communal farmers and extension services should use that as a good practical example.
	• Drought relief is normally too little too late. The process of drought declaration, impact assessment and drought relief is taking up long periods of time and relief in most cases is too late. • The NDMC have to do final inspections before approval of drought relief and the lack of knowledge about agriculture at the NDMC and even most PDMCs is a source of frustration for all affected and for the departments of agriculture. • Drought relief for livestock farmers is limited to transport costs and limited amounts for feed and fodder and this became available normally only late during dry periods. • Affordable drought risk insurance is not available to most farmers and sectors in South Africa.	• South Africa and all the provinces should develop a drought plan as a matter of urgency (Attached to this report is a proposed template for a national and provincial drought plan). • Drought classification should be according to thresholds and drought declaration should be finalized (A proposal for such thresholds discussed in Chapter 3 of this report.) • Disaster management structures at national and provincial level should employ at least one official with adequate knowledge of agriculture and specifically on drought risk. • Index insurance for drought is currently being tested by the FAO and other organizations in developing countries such as Ethiopia, Kenya and Malawi. Index insurance could provide small-scale and communal farmers also with insurance. Re-insurers such as MunichRe and SwissRe are committed to the development of climate related insurance products for agriculture on pre-condition that governments should support and to certain extent subsidise such products. Further research is required in this regard. Government and the agricultural insurers in South Africa should jointly develop drought insurance products (UFS-DiMTEC already initiated first talks with insurance companies during 2015).

11.1.5 Recommendations for Municipalities and Authorities Controlling Communal Land

Table 11.5. Recommendations to municipalities and organizations controlling communal land

	Vulnerability and resilience indicators	**Actions for building resilience**
	• Local municipalities are land owners that lease or provide land to communal farmers, but in most cases these lands are poorly managed and overgrazed, which leaves land users extremely vulnerable to dry periods. Most municipalities have communal land management plans, but they are nowhere properly enforced. Some of the challenges are the following: o Communal land is designated only for small-scale farmers who have no alternative source of income o Councillors make promises to people in exchange for political support and allow government officials to also keep animals on communal land. Extension officers in some cases are amongst these who keep their animals on municipal land. o Maintenance of infrastructure is poor. Land users complain that the municipality does not maintain fencing and water reticulation systems while municipal officials, on the other hand, blame farmers of not paying user fees or lease fees. o The "*Tragedy of the commons"* is the result on all communal land. o Overgrazing is taking place on all communal land	• Land use management plans must be developed and supported by users. Enforcement of community property rules should be clarified with users. Land users (communal farmers) must take ownership of rules and agreements. Municipalities must create collective understanding and agreement on rules and regulations and both parties must adhere to agreements. Extension officers must take leadership in advising farmers and municipality. • Communal farmers should establish study groups under the leadership of extension officers and agricultural officers at local and district municipalities. These study groups must focus on the application of good agricultural practices on communal land. Drought risk reduction strategies should be an integral part of the programme. • Reserve feed and fodder during dry periods are one of the key resilience strategies applied by successful commercial farmers. Municipalities are well aware that communal farmers are extremely vulnerable to the slightest dry period and then they have to purchase feed and fodder at inflated prices because of high demand. Municipalities should coordinate with commercial farmers and buy feed and fodder as a reserve during the good years when prices are low. Such a fodder bank must then be managed for the purpose of emergency feed and fodder during dry periods. • Communal farmers have to pay a land user's fee or lease per SSU or LSU and municipalities must enforce this payment. On the other hand, municipalities are responsible for maintenance of infrastructure on municipal land. An agreement should be reached between land users and the municipality on exactly how maintenance should be handled.

	○ In some cases closer to the Lesotho border, animals from Lesotho citizens graze on municipal land. These animals are also included and also receive drought relief.	• Municipalities must update records of land users and number of animals. They must make sure numbers are kept within the grazing capacity guidelines and also control who is keeping animals on municipal land.
	• District municipalities are responsible for implementation of drought relief through its district disaster management centre in collaboration with extension officers at district level, but they are in most cases poorly structured with little contact with other role players such as commercial agriculture. • Records and data on number of farms, number of farmers, potential water sources, potential feed and fodder sources are not documented and known by local extension officers and district disaster managers. Extension officers and district disaster managers are poorly informed about agricultural structures and its leaders. • Proper drought contingency plans do not exist at local and district municipalities, nor at the PDMC and the DoARD.	• The PDMC and DoARD should develop a drought plan in which institutional structures are spelled out. Drought task teams at district, provincial and national level should be activated during disaster droughts. The roles of these task teams are monitoring, provision of information and monitoring and support with drought relief. Such a task team is constituted on an *ad hoc* basis for drought coordination and should at least include role players from (i) disaster management, (iii) agriculture, (iii) water affairs, (iv) commercial agriculture. Depending on the type, intensity and duration of drought other role players such as social development should also be included. • Local extension officers and district disaster managers must update databases for local organizations, leaders and other relevant structures. It is important that they meet all potential role players and know the local leadership on first name terms. Potential water sources and farmers with surplus feed and fodder must be documented and recorded. This is a continuous process and district disaster managers should update such information on a regular basis. • Contingency plans must be developed for all levels of governance. All role players must participate in the development of such plans. Agriculture should take the lead with the development of an agricultural drought plan while disaster management has to develop the all-inclusive drought plan.

Recommendations for Future Research

Drought mitigation and drought resilience research is a multi-disciplinary challenge and is within the domain of many disciplines. Technology such as drought resistant cultivars, improved irrigation systems and water harvesting are amongst some of the most popular research domains. Adaptation strategies could include alternative agricultural systems, a combination of drought resistant systems or application of a conservative grazing strategy, for example.

This project clearly highlighted certain knowledge gaps for building a drought resilient agriculture sector. The most prominent challenge is to identify methods to decrease the vulnerability of smallholder communal farmers. Most of the challenges identified are common to smallholder communal farmers in Africa. Resilience building solutions will not only increase resilience of this group of farmers in South Africa; Africa as a continent will benefit since agriculture in Africa is based mainly on common land.

The following were areas identified for potential future research:

- Current management practices for common land owned by municipalities, the State or located within traditional areas are not contributing to drought resilience. In fact, farmers farming on such land are extremely vulnerable to external shocks. Land degradation is a major characteristic on common land. It is important to develop a management system that is enforceable and acceptable to both the land owner and the land occupier or farmer.
- Market access remains a challenge for communal farmers, partly due to long distances from major markets, lack of transport or no competition amongst buyers. Research is required in order to unlock markets for smallholder farmers.
- Land reform beneficiaries received land through different programmes as part of the land reform initiative from government. This group of farmers is vulnerable to external shocks and they are not able to handle droughts during the first few years on the farm. They have no reserves, neither the experience, nor knowledge to overcome the challenges associated with droughts and dry periods. The mentorship programme of the Department of Rural Development and the extension services of the provincial Department of Agriculture is not efficient and does not provide the required support for new farmers to sustain themselves during droughts. Further research is required to identify the real problems within the mentioned Departments and to find an efficient way of mentoring and assisting new farmers as well as communal farmers. The success of the Mnqunube mentorship programme amongst more than 7 000 communal farmers is an example of good practice and requires attention as a potential mentorship model that can rejuvenate the rural economies of many regions.

- More research is required on the methodology for drought risk calculation. The use of the CCF7/8[18] and the net capital score were done for the first time in South Africa in this research. A comparison ought to be made between the use of capitals and of the normal risk equation proposed by Wisner and collaborators.
- The lack of drought insurance, especially amongst communal farmers, is a strong indicator of vulnerability. Communal farmers do not have access to insurance and drought insurance is too expensive even for commercial farmers. The development of index insurance products needs to be explored. The research clearly identified the need for an affordable insurance package for smallholder and communal farmers. Future research in collaboration with insurance organisations is required to develop drought insurance products.
- Drought loss functions are important for the calculation of premiums for drought insurance products. Loss functions are available for some irrigated crops, but not for rain fed agricultural systems. The loss functions calculated in this research were based on production output only. Additional costs to sustain the livestock sector during droughts, as well as the impact of price volatility, were not considered and should be included in future research on drought loss functions. The wool system seems to be a well-adapted system to dry periods, but the additional inputs and costs incurred by wool farmers during dry years were not considered.
- Thresholds for drought declaration for different sectors need to be determined. The difference between communal farmers and commercial farmers became clear during this research. Normal dry periods for commercial farmers are already experienced as severe droughts by communal farmers due to their inherent vulnerability. Future research should refine the recommendations made in this report.
- The SAPWAT model was originally developed for irrigation management, but it also has application potential for dry land conditions. Future research is required to further adapt the SAPWAT model for dry land application.
- Hydrological indices are required for the measurement of dry conditions in rivers, dams or groundwater during specific times of the year. Indices for rivers and dams should be comparable for different rivers and dams. Relatively empty dams and rivers at the beginning of the rainy season are less of a concern than at the end of the rainy season. Dryness at a specific point should be compared to the historical dryness at the same point at the same time of the year. Land use developing in the catchment areas will have an impact on flows and dam levels and should also be considered. The same principles and equation as used for the SPI and SPEI calculations might apply for hydrological estimates of different levels of dryness. A simple method for calculation might be the Z-score. More research is required to provide hydrological indicators that are comparable.
- Drought relief and drought support was regarded by all farmers as always too little too late. New research with definite policy and practical implications is required to find a solution for

[18] CCF7 is well documented by Flora *et al*. This study proposes CCF8 and added institutional capital as a separate capital.

especially the communal farmers. Most commercial farmers have already adapted to dry periods and droughts. Extreme droughts, however, have a negative impact on even the best farmers and ultimately the regional and national economy. Methods to smoothe production even in extreme cases needs to be investigated.

- Both communal and commercial farmers mentioned predators as having a larger impact on livestock losses than drought. Considering the increased importance of predators as a threat to mainly the small stock farmers, more research is required in finding practical solutions for predator control. The increased number of game farms has a direct impact on increased predator related losses.
- Psychological stress was mentioned as a contributing factor to vulnerability amongst both communal and commercial farmers. No studies could be found regarding the impact of stress on drought resilience and more research is required in order to determine the impact drought stress has on the capacity of farmers to withstand the negative impacts on drought. This study indicated that stress was, indeed, a contributor to drought vulnerability.

Conclusion

Drought risk reduction and drought resilience are achieved through a combination of several strategies and actions. All role players should work together in achieving drought resilience. We can expect more severe and more regular droughts if climate change scenarios continue on current trajectories. All farmers need to adapt and plan their farming activities according to the dry years and utilise the "*good*" seasons to build reserves and thereby increase resilience. Government entities, on the other hand, should increase efficiency and introduce plans that manage droughts positively instead of increasing vulnerability through implementation of policies with no resilience building capacity.

The importance of drought risk reduction has never been as important as at the present point in time, with looming food insecurity due to high food prices as well as the high failure rate of land reform farmers. Successful land reform is a key factor in building a free and prosperous society in South Africa. Recommendations from this research are therefore important to ensure successful land reform and sustainable food production in the face of recurring dry periods. The role of communal farmers is equally important since, as a group, they own more cattle than all commercial farmers together. Livestock farming is the livelihood of communal farmers and without such income all of them will be socially dependent on government.

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