Classification of Veldfire Risk in South Africa for the Administration of the Legislation regarding Fire Management

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Abstract: The risk associated with vegetation fires (veldfires) in South Africa is substantial, and veldfires cause severe losses to life, property and the environment in most areas of the country. However, this risk has two parts: first, that arising from wildfires (i.e. unwanted veldfires) that cause damage to assets, and, second, the risk arising from ecologically inappropriate fire regimes in environments where fire plays an ecological role. South Africa has adopted the National Veld and Forest Fire Act, No. 101 of 1998 as a major instrument for improved management of veldfires.This paper provides a classification of veldfire risk in South Africa, based in the first instance on ecological information, as a contribution to a strategy for the implementation of the new legislation. We assigned each of the major vegetation types in South Africa to one of 13 different fire-ecology types. A fire-ecology type comprises one or more vegeatation types which have a similar frequency and nature of veldfires. South Africa is divided into six metropolitan and 231 local municipalities and each of these was assigned a fire-ecology type. Wildfire risk was assessed as the combination of the likelihood and consequences of veldfires in each fire-ecology type. The likelihood of veldfire was related to the average fire return period for that vegetation type, determined from the literature. Likelihood ratings were "almost certain" (fires 1 in 2 years), likely (fires 1 in 5 years), possible (fires 1 in 10 years), unlikely (fires 1 in 20 years) and rare (fires 1 in 100 years). The consequences of veldfires in each fire-ecology type were estimated from a range of sources including fire reports and newspaper accounts of veldfires. The consequences of veldfires were grouped into the following categories: catastrophic (regular loss of life and significant economic consequences); major (extensive injuries and serious economic consequences); moderate (localised damage and economic losses); minor (minor financial losses and damage); and insignificant (damage inconsequential). Risk categories were defined as low, medium, high or extreme, depending on the combinations of likelihood and consequences. For example, if veldfires almost certain and catastrophic, risk was extreme; and if they were rare, but had moderate consequences, the risk was low. Grassland and savanna areas, which cover almost 40% of the eastern half of the country, were at highest risk. Mediterranean shrublands, which are well known for their veldfires were rated only as high, because most of the area is mountainous, infertile, and unoccupied, or sparsely occupied.

Keywords: Wildfire risk classification and vegetation fire management legislation.

INTRODUCTION

South Africa has elected to drive development through local government. This means that sustainable economic, social and natural resources development must be integrated locally and so that it complies with national policies and frameworks. This paper examines a way of applying ecological information to local veldfire management (veldfires being fires that occur in vegetation in the countryside).

The risk associated with veldfires in South Africa is substantial, and veldfires cause severe losses to life, property and the environment in most areas of the country. However, this risk has two parts: first, that arising from wildfires (i.e. unwanted veldfires) that cause damage to assets, and, second, the risk arising from ecologically inappropriate fire regimes in environments where fire plays an ecological role. As in most countries with wildfires, the risk can be managed to acceptable levels at acceptable cost, provided a comprehensive approach, based on integrated natural resource management within a proper development planning and management framework, is adopted and applied consistently.

South Africa has adopted the National Veld and Forest Fire Act (the Act), No. 101 of 1998 as a major instrument for improved management of veldfires in the country. This paper describes an element of the system for the consistent implementation of the Act. We use a risk classification, based in the first instance on ecological information, as a contribution to a strategy for implementation. This is for two reasons (a) the standard approach to risk management provides a useful tool for bridging natural-resource management and the protection and development of community assets and (b) in South Africa, local government must formulate Integrated Development Plans to direct local development, and each of these is required to identify the environmental risks and their corresponding risk management strategies, within the area under the jurisdiction of each municipality.

The paper sets out the approach followed in classifying vegetation types and then each metropolitan municipality (large city) and local municipality according to classes of wildfire risk, as a national framework for the implementation of the Act. It also deals with the environmental risk associated with inappropriate fire regimes. These two dimensions of risk need to be examined together, since experience in South Africa and elsewhere has shown that managing the two dimensions separately leads inevitably to long-term environmental and resource degradation, rising costs of wildfire suppression and intractable problems in maintaining a safe environment.

RELEVANT ASPECTS OF THE NATIONAL VELD AND FOREST FIRE ACT

The National Veld and Forest Fire Act (the Act) provides a national framework for the consistent management of veldfires across the whole country. However, the Act requires that it be applied with due consideration of the risk of veldfires, as well as the ecological conditions that determine fire danger and veldfire risk. Risk, in the Act, is with respect to “life, property, and the environment”.

For example, it provides for the formation of local, community-based, fire protection associations for collective management of veldfires in respect of areas which have regular veldfires; or a relatively uniform risk of veldfire; or relatively uniform climatic conditions; or relatively uniform types of vegetation. It also sets a duty that “A fire protection association must at least develop and apply a veldfire management strategy for its area”. Further, the Act requires land owners, to meet several requirements regarding readiness for fire fighting. As well as this statutory framework, there needs to be a consistent basis for setting priorities for veldfire management interventions, such as to support and promote the formation and registration of fire protection associations.

We have adopted an ecological approach to the assessment of veldfire risk as a basis for a strategy for implementing the Act. This is because firstly the South Africa landscape is still mostly dominated by natural vegetation, even if partly transformed. Secondly the ecological classifications provide the framework for the prediction of “natural” fire risk as they reflect both prevailing climate and in most vegetation types, the prevailing natural fire regime.

METHOD OF RISK ASSESSMENT AND CLASSIFICATION

Overview

We use the term wildfire risk here in the standard sense, i.e. it is the chance of a veldfire igniting, spreading and causing damage to one or more assets, measured in terms of likelihood and consequence to the assets. This is derived from the international standard definition of risk as the combination of the probability of an event and its consequence (ISO 2002).

The risk classification set out here is based in the first place on information on the prevailing natural vegetation in any part of the country. For each vegetation type we established the likelihood of wildfires occurring in that vegetation, and the consequences that arise in modern times when such wildfires occur. This combination of likelihood and consequence allows the risk to be rated. Then, using the spatial distribution of vegetation types, we assigned a risk class to each metropolitan and local municipality. This approach requires a number of assumptions, each discussed below.

Determining the fire-ecology type

South Africa has several different biomes each containing a variety of vegetation types. A biome is a large ecological unit with distinctive associations of plant and animal species and climatic conditions (Huntley 1984). Low and Rebelo (1998) developed a vegetation classification of intermediate complexity, which we adopted as the basis for the veldfire risk assessment.

We assigned each of these vegetation types to a separate fire-ecology type. Each fire-ecology type is a set of vegetation types within a given biome that is relatively uniform in terms of the frequency and nature of veldfires that occur within the constituent vegetation types. We derived information on this natural veldfire regime for each biome and vegetation type from literature.

Fire-dependence and climate-dependence

Table 1 sets out the fire-ecology types identified for each biome. Each type that is either grassland or has a prominent grass layer has been classified as a sour-grass or a sweet-grass type (see discussion below).

Table 1. South African biomes and their fire-ecology types derived from their constituent vegetation types according to Low and Rebelo (1998)

Biome	Fire-ecology type	Type of grass cover	Dependence of fire-ecology type on fire or climate
Forest	Forest	Not significant	Climate-dependent
Thicket	Thicket	Not significant	Climate-dependent (except the grassy form of thicket)
Savanna	Sparse Arid Woodland	Sweet	Climate-dependent
	Arid Woodland	Sweet	Climate-dependent
	Moist Woodland	Sour	Fire-dependent
Karoo	Succulent Karoo	Not significant	Climate-dependent
	Nama Karoo	Sweet	Climate-dependent
	Grassy Nama Karoo	Sweet	Fire-dependent
Grassland	Coastal Grassland	Sour	Fire-dependent
	Sour Grassland	Sour	Fire-dependent
	Sweet Grassland	Sweet	Climate-dependent
Fynbos	Renosterveld	Not significant	Fire-dependent
	Fynbos	Not significant	Fire-dependent

There are important aspects of fire and ecology in South Africa that determine the ecologically-based risk assessment we report here. These are:

(a) the degree of fire dependence in a given vegetation type,
(b) the relationship between fire dependence and both bush encroachment and the invasion of natural vegetation by invasive alien plants, and
(c) the inherent relationship between climate, soil, vegetation and fire regime determine the nature of the natural-resource assets that can be cultivated in any given region, and hence the exposure of the asset to related fire risks.

The vegetation of South Africa can be divided broadly into two classes: fire-dependent types (FD) and climate-dependent types (CD) (Bond 1997; Bond *et al*. 2003a). The structure of the vegetation in FD vegetation is not limited by climatic conditions; without fire, the structure changes. FD vegetation requires fires to maintain its biodiversity and would become dominated by woody plant species if fires were excluded (Bond *et al*. 2003a). By contrast, the structure of CD vegetation is controlled by climate, mainly rainfall, and fires are not required to maintain biodiversity.
In broad terms the FD and CD vegetation types can be related to the currently recognised biomes (Table 1). FD types include Fynbos, Grassy Eastern Nama Karoo and areas of the Grassland and Savanna Biomes with more than about 650 mm of rain per year (Bond 1997; Bond *et al*. 2003a). CD types include the arid regions of the Grassland and Savanna Biomes, the Succulent Karoo, most of the Nama Karoo and most of the Thicket Biome. The CD Forest Biome lies almost entirely in high-rainfall areas. It occurs in patches within FD vegetation types but forests do not require fire to

maintain their biodiversity (Granger 1984; Midgley *et al*. 1997). The FD types in the Grassland and Savanna Biomes are mainly dominated by sour grasses and the CD types by sweet grasses. Sour grasses dominate the Grassy Eastern Nama Karoo even though the climate is arid. The Thicket Biome can be broadly divided into two groups: those forms characterised by a high cover or diversity of succulent species (mainly in low rainfall areas) and harmed by fires (CD), and those forms with low succulent cover and diversity and more grasses (FD). The FD types require high intensity fires to prevent them from becoming closed stands of woody species.

From this we see that there is a close correlation between the categories fire-dependent, and climate-dependent on the one hand, and sour and sweet grass vegetation on the other. The distinction between "sour" and "sweet" grasses is important in the fire-ecology types where grasses are the main fuel (Edwards 1984; Van Wilgen *et al*. 1990; O'Connor and Bredenkamp 1997; Everson 1999; Trollope 1999). "Sour" grass cover typically occurs in high-rainfall (> 600-700 mm per year), in high-lying, and in cool areas. It is characterised by grass species, which grow very rapidly, produce coarse grazing and lose their nutritional value when they become dormant. Sweet grass species predominate in climate-dependent types, in areas with lower and less reliable rainfall (< 600 mm) and produce a pasture that retains much of its nutritional value when the grasses become dormant. Sour grasses generally require frequent and regular fire that removes the unpalatable grass left behind by the grazing animals, which would otherwise inhibit grass regeneration and growth, and admit denser shrub and tree populations. Sweet grasses do not require fire for their maintenance (Everson 1999).

The exceptions to this broad pattern of fire dependence and grass type are in the southwest of the country, in the Fynbos and Renosterveld fire-ecology types. Here, fire dependence is not associated with grass type.

ASSESSMENT OF WILDFIRE RISK IN EACH FIRE-ECOLOGY TYPE AND MUNICIPALITY

We assessed wildfire risk and classified for each fire-ecology type using the standard risk assessment and classification outlined in Tables 2-4.

The basis for the classification was an assessment as follows:

(a) assume a critical wildfire scenario for each fire-ecology type;
(b) judge the consequence of such a scenario on the basis of reports on consequences of such fires for the fire-ecology type;
(c) assess the likelihood of such a scenario in each fire-ecology type; and
(d) classify risk according to Tables 2-4.

Table 2. Qualitative and quantitative indicators of likelihood of fire occurring (adapted from Standards Australia, 1999).

Likelihood rating:	Likelihood: indicative frequency	Description
Almost certain	1 in 2 years	Is expected to occur

Likely	1 in 5 years	Will probably occur
Possible	1 in 10 years	Might occur at some time
Unlikely	1 in 20 years	Could occur at some time
Rare	1 in 100 years	May only occur in exceptional circumstances

Table 3. Qualitative measures of consequence (adapted from Standards Australia, 1999)

Level of consequence	Human life vulnerability criteria	Economic vulnerability criteria	Environmental and ecological vulnerability criteria
Catastrophic	Death	Depressed economy in the region. Major impact on the community and region. Long-term external assistance required.	Permanent loss of species or habitats within the area or of water catchment values.
Major	Extensive injuries, evacuation required.	Serious financial loss, affecting a significant portion of the community. Requires external funding to recover.	Habitat destruction, temporary loss of species or catchment values, requiring several years to recover.
Moderate	Medical treatment required.	Localised damage to property. Short-term external assistance required to recover.	Serious impact on the environment that will take a few years to recover.
Minor	Minor injuries only	Minor financial loss. Short-term damage to assets. No external assistance required to recover.	Discernable environmental impact. Assets recover rapidly.
Insignificant	No injuries	Inconsequential or no damage to property	Minor impact on the environment

Table 4. Levels of risk, assessed as the product of likelihood and consequence. (Adapted from Standards Australia, 1999)

Likelihood Rating	Consequence Rating				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	M	M	H	E	E
Likely	L	M	H	E	E
Possible	L	M	H	H	E
Unlikely	L	L	M	H	E
Rare	L	L	L	M	H

Treatment of municipalities and municipal boundaries

Since veldfire management is a local government responsibility, the risk of wildfire needs to be established at as fine a scale as possible. At this stage, the workable level of resolution is the municipality. This level is also useful because, administratively, fire services are a municipal competence, and the areas under jurisdiction are part of a municipality. Local stakeholders will be able to further refine their risk assessments within their municipal boundaries, to the level of resolution they require.

At the scale of the municipality we are dealing in reality with two categories of local government, i.e. metropoles (large cities) and local municipalities. Although the metropoles are regarded as urban areas, each contains substantial areas of open countryside, requiring veldfire management. Municipalities on the other hand are all rural or nearly so.

Assigning wildfire risk to each municipality

The first step was to determine the extent of each fire-ecology type in each metropole and local municipality. This was done by overlaying the municipal boundaries on the map of fire-ecology types using a geographical information system. The area of each fire-ecology type within each municipality is the aggregate mapped area occupied by the vegetation types that it comprises.

These areas do not reflect the actual current extent of each fire-ecology type, since the underlying vegetation map reflects the "potential" area of each type, whereas the natural vegetation has been transformed to a greater or lesser extent by conversion to crops or other cover types. However, we assume that the mapped area indicates the potential extent of the veldfire management problem in each metropole or municipality.

If the municipality was dominated by the fire-ecology type with highest risk, we assigned its risk level to the municipality. If however, the municipality was dominated by a relatively low-risk fire-ecology type, but had at least 30% of a fire-ecology type with a higher risk, we assigned the higher risk class to the municipality. The rationale for this is that this would constitute a veldfire management problem that justifies planning for the risks that it poses. We downgraded the risk rating if the higher fire risk types were found in areas where they would not be considered a hazard to assets. Also, if the incidence of the higher risk category was scattered within a dominant area of a type with lower risk, the rating was downgraded accordingly.

Assessment of the risk of inappropriate fire regimes

The main determinants of the nature of the veldfire management problem at any location in South Africa are vegetation, weather and terrain. This variation is normally described through the identification of biomes. In each biome in which fire is a factor in South Africa there is a fire regime that is appropriate to the maintenance of biodiversity in that biome (Bond 1997). A risk arises to biodiversity when there is a shift to an inappropriate fire regime.

The system of fire-ecology types developed here formed the framework for assessment of the risks attached to inappropriate fire regimes. However to assist in a simple first approximation our assessment focused on only two aspects of biodiversity risk, namely, bush encroachment and alien plant invasions . These two indicators are both important and useful, since they are functionally related to biodiversity, land productivity and catchment water supply.

DETAILED WILDFIRE RISK CLASSIFICATION

Table 5 provides the list of fire-ecology types for the country and the wildfire risk assessment for each. Some of the risk classifications are surprising at first glance. For example the fire-prone Fynbos is rated a lower risk than are Moist Woodland and Sour Grassland, which are both rated in the category of Extreme risk. This is because in both these latter cases, fine fuel in the form of grass accumulates annually and cures after frost or drought to form highly flammable material. In the areas of these types, much of the topography is gentle and soils productive, so that farms, dwellings, settlements, stock and other assets are widely distributed throughout. Veldfires are frequent, move quickly, and can be intense. Because there are many vulnerable assets, the consequences of the critical wildfire scenario are catastrophic in both cases.

Table 5. Risk assessment and assessed risk levels in each fire-ecology type and their area in South Africa.

Fire-ecology type (see Table 1)	**Likelihood of critical wildfire scenario** (see Table 2)	**Consequence of critical wildfire scenario** (see Table 3)	**Wildfire risk level** (see Table 4)	**Area** Km^2	**Percent of total land area**
Forest	Rare	Moderate	Low	10903	0.86
Thicket	Rare	Moderate	Low	37857	2.99
Arid Woodland	Possible	Major	High	211952	16.73
Moist Woodland	Likely	Catastrophic	Extreme	132698	10.47
Sparse Arid Woodland	Rare	Minor	Low	58390	4.61
Succulent Karoo	Rare	Minor	Low	122593	9.68
Nama Karoo	Unlikely	Minor	Low	180056	14.21
Grassy Nama Karoo	Possible	Minor	Medium	77786	6.14
Coastal Grassland	Likely	Minor	Medium	26273	2.07
Sour Grassland	Almost Certain	Catastrophic	Extreme	239230	18.88
Sweet Grassland	Likely	Moderate	High	92023	7.26
Fynbos	Possible	Moderate	High	41752	3.30
Renosterveld	Unlikely	Moderate	Medium	35371	2.79
				1266884	100.00

Fynbos, which is well known for its veldfires, has been rated only as High as most of the fynbos biome is mountainous, infertile, and unoccupied or sparsely occupied. In Coastal Grassland, fuel accumulates as much as it does in Sour Grassland. However, the coastal climate is generally humid, and veldfires in Coastal Grassland are easily controlled (J Oosthuisen, KwaZulu-Natal Fire Protection Association, personal communication).Thus, consequences of wildfires in Coastal Grassland are minor, and the risk level for the type is Medium. The assessed risk level for Arid Woodland is high as the grass biomass can be high after seasons of good rainfall, and constitute a substantial fire hazard.

The relationship between wildfire risk and the understood fire ecology of South Africa’s vegetation types is therefore not perfect. Extreme wildfire risk, by this assessment, is manifest only in fire-ecology types with sour grasses (sour grassland and moist woodland). Low wildfire risk is manifest only in the arid, climate-dependent types of the west. Some climate-dependent types have high risk, and one has low risk. Two fire-dependent types, Coastal Grassland and Renosterveld, have medium wildfire risk, the former apparently because of the humid coastal climate. Overall, however, the principal wildfire management problem occurs across about 60% of the country, mainly in the more humid regions with sour grass cover. Figure 1 is a map of the country showing each municipality classified according to the level veldfire risk.

ECOLOGICAL VELDFIRE MANAGEMENT AND THE BROAD PATTERNS OF VELDFIRE RISK

Table 6 summarises the veldfire risk for each fire-ecology type, measured in terms of the consequences of bush encroachment and alien plant invasions. Note that this is the risk associated with the manifestation of an inappropriate fire regime or inadequate control programmes for invading plants, not the risk to assets of a given wildfire.

Of the 13 fire-ecology types identified, five are fire-dependent, and seven, climate-dependent (Table 1).Broadly, the veldfire risk profile of the country is strongly associated with the pattern of fire dependence, and on whether or not the grass cover is sour (see below). Thus, risk of invasion by alien plants associated with inappropriate veldfire management is high in all fire-dependent types. In climate-dependent types it is high only in forest, and that is because of fires in adjoining fire-dependent grassland or fynbos that expose the forest margin to invasion. Most climate dependent types apparently have a low risk of invasions associated with inappropriate veldfire management, mainly because veldfires are not a factor in most of those environments.

The risk of bush encroachment linked with veldfire management is high in the types with sour grasses, all of which are fire-dependent. It is moderate in the sweet-grass climate-dependent types. Thus, overall, South Africa’s fire-dependent biomes are at risk of some from of severe ecological and land degradation if veldfires are inappropriately managed. However moderate risks in other types together with these high risks mean that veldfires in the largest fraction of our habitats must be managed with great care to avoid environmental degradation.

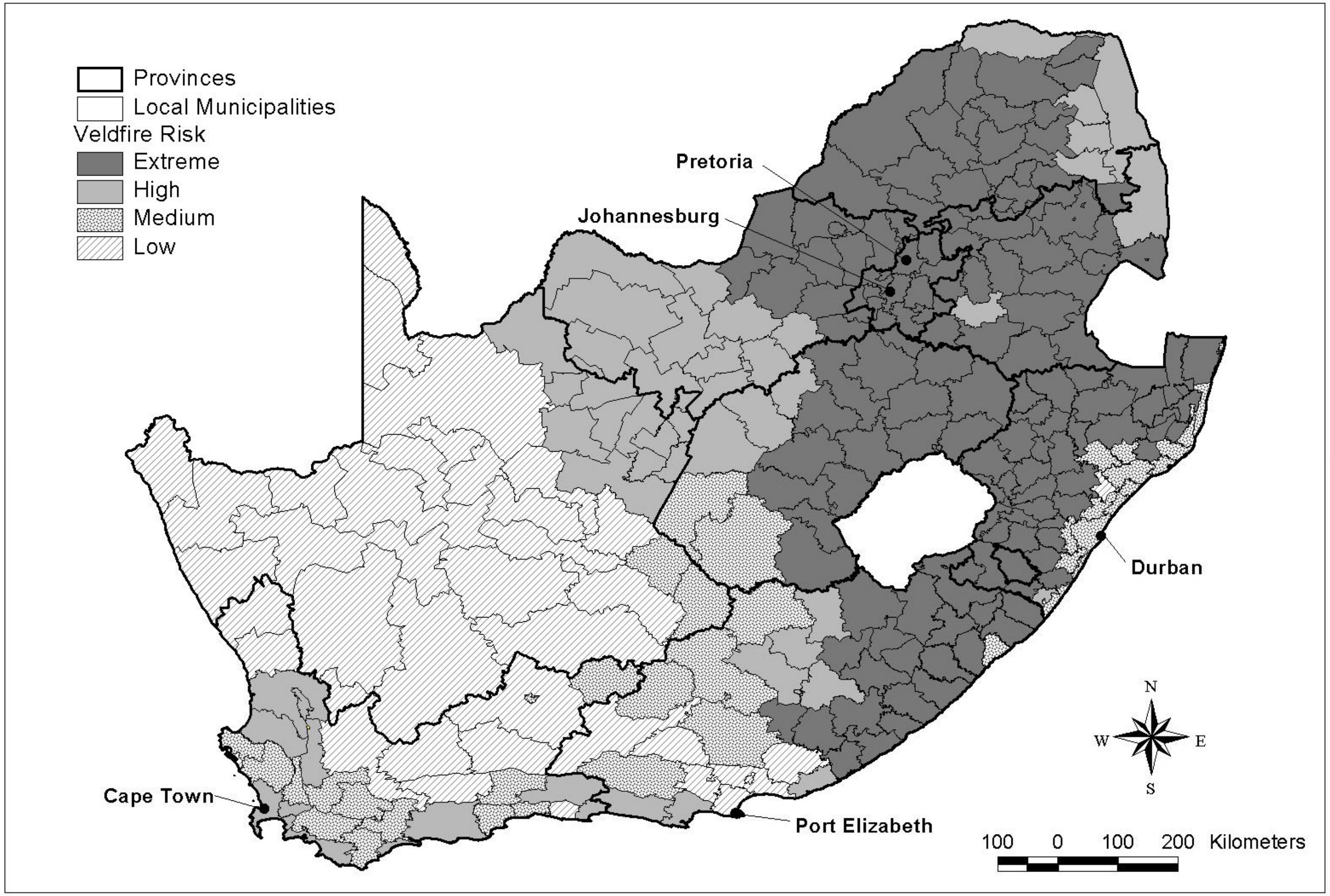

Figure 1: South African municipalities classified according to four levels of veld fire risk (April 2003). Areas of extreme veldfire risk occur mainly in the savanna and grassland biomes while areas of high risk predominantly occur in the savanna and fynbos biomes.

CONCLUSION

This paper is first approximation of the veldfire risk profile for South Africa drawn from readily available ecological information, vegetation maps that ignore current patterns of land-use, and inferred information on the likelihood and consequence of the critical fire scenarios.

Nearly seventy per cent of the area of South Africa is subject to a significant level of wildfire risk (Table 5). Fifty-seven per cent is subject to high or extreme risk. This latter fraction is also subject to a high risk of ecosystem and land degradation if veldfires are inappropriately managed. The 11% that has a medium wildfire risk is also ecologically prone to degradation if land management results in inappropriate veldfire and grazing regimes, and is very difficult to rehabilitate once degraded.

While we have a long tradition of good work on the ecology of fire in South Africa, and substantial experience in applying this in natural resource management, the new political environment, especially the new role for local government, as well as the imperative for sustainable rural development, requires a renewed emphasis on bringing ecology and policy together, and especially to refine our scientific information so that it may be effectively integrated locally. This paper offers a way of doing this as it deals with two forms of veldfire risk in South Africa, i.e. first, the risk associated with the consequences of an inappropriate veldfire regime and second, the risk of wildfires. It thus links the need for veldfire management as a natural resource management tool, to that associated with the emergency management cycle.

The ecological information available on veldfires provides a reasonable framework for local geographically resolved prediction of the level and nature of the veldfire management problem within South Africa’s new system of administration. However, the correlation between ecological information and veldfire risk overall is not perfect. Both the incidence and consequence of wildfires are subject to many indeterminate factors, such as the nature and pattern of land use and development, and the quality of veldfire management achieved. Land use patterns are changing rapidly under the influence of diverse factors, including the expansion of towns and cities, causing an expanding urban-rural interface, and exposing more assets to the hazard of wildfires.

Clearly this situation needs to be improved. In the near future a more detailed vegetation map is to be released for South Africa and this, together with land cover information, will provide that basis for a more accurate veldfire risk assessment for the country. In addition, proper reporting of veldfires and a thorough review of archival information on veldfires will allow better risk assessment within each fire-ecology type.

Table 6. The risk of bush encroachment and invasion by alien plant species in the different fire-ecology types. Bush encroachment assessments, i.e. of increases in the density of woody plant species (trees, shrubs or both), based on information from Bond (1997); O'Connor and Bredenkamp (1997); Scholes (1997); Everson (1999); Stuart-Hill and Tainton (1999); Trollope (1999); Bond and Archibald (2003); Bond *et al.* (2003a, 2003b); Uys *et al*. (2004). Assessments for invasive plants based on information from Van Wilgen *et al*. (1992); Milton *et al*. (1997); Palmer and Hoffman (1997); Richardson *et al*. (1997); Versfeld *et al*. (1998); Vlok and Euston Brown (2002).

Fire-ecology type	**Risk assessment**	
	Bush encroachment governed by fire regime	**Invasion by alien plants governed by fire regime**
Forest	No risk	High - forest margins vulnerable to species which invade after fires have damaged the vegetation; flammable species such as *Chromolaena odorata* increase the vulnerability of the margins to fire; forest interior invaded by species which do not require fires
Thicket	Not known, probably low in forms with high succulent diversity. High – in grassy forms particularly those transitional to Sour Grassland and Moist Woodland	Low - fires do not appear to facilitate invasions
Sparse Arid and Arid Woodland	Low – woody plant recruitment is limited by low rainfall in most years and lowest in the arid west (Kalahari region). A long history of overgrazing, the loss of browsing animals in farmed areas, and low intensity fires have led to bush encroachment in many areas	Moderate to Low - fires may facilitate invasions by herbaceous species but do not appear to facilitate invasions by other species?
Moist Woodland	High – woody plant recruitment is not limited by rainfall except during droughts. Sufficient grass is left for frequent fires but man-made fires are not intense enough to control woody plants. The lack of browsing animals in farmed areas leads to an increase in woody plant densities.	High - fires facilitate invasions by several woody and herbaceous species which can recover by sprouting and have fire stimulated seed germination; invasions can increase fuel load and fire intensities, potentially leading to water repellence and soil loss
Succulent Karoo	Not known, probably low	Low - fires do not appear to facilitate invasions but invasions by annual grasses may create fuel, increase fire frequencies and further facilitate invasions
Nama Karoo	Under debate, relative importance of grasses appears to be controlled by rainfall and season timing of rainfall; grass component typically over-utilised and may have increased shrub densities; grazing and browsing history has also had an impact	Low - fires do not appear to facilitate invasions
Grassy Nama Karoo	Moderate – woody shrub recruitment possibly limited by rainfall; shrub encroachment facilitated by overgrazing and low intensity fires	Low - fires do not appear to facilitate invasions?
Coastal Grassland	High – woody plant recruitment is not limited by rainfall and	High - fires facilitate invasions by several species which can recover by sprouting

	Risk assessment	
	reductions in fire frequency and intensity will lead to bush encroachment	and have fire stimulated seed germination
Sour Grassland	High - woody plant recruitment is not limited by rainfall and reductions in fire frequency and intensity will lead to bush encroachment	High - fires facilitate invasions by several species which can recover by sprouting and have fire stimulated seed germination; invasions can increase fuel loads and fire intensities, potentially leading to water repellence and soil loss
Sweet Grassland	Moderate - woody plant recruitment probably is limited by rainfall in most years. A long history of overgrazing and lack of browsing animals and intense fires has led to bush encroachment in many areas	Moderate - fires may facilitate invasions
Renosterveld	Uncertain, possibly moderate – many experts believe grasses were much more abundant before the advent of pastoralists and European colonists and that fires were possible to likely. Overgrazing, fire exclusion and low intensity fires are believed to have led to the current dominance by unpalatable shrub species	High - fires facilitate invasions by several species which can recover by sprouting and have fire stimulated seed germination; susceptible to invasion by alien grass species which, in turn, can result in an increase fire frequencies; invasions by woody species can increase fuel loads and fire intensities, potentially leading to water repellence and soil loss
Fynbos	Low – a fire regime involving only summer and autumn fires can increase the density of some species, leading to the formation of dense shrublands and the loss of understorey species; low fire intensities may lead to increases in the density of some shrub species	High - fires facilitate invasions by several species which can recover by sprouting, have fire stimulated seed germination, or fire stimulated seed release and seedling recruitment; invasions by woody species can increase fuel loads and fire intensities, potentially leading to water repellence and soil loss

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