Wildfire Risk Assessment for the Northern Cape, South Africa.

Jordaan AD[1], Jordaan AJ[2] and Procter M[3]

Introduction

Southern Africa is one of the world's fire hotspots where millions of hectares burn annually. It is a region known for an environment that sustains burning, marked by distinct dry and wet periods, and combined with low development which necessitates the use of fire in land use management, inadequate policies and institutional infrastructure for fire management, accounts for the high vulnerability to uncontrolled fires. The frequency with which this happens differs across southern Africa, resulting in different probabilities of fire.

In South Africa, veld fires (vegetation fires) cause severe losses to life, property and environment in most areas of the country which means that the associated risk of veld fires in South Africa is substantial (Kruger, Forsyth, Kruger, Slater, Maitre, & Matshate, 2006). Veld fire risk consists out of two parts; firstly the risk that arises from *"unwanted"* veld fires that cause damage to assets, and secondly the risk arising in environments where fire plays an ecological role, but ecologically inappropriate fires occur (Kruger *et al,* 2006).

Veld fires can be caused or ignited in a number of ways. Historically fires are caused mainly as a result of lightning. Africa is one of the continents that are most prone to thunderstorms and lightning and considerable evidence is available on the high frequency of thunderstorms and lightning in western, eastern and southern Africa (Levine, 1996). Lightning fires occur mainly in autumn and early spring (FPA Model Business plan 1998). While recognizing the primary ignition role of lightning in causing vegetation fires in savannah areas of Africa the stage has now been reached that in most regions of the world humans have contributed more to fire ignition than lightning (Crutzen & Goldammer, 1993). This is well illustrated in the Kruger National Park where anthropogenic fires (fires caused by humans) have become the dominant ignition source of fires in that type of savannah community (Troloppe, 1993). Anthropogenic fires are either because of negligence or an accident where the wind carries a fire away from its point of origin. Dumping sites and areas bordering rural villages where conventional ways of cooking is used are often the source or ignition of veld fires. Many run-away fires are also ignited during controlled burning where people are busy with fire-breaks or the burning of crop residues (particularly irrigation farmers). Another major cause for fires in South Africa is arson where a fire is deliberately ignited as a form of vandalism.

Fact of the matter is that veld fires (wild-fires) is part of the eco-system management environment and should be managed in order to reduce the damage caused by fires (economic, environment and social).

Risk assessments applied in South Africa

Forsyth, Kruger and Le Maitre (2010) did a national veld fire risk assessment by using 13 fire ecology types to assess veld fire risk level for South Africa. A fire ecology type is vegetation types that are reletively similar in their intensity, likelihood and impact on the ecosistem.

[1] Research Assistant: DiMTEC, UFS
[2] Director: DiMTEC, UFS
[3] Assistant Director: Department of Agriculture, Free State

Forsyth *et al*. (2010) matched vegetation data from the current national vegetation map (Rutherford & Mucina, 2006) with vegetation types used previously (Low & Rebelo, 1998) and the sour, sweet and mixed grasslands based on Acocks veld types map and they proposed 13 fire ecology types.

A rating was given in terms of the likelyhood and the possible social-, economic- and environmental consequence of a veld fire occuring on each fire ecology type. Based on these assessments an overall risk rating was assigned for each fire ecology type (Forsyth *et al.* 2010).

MODIS satelite observations from 2000 to 2008 was used to support the rating of likelihood of veld fires for the fire ecology types.

Forsyth et al (2010) rated social- and economic vulnerability by using vegetation types as an indicator. Their hypothesis was that vegetation type of an area will influence the population size of that area. For example sour grasslands and moist woodlands are usually more densly populated and more accesable and have well dispersed economic infrastructure and are therefore socially and economically more vulnerable. Most of the Northern Cape is sparcelly populated which is mainly because of the vegetation and low agricultural potential, and therefore given a lower social vulnerability rating (Forsyth *et al,* 2010). The problem with this classification is that it does not consider the actual situation and social vulnerability at grassroots level. It serves the purpose for a national risk assessment but regional fire risk assessments should consider grassroot factors in order to determine social vulnerability to fires. Alternative agricultural systems and type of infrastructure are not captured properly.

Most of the country is shown to be at low levels of risk. Forsyth *et al.* (2010) argues that the South African vegetation is "*fire-adapted*" and can recover relatively quickly after a fire, provided no other complications are present such as woody alien plants invading the veldt. Regional and local fire assessments will have a slightly different result since vegetation types such as woodland, karoo, fynbos and renosterveld take longer to recover than grasslands. Grass recover in most cases within one season under normal rainfall conditions compared to fynbos and renosterveld that still show burn scars 5 – 10 years after it was burned.

Forsyth *et al.* (2010) then combined the hazard (likelyhood) with the economic, social and environmental vulnerabilities (consequences) and provided a veld fire risk map. They used a "conservative" approach by using the highest risk value for each of the different vulnerabilities (social, economic or environmental) of each mesozone, and assigned that value as the overall risk value for that mesozone (Forsyth *et al,* 2010).

What this study by Forsyth et al (2010) was not able to incorporate into its assessment was the capacity of a community to manage the risk of a veld fire.

Kruger *et al*. (2006) used the same approach as explained above by using vegetation data and the same 13 fire ecology types to assess veld fire risk. Kruger *et al.* (2006) assigned a fire-ecology type for each local municipality in South Africa. Each fire ecology type (local municipality) had a likelihood rating (*rare*, *unlikely*, *possible*, *likely* or *almost certain*) and a social-, economic- and environmental consequence rating (*insignificant, minor, moderate, major or catastrophic)* which was combined for an overall risk rating (*Extreme, High, Medium* or *Low*). Likelihood was rated according to the average return period of each fire ecology type. The consequences of veld fires were assessed with qualitative measures that Kruger *et al.* (2006) adapted from Standards Australia (1999).

Each local Municipality was assigned a risk rating and the results were shown on a map of South Africa's local Municipalities. This risk map is not as accurate as the one found in the study by Forsyth *et al.* (2010) because each local municipality was assigned only one fire ecology type which dominates each local municipality region. Each local municipality are also assigned just one risk category where in reality there might be more than one risk category or fire eology types present within the borders of a local municipality.

Methodology applied in this study:

This assessment used the data from Kruger *et al* (2006) and Forsyth *et al* (2010) as a basis and as some of the indicators alongside more detailed micro and meso-level indicators in order to equate a more accurate and detailed veld fire risk map for the province.

Both Kruger *et al.* (2006) and Forsyth *et al*. (2010) admit that other factors such as land use, the type of veld fire management achieved and information on previous reported fires should be considered for a more accurate risk calculation. Forsyth *et al*. (2010) also mentioned that the ability of a community to manage a veld fire should be considered. These factors are incorporated into the veld fire risk formula used for this study.

Risk

The UNDP (2004) express risk by the equation Risk = Hazard X Vulnerability. Most literature suggest disaster risk by the same equation namely; Risk = Hazard X Vulnerability (R=HxV) (Wisner, 2006) (Holloway & von Kotze, 1999). Others expand the formula by adding manageability or capacity to the equation and propose the equation: Risk = (Hazard X Vulnerability) / Manageability or Capacity (Heijmans & Victoria, 2001) (ISDR, 2000). The most commonly used formula in disaster risk assessments in South Africa is the equation R = (H X V) / C.

The equation used in this wild fire risk assessment is as follows:

$$R = \frac{H \times \sum_{i=3}^{3} Vi}{\sum_{i}^{2} Ci} \quad (1)$$

$$R = f(H, V, C)$$

Where: R = Disaster Risk for a veld fire

H = Probability of hazard with a certain magnitude

V = Vulnerability at specific time and space

C = Capacity or ability of a community to manage, cope or prevent a veld fire event

Data capturing

Members of FPA's (Fire Protection Associations) and land owners assisted with the assessment of the different variables impacting on fire risks. These participants were interviewed and involved in working groups where they categorize and map the following factors on a scale from 1 to 5:

- Fuel load
- Previous fires
- Economic vulnerability
- Social vulnerability
- Environmental vulnerability
- Preparedness or manageability (dealing with prevention and mitigation)
- Coping capacity (dealing with response capacity)

Maps with a scale of 1:50000 with 3 minute X 3 minute grids (approximately 7km X 7km) were used as working maps and participants in the research had to evaluate all the above mentioned factors by colouring each grid according to colour codes. Each factor of risk was rated into 5 categories and each factor was indicated on a different map. Using this local knowledge of local participants, combining it with other information and previous risk assessments, the province was then rated according to the 5 categories of each of the mentioned risk factors and spatially plotted through GIS with each 3x3min grid having its own risk factor value on the 1-5 scale. This methodology was originally developed by Proctor (2010) for his master's thesis. The method used in this study provided a way of ground-truthing previous fire risk assessments done by Kruger *et al* (2006) and Forsyth *et al* (2010).

Hazard

Hazard is the product of probability and intensity. For the fire risk assessment probability (likelihood) was determined by previous incidents of fire within a specific 3 X 3 min grid and intensity was measured by the fuel load within each grid.

The following equation was used for Hazard assessment:

$$H = P * I \qquad (2)$$

$$H = f(P; I)$$

Where:

P = Probability

I = Intensity

Likelihood

Likelihood (probability) can be defined as a return period of a veld fire or the likelihood that a veld fire event will occur at a certain place during a certain time. Likelihood of veld fires was determined by combining inputs from local participants as well as MODIS satellite data.

FPA members and land owners categorized likelihood according to table 4.1.

Table4. 1: Repetitive incidents of fire (adapted from Kruger *et al.* 2006).

Repetitive incidences of fires (At least 8 times in a 10 year period)	**5 Catastrophic (most likely)**
Repetitive incidences of fires (At least 6 times in a 10 year period).	**4 Major (likely)**
Repetitive incidences of fires (at least 4 times in a 10yearperiod).	**3 Moderate**
ONE Fire in the last 10 years	**2 Minor (unlikely)**
No fires detected.	**1 Insignificant (very unlikely)**

Intensity

The intensity of a veld fire refers to the size and the heat of a fire at a specific point. The intensity is directly correlated with the fuel load or type and size of vegetation if all other factors such as wind and temperature remain constant. Fuel load refers to the amount or density of the vegetation. If there is high density of vegetation like a forest or dense grassland and a fire event occurs, flames are expected to be very high which means that there is a high fuel load. In the case of lower density vegetation like the Karoo, the intensity of the flames is expected to be much lower because there is little vegetation or "*fuel*" for the fire to burn. Fuel load is measured in kg/ha. Other factors apart from fuel load also influence the intensity of a veld fire like the age of the grass. Older grasses may burn with more intensity than younger or newer grasses.

FPA members and land owners were asked to classify fuel load according to the criteria shown in Table 4.2. They were not able to classify the fuel load according to the amount of vegetation (kg) per ha and were given guidelines to enable classification (Willis, van Wilgen, Tolhurst, Everson, D' Abreton, & Flemming, 2001)

Table4. 2: Fuel load categories.

Fuel load > than 3000 kg/ha; Grasses older than 3 years old; Flame lengths will be in the order of 5 – 15 m or more; Rates of forward spread of head fires can exceed 4.0 kilometres per hour; The threat of disastrous Veld fires at provincial level exists under these conditions	**5 Catastrophic**
Fuel load > than 2000 kg/ha; Flame lengths between 2 and 5 m, and rates of forward spread between 1.5 and 2.0 kilometres per hour; The threat of disastrous Veld fires exists at municipal level under these conditions.	**4 Major**
Fuel load less than 1500 kg/ ha; Flame lengths in grasslands between 1 and 2m, and rates of forward spread between 0.3 and 1.5 kilometres per hour.	**3 Moderate**
Fuel load less than 1000 kg/ha; Flame lengths in grassland lower than 1.0 m and rates of forward spread less than 0.3 kilometres per hour.	**2 Minor**
Fuel load less than 500 kg/ha; Flame lengths in grassland lower than 0.5 m and rates of forward spread less than 0.15 kilometres per hour.	**1 Insignificant**

Source: KZNFPA

Vulnerability

Vulnerability is also defined as the consequences or impact of a fire on a system such as the environment, economy and social environment. The National Veldt and Forrest Fire Act define the risk of fires in respect to "*life, property, and the environment*" (Kruger, 2006). In order to capture the consequences with respect to "*life, property and environment*" in this study, vulnerability is defined as the sum of environmental-, social- and economic vulnerability.

$$V = \sum_{i=1}^{3} V_i \qquad (3)$$

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

Where:

V^{env} = Environmental Vulnerability to a veld fire event

V^{soc} = Social Vulnerability to a veld fire event

V^{econ} = Economic Vulnerability to a veld fire event

Environmental Vulnerability

Environmental Vulnerability is the ecological and environmental impact that a veld fire can have on the area in case of a fire event. Some areas are ecologically or environmentally more sensitive than others. Fires can destroy certain ecosystems and species, and some biomes (like grasslands) can quickly recover within a couple of months.

The information obtained from the work regarding ecology types done by Kruger *et al,* (2006) and Forsyth *et al* , (2010) was supplemented and ground-truthed with inputs from FPA members and land owners as well as grassland scientists. This information on vegetation and environmental vulnerability contributed toward the classification of the province according to the classification in Table 4.3. (Standards Australia, 1999)(Kruger *et al*, 2006)(Forsyth *et al,* 2010).

Table4. 3: Categories of environmental and ecological consequences.

Permanent loss of species or habitats within the area or of water catchments values.	**5 Catastrophic**
Habitat destruction, temporary loss of species, or temporary loss of catchment values, requiring several years to recover; Game burnt; Land degradation	**4 Major**
Serious impact on the environment that will take a few years to recover; Burn scars still visible 5 years after burning; Stock losses.	**3 Moderate**
Discernable environmental impact; Assets/vegetation recovers rapidly; Vegetation back to normal the following season.	**2 Minor**
Minor impact on the environment; Vegetation back to previous condition within the same season provided normal precipitation	**1 Insignificant**

Social Vulnerability

Social Vulnerability refers to the social structures like households and people that are affected in the event of a veld fire. This can be the amount of lives lost, people injured or traumatic experiences during a veld fire event.

Documented data of the social impact such as deaths or injuries as a result of fires in the Northern Cape were not available and therefore local participants were utilized. Participants indicated the relevant incidents according to Table4.4 (Standards Australia, 1999) and (Kruger *et al* 2006).

Table4. 4: Social vulnerability categories.

Death; Loss of livelihood; Highly traumatic for family; Seriously stressful to family members; Permanent job losses to farm workers	**5 Catastrophic**
Extensive injuries, evacuation required; Temporary loss of livelihood; Take years to recover socially; Traumatic for farmer/landowner and family; Stressful to farmer/landowner; Some job losses to farm workers	**4 Major**
Medical treatment required; Livelihood affected temporary Temporary stress to farmer/landowner	**3 Moderate**
Minor injuries only – first aid treatment required; Minor stress to farmer/landowner No effect on livelihoods	**2 Minor**
No injuries; No social impact; No stress and trauma	**1 Insignificant**

Factors such as population density and settlements surrounded by high fuel load vegetation were also considered in the risk assessment.

Economic Vulnerability

Highly productive or economically significant areas and also areas that will struggle to recover economically in the event of a fire were maped by local participants. Categories of classification are shown in Table4.5 (Standards Australia, 1999)(Kruger *et al*, 2006).

Table4. 5: Categories for economic vulnerability.

Depressed economy of the FPA; Extensive and widespread loss of assets; Major impact across a large part of the community and region; Serious impact and loss of livelihood; Long-term external assistance required to recover; Replacement of more than 80% of fences needed	**5 Catastrophic**
Serious financial loss, affecting a significant portion of the community; Requires external funding (e.g. from disaster management funds) to recover; Stock burnt; Replacement of more than 50% of fences needed; Impact on livelihood	**4 Major**
Localised damage to property; Short-term external assistance required to recover; Stock require veterinary attention; Some replacement of fences needed	**3 Moderate**
Minor financial loss; Short-term damage to individual assets; No external assistance required to recover; No damages to fences Some damage to water articulation systems (plastic pipes)	**2 Minor**
Inconsequential or no damage to property; No economic impact on business No damage to fences and water articulation systems (plastic pipes)	**1 Insignificant**

Land use and economic value of agricultural systems was also considered and compared with the input from the local farmers and land owners. In the final instance the opinion of local farmers weighted more than other factors.

Preparedness and Coping Capacity

$$C = \sum_{i=1}^{2} Ci \qquad (4)$$
$$C = f(C^{prep}, C^{cap})$$

Where:

C^{prep} = Preparedness

C^{cap} = Coping Capacity

Preparedness shows the level of communities to prevent and deal with veld fires. Fire risk can be decreased with proper preparedness arrangements. Preparedness refers to the ability of the community to stop the hazard from occurring or be prepared for it (pre-fire event). Coping Capacity (Manageability) refers to the ability of a community to respond to a veld fire event (post-fire event).

The rating of preparedness and coping capacity is slightly different from the ones used for Hazard and Vulnerability. Hazard and Vulnerability risk assessment tables (Tables 4.1-4.5) awarded a low value if the specific factor of risk was low. When fuel load, probability or one of the vulnerabilities are low, it is given a low value out of 5, because it would result in lower level of risk. When vulnerability is high, it meant that risk increases, and therefore needed to receive a higher value out of 5. Conversely risk actually increases if preparedness and coping capacity is low, and risk decreases when these factors receive high values. Therefore the assessment tables for preparedness and coping capacity differ in the order of their values from the vulnerability values. As can seen the values in Tables 4.6 and 4.7 are an inverse of Tables 4.1 to 4.5 where the more dangerous scenario is now given a lower instead of a higher value. Table 4.6 shows the 5 categories in which manageability is categorized. Local participants rated their areas' manageability according to these 5 sub-categories.

Table4. 6: Categories for preparedness.

No Mitigation measures such as buffer zones or firebreaks in place; Total lack of compliance in terms of section 12 of the NVFFA; No FPA; Farming community not organized in terms of fire prevention planning at all; No early warning systems in place; No communication between farmers and municipality; No disaster management facility at municipal level	**1 Totally unprepared**
Fire Breaks on western boundaries or in place; Fire breaks made by mowing only; District roads regarded as firebreaks, no further measures taken; No FPA's; No communication and coordination between landowners and municipality	**2 Unprepared**
Hazard and Risk mapping completed, analysed and measures taken; Strategic Buffer zones identified and in place; 30% 0f area covered by buffer zones; No FPA but organization of wild fire prevention at farmers organization level	**3 Moderately prepared**
Hazard and Risk mapping completed, analysed and measures taken; Strategic Buffer zones identified and in place; 60% of the area covered by cultivated lands; Controlled burning practised to reduce fuel loads; FPA's established with constitution and plans	**4 Prepared**
Hazard and Risk mapping completed, analysed and measures taken are proving effective. (Average area burnt declining by at least 20% annually); 75% of the area covered by cultivated lands; Awareness campaigns conducted annually. Bill boards and pamphlets; Burning permit in use; Strong working relation between farmers and municipality fire service/disaster management; Working on fire team available within 1 hour; >50% of farmers and farm workers trained and equipped with fire fighting equipment; FPA's established with constitution and contingency plans plus regular meetings and excellent communication between farmers	**5 Excellently prepared**

Table 4.7 shows the 5 classification categories for coping capacity. FPA members, land owners and disaster management personnel rated coping capacity according these 5 categories.

Table4. 7: Categories for Coping Capacity (Manageability).

The area is mountainous, unoccupied, or sparsely occupied; Access only on foot likely to take > 3Hrs but expedited by Helicopter; Fire likely to exit FPA / Provincial Boundaries; Aerial support likely to become essential to extinguish the Fire. Fire will probably burn for more than 48Hrs before it is extinguished; Absentee landowners; (Where no Managerial capacity exists)	**1 Extremely hazardous. Absolutely no capacity to extinguish fires within 48 hrs.**
Access possible by motorbikes or foot only likely to take > 2Hrs; Access by LDV'' to within 200 m of the fire available on 10% of the area; Back-burning, combined with aerial support are the only effective means to combat fires. External Resources from outside the FPA essential; Fire likely to exceed FPA boundaries; Fire will probably burn for more than 24 Hrs	**2 Difficult**
Undulating terrain, Access by LDV'' to within 200 m of the fire available on 25% of the area; Access on foot to the remainder is likely to take at least 1Hr; Maximum available resources from within the FPA deployed; All Resources from additional cells within the FPA essential; Fire likely to exceed FPA cell boundaries; Fire will probably burn for more than 12 Hrs; Fire fighters respond within 6 hours	**3 Moderate**
Access by LDV to within 200 m of the fire available on 50% of the area; Suppression is readily achieved by direct manual attack methods; Additional support from neighbouring cells within the FPA needed; Fire likely to burn over farm boundaries to neighbouring farm; Fire should be contained in less than 12 hours; Fire fighters respond within 3 hours	**4 Mild**
Access by LDV to the entire area; A few field crews with basic fire fighting tools can easily suppresses any fire that may occur; Fire likely to be contained on the farm where it originated; Initial attack deemed to be able to contain the fire within 6 hour period; Fire fighter respond within 1 hour	**5 Simple**

The topography and more specifically slope in the final instance was also major factor impacting on the classification for coping capacity. The classification for coping capacity obtained from the landowners were matched with a slope map and a near 100% fit was found with slopes 15% to 25% classified as difficult (4) and slopes >25% classified as hazardous (5).

Fire Risk

Calculating risk values is a much more complex issue than just equating all the data and have the result that represent the risk for a specific grid cell. Since all the data, including the likelihood are qualitative, one cannot expect a quantitative output that represents risk. At the most, the results of the risk equation provide a relative value to each other. One can therefore use the results of the risk equation to compare the fire risk level of one geographic area with the fire risk level of others.

The methodology for calculating risk based on qualitative classification is not above critique. Zero risk is not reflected properly and is grouped together with very low or insignificant values. The intensity and the likelihood classification of the hazard deserve the same critique that was raised in the case of likelihood. The lowest value one can allocate to intensity (fuel load) is one yet in certain areas fuel load is so low that the possibility of fires are zero; there is nothing to burn and then the result for the risk equation should be zero. With the methodology proposed by the literature and used in this study, one would still get a value for risk even though it should actually be zero. The problem is addressed when the low risk results obtained from the calculation are grouped as a one (insignificant risk) together with the potential zero results.

The correct weighting of the different risk factors is also a major challenge and could be refined from this assessment. At this stage the weighting for fuel load and likelihood is the highest contributing factors since the two factors are multiplied with each and then also with vulnerability and manageability, whereas other whereas the other factors are only added together.

Results

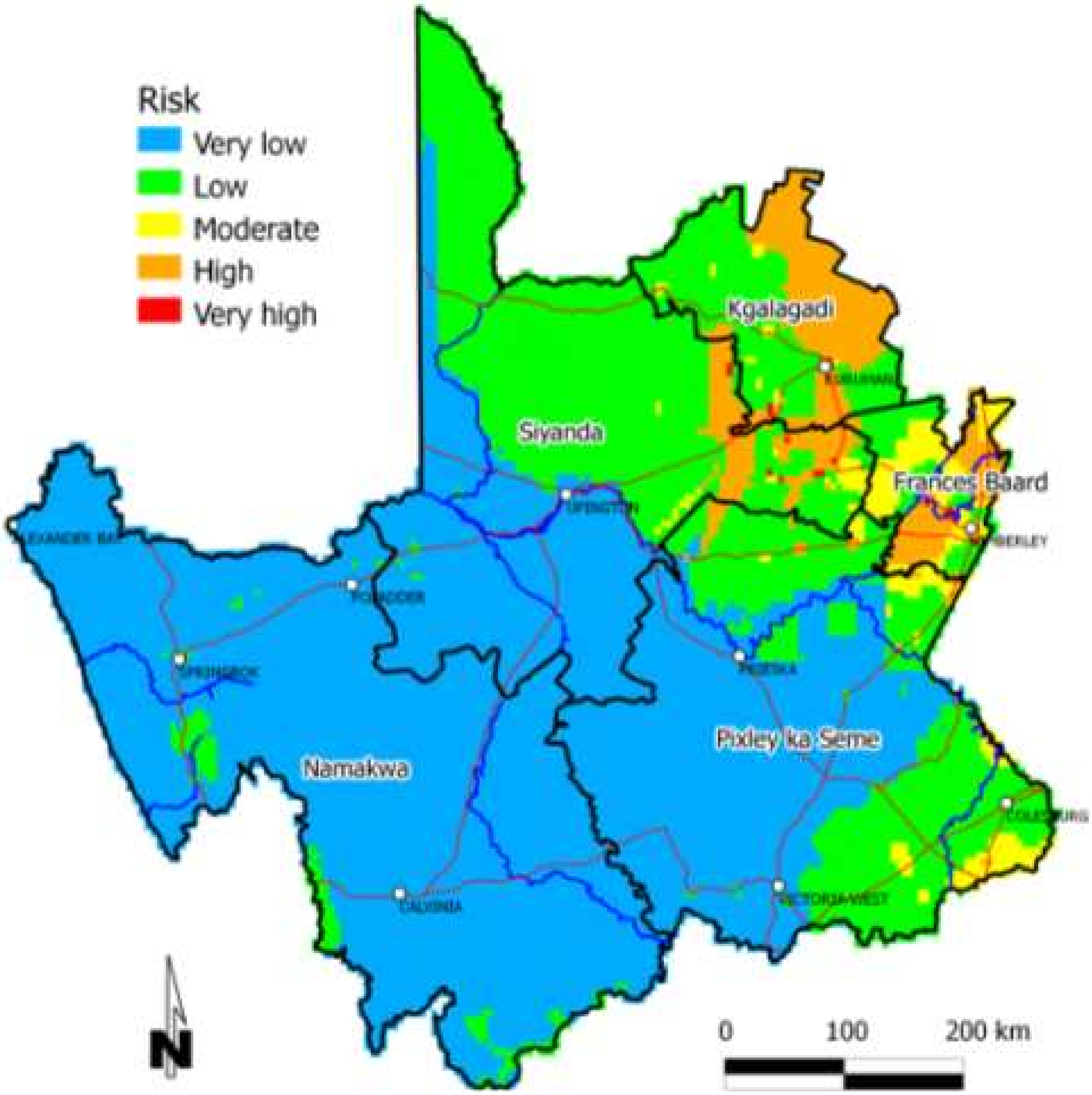

Figure4. 1: Fire risk map for the Northern Cape.

One should keep in mind that the information obtained from landowners and local people was the basis of this map. We only adjust classifications where land owners differ substantially from others; for example everybody classify fuel load a three and a specific group in another region classify the same fuel load a two; in such cases we made the necessary adjustments.

The final result shows higher fire risk at the north east corner of the province with the centre, southern and western part of the province with insignificant fire risk. It is important to note that the risk assessment was based on normal years with normal vegetation. During years of above-normal rainfall such as the first 5 months of 2011, the fuel load will increase accordingly and the fire risk might be much higher during the following fire season.

Conclusion

The Northern Cape is the province in South Africa with the lowest wild fire risk, yet hundreds of thousands of hectares burnt annually. The risk assessment methodology followed during this assessment relied heavily on local knowledge and the similarities between this assessment and the results obtained from the assessment done by Forsyth *et al* (2010) is remarkable. One should note that the national fire danger atlas was done at a macro scale, this assessment at the meso-scale and the district municipalities should do the micro-scale assessments with more detail.

Bibliography

Ackocks, J. *Veld Types of South Africa.* Pretoria: Government Printer: Department of Agriculture.

Crutzen, P., & Goldammer, J. (1993). *Fire in the Environment: The Ecological, Atmospheric, and Climatic Importance of Vegetation Fires.* Berlin.

Forsyth, G., Kruger, F., & Le Maitre, D. (2010). *NATIONAL VELDFIRE RISK ASSESSMENT: ANALYSIS OF EXPOSURE OF SOCIAL, ECONOMIC AND ENVIRONMENTAL ASSETS TO VELDFIRE HAZARDS IN SOUTH AFRICA.* Stellenbosch: CSIR.

Heijmans, A., & Victoria, L. (2001). Citizenry-Based and Development-Oriented Disaster Response: Experiences and practices in Disaster Management of the Citizen's Disaster Response Network in the Philippines. 118.

Holloway, A., & von Kotze, A. (1999). *Living With Drought: Drought Mitigation for Sustainable Livelihoods.*

ISDR. (2000). *Wildfire Prevention in Australia.* ISDR.

ISO. (2002). *Risk management vocabulary: guidlines for use in standards.* Geneva: ISO/IEC Guide 73:2002(E/F). First Edition 200 . InternationalOrganization for Standardization.

Kruger, F., Forsyth, G., Kruger, L., Slater, K., Maitre, D. L., & Matshate, J. (2006). *Classification of Veldfire Risk in South Africa for the administration of the Legislation regarding Fire Management.* V International Conference on Forest Fire Research. D. X. Viegas (Ed.).

KZNFPA. (2011, March 09). *Kwa-Zulu Natal Fire Protection Assocoation - Firestop.* Retrieved from http://www.firestop.co.za

Levine, J. (1996). *Biomass Burning and Global Change, Volume 1.* Massachusetts Institute of Technology.

Low, A. a. (1998). *Vegetation in South Africa, Lesotho and Swaziland.* Pretoria: Department of Environmental Affairs and Tourism.

Low, A., & Rebelo, A. (1998). *Vegetation in South Africa, Lesotho and Swaziland.* Pretoria: Department of Environmental Affairs and Tourism.

Procter, M., & Jordaan, A. (2010). *Masters thesis.* DiMTEC, University of the Free State: Unpublished.

Rutherford, & Mucina. (2006). *The Vegetation Map of South Africa, Lesotho and Swaziland.* Pretoria: SANBI.

Standards Australia. (1999). *Australian Standard - AS/NZS 4360 Risk Management.* Sidney: Standards Australia.

Troloppe, W. (1993). Fire regime for the Kruger National Park for the period 1980 - 1992. *Koedoe. 36. 2.* , 45-52.

UNDP. (2004). *Reducing Disaster Risk: A Challenge for Development.* New York: Bureau for Crisis Prevention and Recovery.

Willis, C., van Wilgen, B., Tolhurst, K., Everson, C., D' Abreton, P., & Flemming, L. P. (2001). *The Development of a National Fire Danger Rating System for South Africa.* Pretoria: Department of Water Affairs and Forrestry.

Wilson, A. (2004). *Analysis of wildfire threat- issues and options.* Melbourne, Australia: Fire Management Department of Sustainability and Environment.

Wisner, B. (2006). *Risk Reduction Indicators.* (bwisner@igc.org).