Drought risk assessment for extensive farming in the Northern Cape Province.

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Abstract

The Department of Agriculture in the Northern Cape commissioned a Drought Disaster Risk Assessment for the province as part of their disaster management planning. The methodology applied in the risk assessment combines the drought hazard with its economical, social and environmental impacts as well as the affected groups to prepare and cope with drought.

The Standard Precipitation Index (SPI) was used as the preferred index for the drought hazard and this was calculated by using the WR90 precipitation data - which cover an 80-year period – for each tertiary catchment. Detailed analyses of meteorological data were done and the sum of drought severity calculated for each catchment. Through SPI data, the probability, intensity and duration of dry periods were calculated in order to inform drought severity, which was then used as a hazard value in the risk equation. The value for hazard was then combined with an index for economic, social and environmental vulnerability as well as the coping capacity of affected groups. Tertiary catchments were used as basis of calculation and results of the different variable as well as the drought risk map for the NC are shown on GIS maps.

Some of the main findings are that the increase of drought incidence in the NC is not the result of less rain since mean annual rainfall increased over the past 100 years. The incidence of wet extremes increased since the 1970's and the peak seasonal precipitation is later in the season. The study also conclude that natural resource management and factors such as over-grazing, rather than climate change the blame should carry for the high incidence of drought in the province.

Introduction

Drought disaster Risk Assessment is the base for drought risk reduction planning. It provides a roadmap for future planning and policy formulation. The Northern Cape (NC) is the largest and also the most arid Province in South Africa with a strong economic base in mining, agriculture and tourism. The NC is home to the second most mines in South Africa after Gauteng and also the largest contributor to GGP in the Province, which reduces the provincial vulnerability to drought disasters. Agriculture with its downstream and upstream impact is second in terms of GGP contribution and consists of two main sectors, namely irrigation agriculture along the Vaal and Orange rivers and secondly the extensive livestock industry on the arid hinterland.

Dry conditions are part en parcel of the climate of the NC and the farmers, both commercial as well as communal and small-scale experience dry periods on a regular base. Most farmers in the NC understand the challenges of drought and they are conscious about the fact that the next drought could follow soon after the 2011 above average seasonal rains. They just came out of a dry period with certain farmers still suffering the aftermath of the 2010 drought.

Drought Risk Assessment

The disaster risk assessment methodology as stipulated in the Disaster Management Act (Act 57 0f 2002) as shown in Figure 1.4 was used as the framework drought risk assessment in the NC. Stage one consisted of the hazard and vulnerability assessment for droughts.

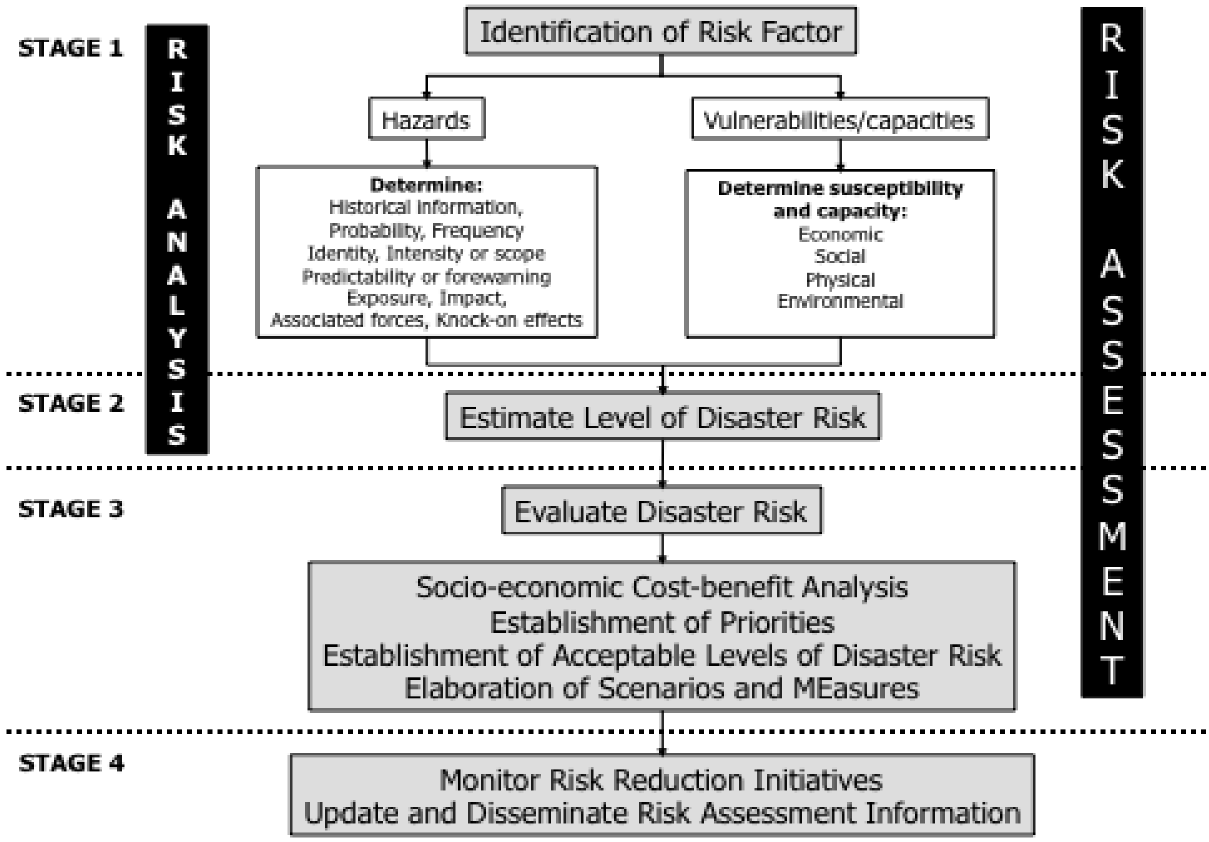

Figure 1: Disaster Risk Assessment Methodology
(Source: NDMF, 2005)

The main determinants for hazard assessment – in the case of drought – is water deficit for normal production because of either too little precipitation and too high evapotranspiration. Assessment of these factors were done based on historical meteorological data, on site inspections of affected areas or sectors, modelling of impacts and contributions from focus groups and stake holders.

Vulnerability assessment also forms part of phase one and susceptibility and capacity of different sectors were analysed using available data and data obtained during this research. The sectors included are farm workers and their families, farmers and/or land-owners, seasonal labourers and their families and labourers and their families working in the secondary economy that depends on primary agricultural production. Also important are the people living in urban areas and utilizing the communal land owned and managed by municipalities.

- **Economic vulnerability** for drought refers to the vulnerability of the economy of communities, towns, districts the province and also vulnerability of different sectors toward droughts. One can calculate direct economic loss during extreme droughts by the loss in production for instance for wool (kg/unit animal) or meat production (kg/ lamb weaned) or progeny (number of animals died) or additional feed and fodder purchases. Intangible elements of economic vulnerability such as progeny the next season are not immediately visible during and immediately after the drought disaster but also have a huge impact on farm profitability. Other intangibles include loss of markets due to under-supply during extreme droughts, which might open the door for other suppliers to enter the market or consumers might move to alternative products if prices become too high during periods of under supply (NDMC (US), 2006). Other economic impacts for drought disasters include the possible loss of jobs, resulted in lower than normal turnover in small towns and communities (ECLAC, 2009). The economy of most towns in the NC depends on the agricultural sector and droughts also impacted on businesses in those towns.

- **Environmental vulnerability** to drought refers to the susceptibility of the environment and more specific 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 distinction of certain species. Locusts in combination with drought could damage the vegetation cover to such an extend that it take many years to recover to its original state (NDMC (US), 2006).
- **Social vulnerability** to drought refers to the vulnerability of farmers, the farm workers and the local community to the negative impacts of a severe drought. Severe drought might cause high stress levels amongst farmers, which impacted directly on the health condition of farmers and their families and the potential of the farmer to make good decisions (NDMC (US), 2006). Farm workers might be affected by losing jobs and the local community ultimately could be affected due to the economic slowdown of a small town.

The **second (sub) phase** consist of the estimation of disaster risk by combining the information obtained from the hazard and vulnerability assessments. Different equations for risk exists (Morimiya, 1992; UNDP, 2004; Wisner *et al*, 2004) but the adjustment of Wisner *et al's* equation proposed by Jordaan (2007) were used in this research.

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

Where: R = Disaster Risk for disaster
H = Probability and of hazard j with a certain magnitude
C_H = Capacity or factors that impact on probability and impact or magnitude of hazard j
V_{econ} = Economic vulnerability
V_{env} = Environmental vulnerability
V_{soc} = Social vulnerability
C_{econ} = Capacity to deal with economic vulnerability
C_{env} = Capacity to mitigate and limit environmental vulnerability
C_{soc} = Capacity to mitigate and limit social vulnerability

The above-mentioned methodology served as the basis to calculate and prioritise drought risks. Figure 1.5 shows the framework for main risk factors, the factor components and examples of indicators considered for drought risk assessment in this research.

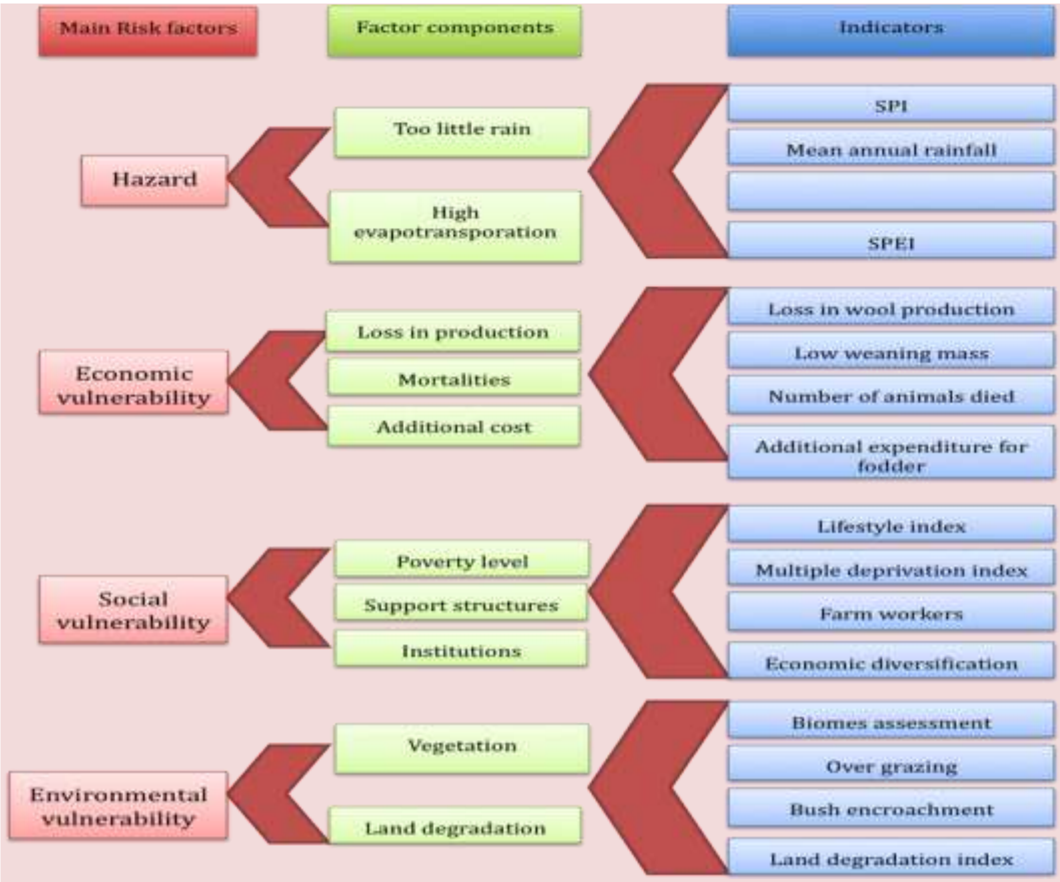

Fig 2: Framework illustrating Main Risk factors, factor components and indicators for drought risk assessment

One of the main challenges in drought risk assessment is the identification of all the indicators and the weighting of these indicators in relation to each other. Meteorological drought impact is a key indicator to vulnerability but methodologies to calculate impacts are not consistent and databases for assessing impacts are not readily available (Gbetibouo and Ringler, 2009). In the absence of quantitative and reliable analyses of estimated losses, drought impacts tend to be under-estimated. Executing cost-benefit analyses from such data then under-estimate the benefit of mitigation. This study however provided and applied a rigorous methodology for drought risk assessment.

The drought disaster risk assessment was done with the focus of future risk reduction in mind and made use of available historical weather data to determine certain trends, cycles or patterns in the climate of the NC. Available climate data for the province is to a large extend out-dated but stretches from 1920 and was very useful since the 1927 and 1933 droughts were covered within the range of this data. The WR90 rainfall data was the most useful and historical trends and SPI indices could be analysed. Because of the link of the WR90 data to quaternary catchments, it was decided to use the tertiary catchments as the unit of analysing and reporting.

Drought Hazard

The start and end of a drought is often difficult to identify and quantify. Meteorologists and scientists developed a number of meteorological indicators for drought yet none of these satisfy the need under all conditions. Examples of these are (i) percent of normal precipitation, (ii) Palmer Drought Severity Index (PDI) (Palmer 1965; Alley, 1984; Karl & Knight, 1985), (iii) Rainfall Anomaly Index (van Rooy, 1966), (iv) Mean monthly rainfall deficit, (v) Zucchini-Adamson models (Zucchini, Adamson & McNeill, 1991), (vi) Relative drought resistance method (Roux, 1993), (vii) Rainfall deciles method (Erasmus, 1991), (viii) Roux expert system (Roux, 1991) (ix) PUTU suite of plant models (Fouche, de Jager & Opperman, 1985; Fouche, 1992), (x) ZA schrubland model (Venter, 1992) (xi) Crop moisture index (CMI) (xii) Surface water supply index (SWSI) (Shafer & Dezman, 1982) (xiii) reclamation drought index (xiv) deciles (Gibbs & Mather, 1967) (xv) Standard Precipitation Index (SPI) (McKee, Doesken & Kleist, 1993) (xvi) Standard Precipitation Evapotranspiration Index (SPEI) (Beguira, Vicente-Serrano & Angulo-Martinez, 2010) (xvii) NDVI which is not a meteorological index but rather an index measuring the impact of dry conditions on the vegetation, and others which is not relevant in the context of this study (du Pisanie, Fouche & Venter, 1998; Wilhite, 2000; WMO, 2006; Vasilaides & Loukas, 2009).

The SPI was used as an indicator for drought in this study and one of the questions yet unanswered is when is a drought disastrous and when is it another dry spell? The SPI provided a quantifiable index indicating wet periods (0 to 3) and dry periods (0 to minus 3) for different time periods. McKee *et al* (1993), McKee *et al* (1995) and Hayes (1999) classifies different droughts according to SPI values as follows:

- Minus 1 to minus 1.499 moderate drought
- Minus 1.5 to minus 1.999 severe drought
- Less than minus 2 extreme drought

For the purpose of drought risk calculation in this study the 24 month SPI with values of below 1.5 was used as an indicator of disaster droughts. SPI calculations and exceedence probability was calculated for all 38 tertiary catchments in the Northern Cape. An example of drought severity based on the SPI calculation for the Barkley West area is shown in Fig 3.

Dates	[Sep 1922, Dec 1922]	[Mar 1923, Jul 1923]	[Dec 1923, Jan 1924]	[May 1927, Jul 1927]	[Oct 1933, Nov 1933]	[Feb 1947, Apr 1947]	[May 1965, Aug 1965]	[Oct 1965, Jan 1966]	[Mar 1966, Dec 1966]
Duration[Months]	4	5	2	3	2	3	4	4	10
Intensity	1.7	1.58	1.65	1.56	1.72	1.7	1.54	1.86	1.8
Severity	6.8	7.9	3.3	4.68	3.44	5.1	6.16	7.44	18.

Fig 3: SPI and drought severity in tertiary catchment C91.

From the SPI data the exceedence probability was also calculated and used in the calculation for drought risk. An example of the results for exceedence probability for drought in the Barkley west region is shown in Fig 4. From these results the probability for extreme droughts in Barkley West are 0.64%, 9.38% for severe droughts and 30.85% for moderate droughts.

Fig 4: 24 month SPI exceedence probability for catchment C91.

The long term precipitation for all catchments was also calculated and analysed and the most important conclusion as far as rainfall is concerned is the fact that the Province received on average more rain per annum than 100 years ago. The analyses shows increases of between 0.1 mm per annum up to 1.1 mm per annum for certain catchments but the positive trend is not statistically significant in all catchments (p=0.239 in the Barkley West example).

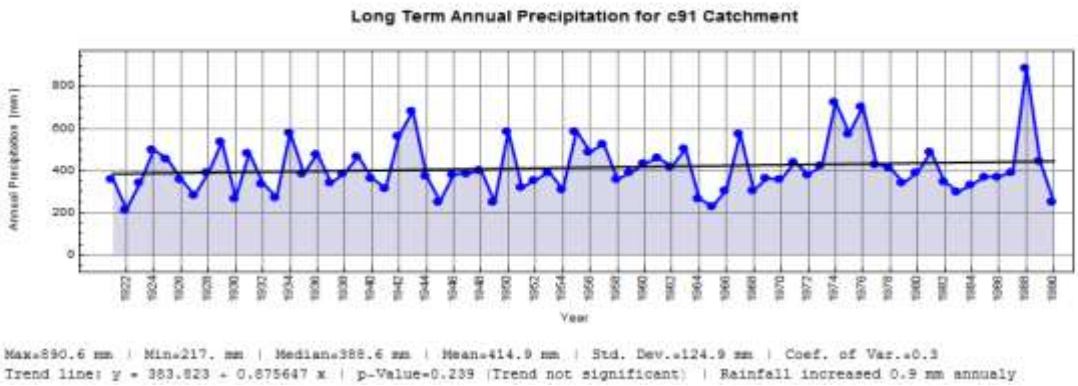

Fig 5: Long term annual mean precipitation for catchment C91.

Fig 5 shows the result of mean annual precipitation for catchment C91. The trend is positive (y=383.823+0.875647) with p value = 0.239 (not significant). The mean annual precipitation for C91 is 414.9mm with median 388.6mm and coefficient of variance 0.3. The mentioned data was calculated for all tertiary catchments, integrated and used in the equation for drought hazard risk (for detail equations refer to Jordaan, Sakulski & Jordaan, 2011).

Based on hazard data a risk map was also constructed for the NC. Fig 6 shows the comparative drought hazard map for the NC. It is interesting to note that the region with the lowest drought risk is located in the northern part of the province. Lowest hazard risk is to a large extend associated with coefficient of variance and probability for SPI<-1.5. The highest drought hazard risk area is in the Richtersveld area. Note that the drought impacts are not considered in the hazard calculation.

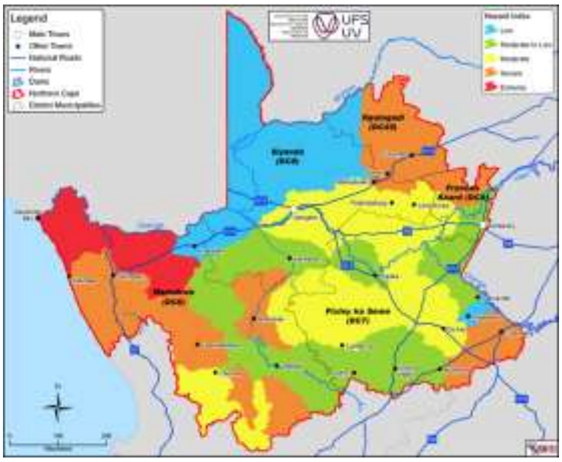

Fig 6: Drought hazard map for NC.

The trend for evapotranspiration seems to be negative yet both trends for precipitation and evapotranspiration are not statistically significant. This does not mean that this trend will continue for the next 100 years. Also clear from the monthly rainfall analyses is the shift in peak rainfall patterns to later. A decline in precipitation was detected for the months September to November and an increase in precipitation from January to March.

Some catchments show a definite dry and wet cycle but the time-span for these cycles are not constant and one cannot use this as a basis for forecasting dry and wet periods. These cycles vary from 12 years to 20 years and differ from catchment to catchment. The precipitation analyses clearly show an increase in extreme weather events since the mid 1970's with most of the extreme toward wet cycles. The most extreme droughts were recorded during the 1920's and

1933 with drought severity above 50 in many catchments. This type of drought was never experienced since 1933. The mid 1970's wet period was the wettest period experienced for 100 years and this contributed also toward the higher than normal average precipitation toward the end 1900's. The increase in extremes is consistent with climate change predictions, yet we believe that 100 years of data is not sufficient to make any conclusions for future trends. In contradiction to IPCC forecasts we might see a decrease in mean precipitation the next 100 years or the positive trend might continue.

Important is the fact that the deterioration of the graze land might not be the result of climate change or less rain or anything to do with weather. The fact that farmers have the perception of dryer conditions and more extreme droughts might be the result of over-utilization and mismanagement of the natural resources such as grazing and ground water. This is evident on communal land where communal farmers experience severe droughts regularly during normal dry periods. Commercial farmers also acknowledge the impact of over-grazing and mismanagement and its contribution to drought.

Vulnerabilities

The following equation was used for the calculation of vulnerabilities:

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

$$V = f(w_1 V_{econ}, w_2 V_{soc}, w_3 V_{env})$$

Where:
V_{econ} = Economic vulnerability
V_{env} = Environmental vulnerability
V_{soc} = Social vulnerability
w_i = Weight of vulnerability
w_1 = 0.5 = Weight for economic vulnerability
w_2 = 0.2 = Weight for social vulnerability
w_3 = 0.3 = Weight for environmental vulnerability

Social vulnerability might not be the major contributor to drought risk and is in most cases the result of financial stress. Factors considered for social vulnerability included depravity index (Noble *et al,* 2010), services, education, alternative livelihood sources, institutions, regional diversification and support structures. The study found that farmers are in general well educated and prepared for the impact of droughts although they reported negative impacts such as depression and stress during droughts. Farm workers are to a large extend protected from the direct impact of drought through their employers. No evidence was found where farm workers on commercial farms were retrenched because of drought except in cases where the farmers also lost all or some of his/her land.

The small-scale farmers on the other hand are very vulnerable since they sometimes lose their total livelihood during droughts. Not only are small-scale and communal farmers socially vulnerable to droughts; their vulnerability is also exacerbated by factors such as (i) no land ownership, (ii) competition for limited over-grazed land, (iii) poor infrastructure, (iv) poor land management, (v) negative market forces, (vi) lack of economies of scale, (vi) high feed en fodder prices, (vii) no access to capital and other factors. Even under the same dry weather conditions, these farmers might experience severe droughts whereas commercial farmers might experience it as only a dry period.

Vegetation was the main determinant for **environmental vulnerability** but factors such as soil quality, slope, and land degradation were also considered contributing factors to environmental vulnerability. The carrying capacity of the Province was determined at the hand of the 1993 official carrying capacity and according to that the Province has the capacity for 7,892,300 SSU. Data from the Department of Agriculture (2010), Cape Wools (2010) and the Red Meat Producers Organization (2010) shows a total of approximately 9,7000,000 SSU in the Province (excluding game, donkeys, horses). If that is compared with the official carrying capacity for the Province it shows that the Province is over-stocked by more than 24% and that excludes game, donkeys, horses and other animals for which data is not readily available.

Economic vulnerability was determined using factors such as (i) production output per unit during drought stress, (ii) price sensitivity of products, (iii) on-farm diversification, (iv) alternative sources of income, (v) regional economic diversification, (vi) government support, (v) institutional support and (vi) entrepreneurship opportunities. Economic impact was also calculated as mean annual loss (MAL). The MAL for the Northern Cape adds up to R196 million per annum at mean R5.77 per ha and R27.10 per SSU. That is the amount of money farmers' loose every year in production without taking into consideration price sensitivity for dry conditions. If the total Province have the same drought with SPI index -2, the loss in production for that one year add up to R1.8 billion plus R900 million for loss in production the following years. The highest MAL for a catchment is R69.30 per SSU in catchment D82 and the lowest MAL of R5.36 is for catchment D42. The high MAL's is the result of higher probability for extreme droughts compared to very low probability for extreme droughts in catchments with low MAL. The implication of the MAL is that it provides a guideline on how much money should be saved during the good years in order to cover losses during droughts. It is also useful to compare different areas and the drought impact of different areas. The mentioned calculations were based on qualitative inputs from farmers regarding their losses during droughts. Further detailed research is needed in order to develop drought loss functions for different sectors.

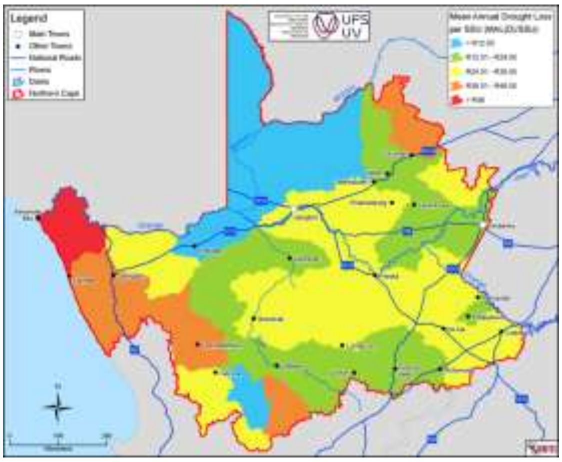

Fig 7: MAL for NC.

Coping capacity

Coping capacity for drought was also determined by analyzing the capacity of farmers, farm workers and rural towns to cope with droughts. Factors considered for equating coping capacity included (i) land ownership, (ii) on farm diversification to provide own feed and fodder during drought, (iii) government support during drought, (iv) institutions in support during drought, (v) alternative sources of income, and (vi) non agricultural entrepreneurship opportunities. The following equation was used for the calculation of coping capacity.

$$CC = \sum_{i=1}^{3} w_i^{cc} CC_1$$

$$CC = f(w_1 CC_{farm,} w_2 CC_{fw}, w_3 CC_{town})$$

where: CC_{farm} = Coping capacity of farmers and land owners
CC_{fw} = Coping capacity of farm workers
CC_{town} = Coping capacity of rural towns
w = Weighting factors

Drought Risk

All the mentioned factors were used in the drought risk equation and a drought risk map was compiled for the NC (Fig 8). According to these results the areas with the highest drought risk are located in the upper north west of the Kgalagadi district municipality and in the Richtersveld. The impact of drought such as vulnerability to the local economy and environment, land degradation and the lack of coping capacity finally became the determinants for drought risk in the two high risk areas. Farmers from these areas do not have land ownership rights and they cite the lack of land ownership as the main reason for over-exploitation and resultant land degradation.

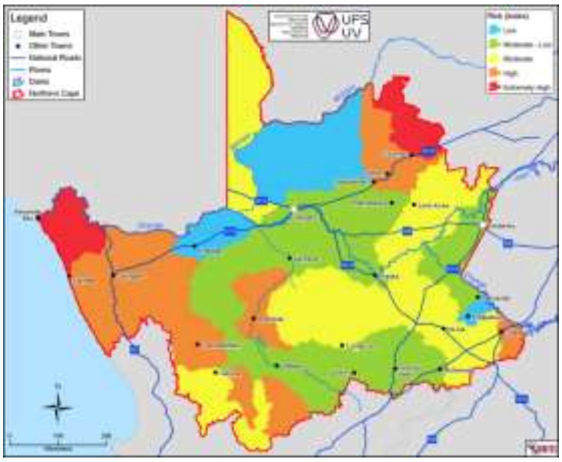

Fig 8: Drought risk map for NC.

General remarks

Farmers in the NC acknowledged that they should implement own risk reduction measures. The introduction of the *"monitor farms"* is an excellent initiative from Northern Cape Agri to set certain guidelines for drought monitoring. Farmers are concerned about the time span between applications for drought support and the declaration of areas as drought disaster areas. That includes the support from government. Both communal small-scale farmers and commercial farmers cannot wait until after the drought for the necessary support. The lack of proper contingency plans is of concern.

Farmers were also concerned about the methodology for drought declaration. At the centre of the problem here is that over-grazed land are sometimes classified as drought stricken since the NDVI cannot make a distinction between poor vegetation and over-grazed vegetation.

Farmers reported the subsidy system for feed and fodder purchase as sufficient. The possibility of drought insurance and/or tax free saving schemes was also mentioned as tools to increase coping capacity

Farmers, commercial as well as small-scale subsistence have all consensus that drought loss is little compared to predator losses. Predators was not regarded as a potential disaster until now, however, considering the feedback from farmers, the authorities should view this issue more seriously. Commercial farmers reported progeny losses amongst small stock as between 10% and 35% and communal small-scale farmers reported losses averaging 50%. Studies by van Niekerk and de Waal (2010) highlighted the significance of this problem

Recommendations

A national policy dealing with all drought related issues should be implemented. Drought does not have borders and all provinces should be guided by a national policy and framework. Provinces should use risk assessment as a basis for the development of disaster management planning. Such a plan should include the necessary contingency plans; it must be approved and accepted by all role players; the MEC, the DG and Treasury must approve and sign it and contingency plans should be activated immediately after drought disaster declaration. Money and resources should be released as stipulated in the plan immediately after drought declaration.

Detailed research should be conducted regarding over-stocking in the NC. Problem areas and –cases should be identified and measures put in place to enforce sufficient stocking rates.

The problems related to communal land should be addressed as a matter of urgency. The *"tragedy of the commons"* should not be accepted as a given. Strict measurement should be enforced on both the land-owners and land users. Communal farmers should be assisted in a special way but their support should be coupled to certain preconditions designed to prevent a continuation of their problems. The extension officers should play an important role in the support to these farmers, specifically with regards to improved management principles.

Refine the methodology for drought disaster declarations. Implement the use of SPI and decide on a specific threshold for drought declaration, which is nationally uniform. More research is needed to determine the threshold for disaster drought and the lack of drought loss functions make drought declarations based on economic considerations nearly impossible. Vulnerability is important in the determination of disaster risk but the methodology for drought declaration should limit the impact of *"man-made"* vulnerabilities such as over-grazing and poor management.

Conservation farming and the long-term advantages thereof should be supported and promoted. The Landcare program play a positive role in this regards but commercial land-owners should be more involved at their level. Extension services should be the vehicle to promote this. Expand the capacity of extension services in order to advise at commercial farm level as well. The focus on small-scale farmers and the appointment of extension officers without proper training limit the influence of the Department in the commercial sector.

Disaster management and extension services within the department should work close together. Collaboration between government departments is essential for proper implementation of a drought risk reduction plan. Provincial disaster management and disaster management at the DoAFF should coordinate and plan together.

The role of district municipalities in agriculture and their responsibility with drought risk reduction and drought relief should be clarified. If it is expected from district municipalities to play a more important role in drought disaster relief, the communication between municipalities and the farming sector should be increased drastically. Currently there is too much distrust between them.

Investigate the possibility of index insurance against drought. The SPI can be used as a basis for such insurance.

Conduct research to determine loss functions for different drought severities and refine the methodology for disaster risk assessment

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