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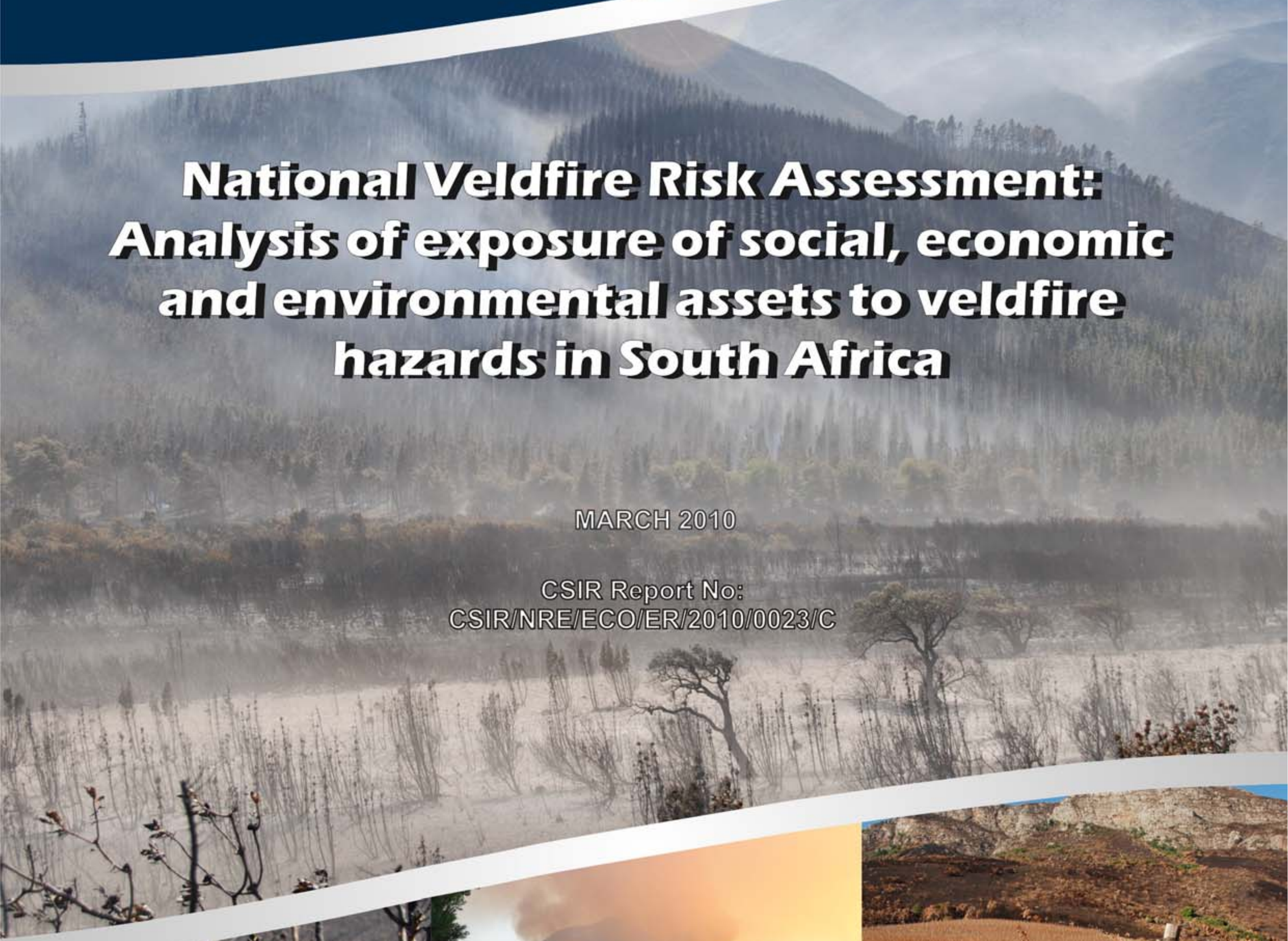

National Veldfire Risk Assessment: Analysis of exposure of social, economic and environmental assets to veldfire hazards in South Africa

MARCH 2010

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NATIONAL VELDFIRE RISK ASSESSMENT: ANALYSIS OF EXPOSURE OF SOCIAL, ECONOMIC AND ENVIRONMENTAL ASSETS TO VELDFIRE HAZARDS IN SOUTH AFRICA

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SUMMARY FOR POLICYMAKERS

S.1 Introduction

Veldfire is an important natural hazard in South Africa.

This report addresses the requirement of the Department of Agriculture, Forestry and Fisheries (DAFF) for a revision of the national veldfire risk classification developed in 2004.

As the organ of state accountable for the implementation of the National Veld and Forest Fire Act, No. 101 of 1998, the DAFF requires a risk assessment and map of risks of veldfire, according to the requirements as set out in the National Disaster Management Framework (NDMF). This assessment should integrate with relevant provisions in the National Veld and Forest Fire Act, for example, the fire danger rating system. It should provide an assessment at the policy level, to support operational assessments and mitigation plans in the provincial and local spheres of government. It should integrate with bioregional plans in terms of the National Environmental Management: Biodiversity Act as well as Integrated Development Plans.

The purpose is to serve as a national framework for implementing the National Veld and Forest Fire Act, and thus to provide a consistent basis for setting priorities for veldfire management interventions such as the promotion of and support to Fire Protection Associations. It also is to serve as the veldfire risk assessment for the National Disaster Management Framework.

The risk assessment is required for the whole country, so that areas with no risk are identified, as well as those at risk.

The assessment serves the purposes of policy, not operations. Therefore, it should address inherent veldfire risk, rather than residual risk after taking account of the mitigation provided by risk management. This is to meet the objective in the NDMF, i.e. to establish a uniform approach to assessing disaster risks that will inform risk management planning and reduction to be undertaken by organs of state and other role players.

Since the 2004 classification, scientific research has improved our knowledge of fire in South Africa substantially. In addition, better datasets are now available for improved risk assessment, including a very detailed vegetation map, a new land cover map showing the extent of transformed land, and the detailed spatial socio-economic data for the National Spatial Development Perspective.

This present assessment will require periodic review as information improves and conditions change. But it reflects best available information on current conditions of veldfire risk.

This work follows the ISO31000 and AS/NZS 4360 with respect to comparative risk assessment. These standards do not require the explicit treatment of vulnerability, which is a specific requirement in other approaches, such as the NDMF, and the United Nations International Strategy for Disaster Reduction (see below). Instead, we identify vulnerable values and assets in each of our analysis units, and use this information to guide the analysis of the consequence of veldfire events.

In this report, veldfires refer to fire in vegetation in general, and of wildfires specifically to unplanned vegetation fires.

S.2 The wildfire situation and recent trends in risk factors

S.2.1 Overview

South Africa's information systems for the reporting of veldfires (in particular, the National Veldfire Information System) are not yet operating. A quantitative analysis of the veldfire situation is therefore not possible.

Nevertheless, available evidence indicates that the situation in rural South Africa, and the urban-rural interface, is serious, worsening, and significantly affecting significantly our progress in achieving rural development goals.

The wildfire situation has evidently worsened significantly during the past several years. There have been major catastrophic fires in many areas. 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.

Members of the insurance industry report that the risk in the rural environment has progressively increased over the past 10 years; although this is not all owing to veldfire risk, veldfires are an important contributor to the trend.

The extreme wildfire episodes of 2008 illustrate the problem. Late August and early September 2008 was a period was marked by extreme dryness and strong gusty northerly to westerly winds, ahead of a major regional weather front, following a long rainless period in the interior and east of the subcontinent. Large areas of Sparse Arid Woodland, Arid Woodland and Moist Woodland were burnt in the same period. Fire response capacity was overwhelmed throughout the region. In South Africa, scores of people lost their lives in the fires, and economic losses amounted to billions of Rands.

In this assessment, we have factored such episodes into the specific fire risk scenarios used in the risk analysis (see below). However, such "megafire" episodes have been poorly reported to date and little researched; events of this kind need further study and proper factoring into future risk assessments.

S.2.2 Consequences of wildfires

The information on loss of life and injury owing to veldfires is still poor, but there is much anecdotal evidence that it is a significant factor in the health profile of rural communities. Deaths run to perhaps hundreds in bad years. Social losses regularly accompany these incidents, involving at least the loss of homes and livelihoods.

There are also pervasive health effects from extensive, untimely fires, such as smoke pollution under conditions of atmospheric stability during winter on the Highveld of Gauteng and Mpumalanga.

The best documented economic losses to fire are in the forest sector. Here, losses have been increasing exponentially during the past decade. During the period from January to August 2007, 61,700ha of plantation forest burnt in KwaZulu-Natal and Mpumalanga, 2,9% and 9,5% of the total area of plantations respectively in these two provinces. ForestrySA estimated the value of standing timber burnt amounted R1,33bn (2007 prices), and that of this, 40% would be unsalvageable. More important however, were the forward effects of the disaster, with the consequent impacts on wood flows, especially sawlogs for construction timber, being felt throughout the economy. This was accompanied by closure of manufacturing capacity, loss of rural jobs, and many other adverse effects.

In addition to these documented losses, there are regular reports of others: emergent farmers lose their livelihoods, commercial framers lose livestock, fodder banks, machinery and equipment, and the ecotourism industry loses resorts and wildlife. Local communities also suffer periodically from the loss of important resources such as thatch grass, in wildfires.

The overall effect of the current level of fire risk in rural South Africa is to constrain, if not depress, the opportunities for local economic development. This is because investment is inhibited by the high risk to financial returns, high costs of insurance, or reluctance of reinsurers, and so on.

Wildfires can often be beneficial in protecting biodiversity and maintaining ecosystem services; managers of protected areas as well as production landscapes will often allow wildfires to continue, as long as confined to the desired areas, for their ecosystem benefits. Managers employ prescribed burns for the same purpose.

Wildfires in South Africa cause environmental loss if untimely or extreme, or where wildfires occur on transformed or degraded land, such as through plant invasions. The extreme fires of August 2007 in plantations in Mpumalanga reached intensity levels such that coarse fuels on the ground burnt entirely, with the heat destroying the structure of surface soil horizons; excessive erosion followed during the rainy season, resulting in loss of soil fertility and sedimentation of river channels and wetlands downstream.

S.2.3 Trends in veldfire risk factors

Risk factors are the underlying natural or human causes of a given level of veldfire risk.

The situation in plantation forests appears to have deteriorated markedly, with the results as reported above. Safire argues that, in plantation forestry, the risk levels have increased because of the strong trend toward the practice of leaving slash unburnt after clearfelling, "for conservation reasons", though forest managers are now reviewing this policy. They mention other contributing factors as including neglect of silvicultural tending practices in the forests, as well as a lack of trained staff and management on corporate estates and "managed farms", and instead, a reliance on forestry contractors, who are either not resident or not familiar with the territory, or both, and thus ineffective in responding to wildfire. This is despite improvements in fire detection, according to Safire.

Safire also reports an apparent current increase in the severity of fire weather as reflected in the calculated fire danger indices and wind speed. This is possible, but is likely to be due to cyclical oscillations in climate over the regular cycle may also play a role.

The spread of alien invasive plants continues in certain areas. The consequences are diverse, since the effect on fuel varies with the species that invades, and the density reached. In some parts, where species of pine have become dense, the potential for blow-up fires may have increased.

In general, there are many anecdotes regarding risks arising from changes in land ownership, resulting in new owners with little capacity for fire management, or who are absent. The trend arises from the land reform programme on the one hand, and the development of resorts and other gentrification near montane and savanna protected areas on the other. An important factor in this tend is the question of ignorance of fire, especially the failure to recognise the recurrence of rare megafires, such as in recent Australian fire history. But the problem also exists in South Africa.

In South Africa the pattern and trend in rural populations have apparently had the following effects: (a) human activity remains a pervasive source of ignitions, (b) poor rural security and land tenure uncertainty combine to increase the likelihood of arson, (c) scattered human settlements and the growing extent of the urban-rural interface (including the poor households in informal settlements) have expanded the extent of households vulnerable to fire, (d) in regions of commercial farming, depopulation has reduced the human resources available for fire management, (e) land reform outcomes have had complex effects but most important is that new owners lack the know-how to live with veldfires and (f) gentrification has caused many regions to be subject to neglect arising from absentee land owners, or the segregation of resort owners from the resident communities.

Accompanying all these changes are many institutional changes, some of which have mitigated the trends in risk factors outlined above, while others have aggravated it. The successful establishment of Working on Fire and the progressive deployment of Fire Protection Associations are contributing to the mitigation of risk factors. The trend toward outsourcing of forestry work to contractors may have aggravated the trend (see above), while the catastrophic consequences of the Kruger National Park fire of September 2001 arose in part due to the new and unskilled personnel responsible for controlling that fire, and other concurrent institutional changes.

These trends have been accommodated in the specific fire risk scenarios developed in this study.

S.3 Climate and climate change

Changes in climate will influence the future occurrence of wildfire and the area burned through various pathways that involve weather conditions conducive to combustion, fuels to burn and ignition agents. As humans manage fire in most parts of the world, the resulting changes in fire occurrence patterns will also be

contingent on human activity, government policies, and institutional development.

Recent research on the trends in surface air temperature for 1901 to 2002 show an increase of up to 1.4 degrees C over the centre of South Africa (i.e. the NE half of the Free State, and adjacent N Cape and NW Province), decreasing to about 0.8 to 1.0 degrees C near the coast. This seems to override the natural climate oscillation in the country, and with the many other risk factors discussed above, may have contributed to apparent recent trends of increases in wildfire risk.

The climate-change outlook for South Africa is uncertain, as it is elsewhere. Nevertheless, the risks attached to the more extreme scenarios are sufficiently high, that a prudent policy of insurance against these risks is appropriate, if at reasonable present costs.

The IPCC concludes its chapter on adaptation: "Responding to climate change involves an iterative risk management process that includes both mitigation and adaptation, taking into account actual and avoided climate change damages, co-benefits, sustainability, equity and attitudes to risk."

Such an adaptive risk management process is appropriate in South Africa. Here, implementation of the statutory provision for a fire danger index will provide a system for institutionalising such adaptation, since the FDI will track real weather and climate variation.

This study does not bring climate change predictions into the risk analysis, for several reasons. First, in South Africa as in the Western US and elsewhere, the past one or two decades have already experienced an increase in fire risk: thus the recent historical record provides sufficient information for plausible near-term future fire risk scenarios. Second, the national veldfire risk assessment reported here will need in any event to revised about five to ten years into the future, when the next assessment can be informed by the data and experience acquired in the interim.

S.4 Responding to the wildfire risk: the requirements of the National Disaster Management Framework

An important requirement in the NDMF is Key performance area 2: Risk assessment.

In the NDMF, disaster risk refers to the chance that there will be a harmful impact of some kind due to the interaction between natural or other hazards and conditions of vulnerability.

The NDMF requires risk assessment as the first step in planning an effective risk reduction programme.

Risk assessment planning requires identification of key stakeholders, as well as consultation with them about the design and/or implementation of the assessment and the interpretation of the findings.

In the NDMF, risk assessment is a process that determines the level of risk by:

- analysing potential hazards and/or threats
- assessing the conditions of vulnerability that increase the chance of loss for particular elements-at-risk (that is, environmental, human, infrastructural, agricultural, economic and other elements that are exposed to a hazard, and are at risk of loss)
- determining the level of risk for different situations and conditions
- helping to set priorities for action.

S.5 Comparative assessment of veldfire risks

Since the veldfire risk assessment requires a uniform procedure for the comparison and rating of risks across a variable environment, it requires the method of comparative risk assessment (CRA) as reported here. Figure 1 below illustrates this procedure.

This procedure corresponds with the procedure set out in the NDMF. It addresses all the measures required in NDMF Step 1 ("Identify and describe the risk") are included in the procedure followed here, and our risk analysis provides for part of Step 2 ("Analyse the risk").

The procedure did not address the following parts of Step 2 in NDMF.

1. Identify relevant capacities, methods and resources already available to manage the risk.
2. Assess the effectiveness of these, as well as gaps, inconsistencies and inefficiencies in government departments and other relevant agencies.

The reasons are:

1. The present risk assessment is for policy purposes and the output is to guide full risk-management plans in the provincial and local government spheres, as well as in FPAs
2. It is at these local scales that managers will identify individual assets and their vulnerabilities, the risks to them that arise from veldfire hazard, and thus establish the gaps in capacity that need to be filled
3. The present assessment provides the framework for consistency in risk management in these other three spheres that is required by the NDMF
4. And finally, addressing Step 2 fully would require resources and time to the extent that the national assessment would be much delayed, this delaying the risk management procedures in these other three spheres.

The approach followed is consistent with the procedure specified for risk assessments by FPAs in the preparation of their business plans (in Department of Water Affairs and Forestry guidelines for the establishment and management of Fire Protection Associations in terms of the National Veld and Forest Fire Act No 101 of 1998 as amended).

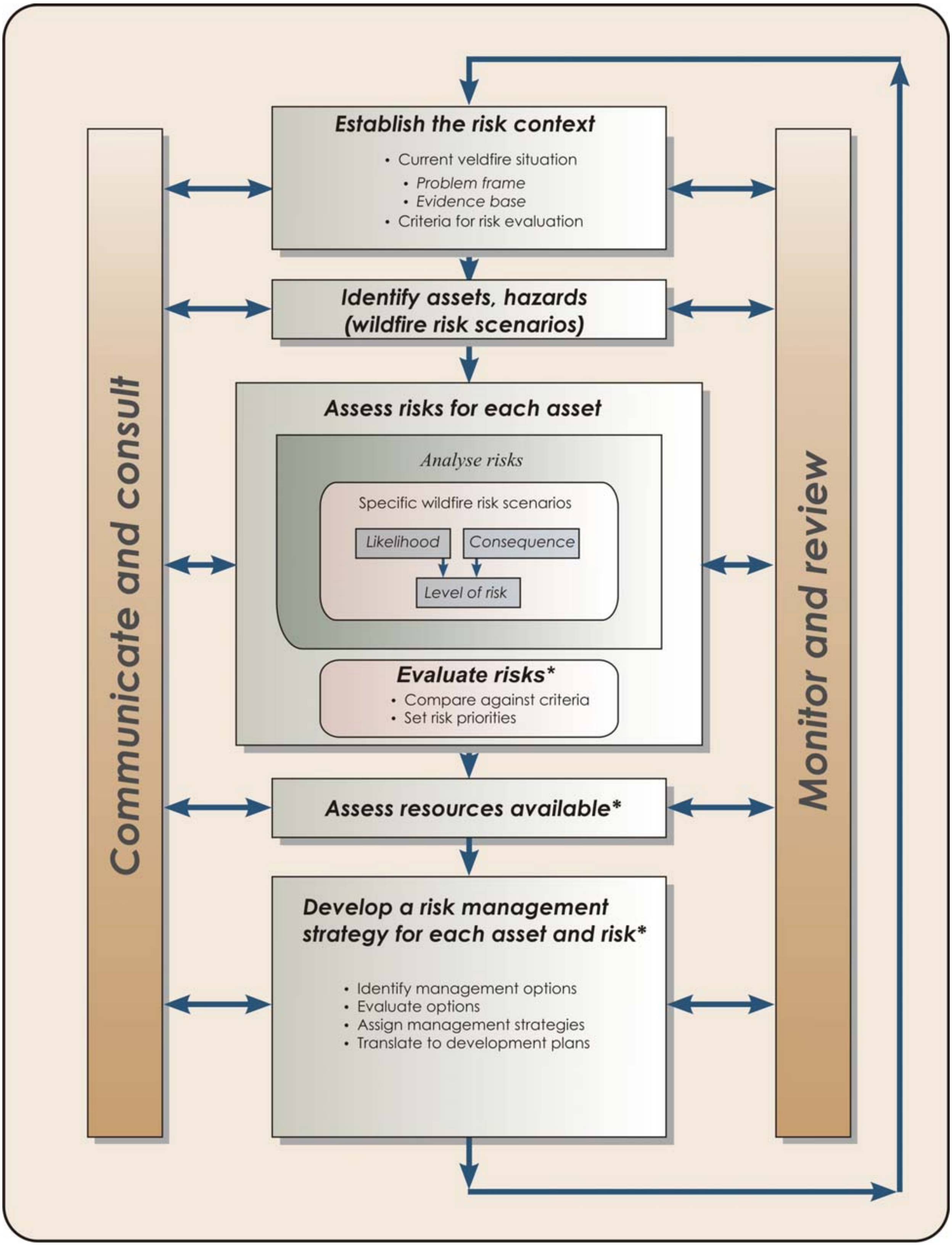

Figure 1. The standard risk management framework, adapted from AS/NZS 4360. Boxes marked with an asterisk indicate the steps not included in this assessment, other than to provide indicative recommendations.

S.5.1 Definition and interpretation of risk

The definition of risk, from AS/NZS 4360, is: "The exposure to the possibility of such things as economic or financial loss or gain, physical damage, injury or delay, as a consequence of pursuing a particular course of action. The concept of risk has two elements, i.e. the likelihood of something happening and the consequences if it happens." The "something" in this case, is a specific veldfire risk scenario.

That is, for veldfire,

Risk = a function of the likelihood and the consequence to a vulnerable asset

of a given veldfire risk scenario, i.e. hazard.

Here, risk is analysed in terms of the consequences of a veldfire event in terms of the three endpoints, social, economic, and environmental consequences. We approached this, first through consultation in workshops, and then, by examining the available reports on fires in South Africa over about the last 10 years, as well as by using spatial data that represented the location of and variation in proxy measures of assets, values and their vulnerabilities, as set out below.

S.5.2 Vulnerable social assets

We used life and health as measures of social assets, i.e. we simply took the exposure of people to the hazard of veldfires as the endpoint measure. However, we assumed social vulnerability to be a function of the proportion of people living below the mean living level. This measure correlates strongly with the distribution of dispersed rural settlements.

There is general concern about the vulnerability of communities at the urban-rural interface. We did not however include this in the present risk assessment, mainly because such vulnerability is not readily detected at the national scale, and the assessment of risk at that scale is best done locally, with local knowledge and consultation.

S.5.3 Vulnerable economic assets

We identified economic assets that are vulnerable to veldfires from the available reports for damaging wildfires. We used information from fire reports on losses in fires as well as the map of agro-forestry gross value added to guide the assessment of economic consequences of specific-risk scenarios.

These assets included infrastructure (such as power lines), industrial facilities (e.g. sawmills), fodder, livestock, homesteads, resorts, and plantation forests. We excluded dryland crops, such as maize, since these seldom suffer loss. In addition, certain harvestable natural resources, such as thatch-grass stocks, are lost in fire, to the detriment of local communities. These resources now are largely confined to protected areas and commercial farms; we provide for this in the specific risk scenarios where appropriate.

Each specific fire-risk scenario lists vulnerable economic assets.

S.5.4 Vulnerable environmental assets

Most, if not all, ecosystems in areas of fire risk are resilient to veldfire, being fire-dependent or fire-independent. Thus, in most cases, we did not rate ecosystems as vulnerable to veldfires. This applies even where the conservation status of ecosystems has been rated in biodiversity assessments as being vulnerable to factors other than fire.

The fire-ecology types of Natural Forests, Thicket, and Sparse Arid Woodland (see below) are fire-sensitive. However, fires penetrate these types only rarely, and the ecosystems recover in the long interfire periods. These types are not taken as being vulnerable.

Ecosystems, such as fynbos, that are vulnerable to invasion by alien plant species after fire, present a special case of veldfire vulnerability. Here too we did not treat plant invasion as being a factor in vulnerable environments, but leave such an assessment to local-level veldfire risk assessment. This is because alien plant invasions after fire depend on the state of alien plant control at a given place at the time of a fire, information not available for the present assessment. The Working for Water Programme has commissioned the National Invasive Alien

Plant Survey, which may be useful in future veldfire risk assessments.

Environmental values are vulnerable where fires occur in forest plantations. This is the case where intense blow-up fires occur in plantations with high ground fuel loadings, or where there are heavy ground fuels of slash after clearfelling. In such circumstances, the fire will often destroy the structure of the surface soil horizon, causing accelerated erosion, and consequent loss of soil and catchment values. We take account of this in the fire risk scenarios and the risk assessments attached to these.

There are dense invasions of invasions by species of pine, which may burn like plantation forest with the same environmental consequences, but assessment for such cases awaits the outputs from the National Invasive Alien Plant Survey.

S.5.5 Specific veldfire risk scenarios

Specific veldfire risk scenarios formed the basis of the veldfire risk analysis. These describe the main source of danger against which to take precaution. These scenarios are plausible descriptions of possible wildfire events, which define the kind of event that must determine a cost-effective but affordable risk management strategy that would be the desired standard or norm for a given situation. It should be normative in the sense that if the strategy were implemented, people would feel reasonably safe in that environment, and economic development would proceed under conditions of manageable risk, while environmental values are protected and ecosystem services sustained.

Risk analysis tables adapted from AUS/NZS 4360, and tested and approved in workshops, provide the algorithm according to which risk is analysed for each separate risk, and assigned a risk level ranging in four classes from low to extreme. These provide linguistic scales for the ranking of the perceived and informed judgements of the likelihood and consequence of a risk scenario, in a given environment, by the panel involved in the analysis (and in a way that the analysis may be tested in a wider audience).

S.6 Fire ecology in South Africa

S.6.1 Introduction

Fire in the ecosystem is an ecological process and part of our environment. It has a fundamental role in sustaining biodiversity. However, if fire is mistimed, occurs too frequently or too seldom, or is too severe, it may result in ecosystem degradation.

Without fire, many of our ecosystems would look quite different, because fires rejuvenate grasses and fynbos shrublands and prevent the development of dense woodlands and forests.

Most of South Africa has strongly seasonal rainfall and a dry season which lasts for five or more months. The eastern half of the country receives enough rainfall for the grasses to produce enough fuel to support a fire every year or two. This means that veldfires are frequent and inevitable. Originally most fires were caused by lightning but our ancestors learned to light and manage fires more than a million years ago, exploiting and augmenting the natural causes of fires to manage the vegetation for their own purposes. Today, more than 90% of fires are lit by people, either deliberately or accidentally.

S.6.1.1Fire regimes

The “fire regime” is the history of fire in a particular vegetation type or area including the frequency, intensity and season of burning; it is the combination of elements that typifies fires in a given region, under assumed natural conditions.

Fire regimes are ecological drivers - they shape the functioning, structure and composition of the ecosystem. If the frequency, intensity, type, season or size of fires diverges from the natural range of variation under which the ecosystem evolved, the ecosystem structure and processes will change. Alteration of key elements of a fire regime may cause current or long-term conditions that threaten the persistence of native plant and animal populations associated with that fire regime.

In some cases the change can be rapid such as when too-frequent fires exterminate tall protea shrubs, changing a tall fynbos shrubland into short-shrubland in just one or two fires. In others it can take a long time such as changes in the shape and size of a forest patch with strongly fire-resistant dominant trees.

Fire regime alteration can be defined as the extent to which the prevailing patterns of fire diverge from the ecologically acceptable ranges of variation in key fire regime elements for that ecosystem type. This creates an ecological hazard.

In turn, what is defined as ecologically acceptable is usually based on what is inferred to be 'natural', i.e. the regime under which that ecosystem evolved.

Thus, altering one or more fire regime elements may stress an ecosystem by significantly changing its composition, structure or function, which in turn, can establish a trajectory toward a fundamentally different ecosystem type and fire regime.

Where these changes lead to a reduction of the benefits we derive from the ecosystem ('ecosystem services', such as pasturage, or water yield), we say that the ecosystem is 'degraded'. In the context of this report, "inappropriate" fire regimes can be defined as those regimes that are altered in such a way as to depart from ecologically acceptable ranges associated with the continued conservation of a particular ecosystem type.

The results of numerous long-term fire experiments show that the exact return period between fires, and the time during the dry season when fires are ignited, hardly makes any difference to the outcome, unless they are taken to extremes. For instance, in grasslands and savannas, annual burning differs from burning every two to five years, and both differ from no burning at all: but between these limits, natural variation due to climate fluctuation and herbivory (grazing and browsing) masks any measurable difference.

Fynbos ecosystems, unlike savanna and grasslands are sensitive to certain changes in fire recurrence intervals. They have species which survive fires only as seeds and take several years to flower and produce sufficient seeds to re-establish viable populations after fires. However, the minimum intervals between fires can be longer than the time needed for the fynbos to accumulate sufficient fuel to burn. In these cases managers need to ensure that fire recurrence intervals are not too short for these species to survive because the only a small change in the fire interval is needed to result in local extinction.

Similarly, fires in the wet season have different outcomes to fires in the dry season, but dry season fires hardly differ among themselves. As a result, the rules for lighting or permitting fires have become much less restrictive. Thus, the ecological hazard of altered fire regimes arises only with substantial departures from the ecological norm.

There is also good evidence that natural fire regimes vary in return period, season of ignition, intensity and size of fire and that this variation is important for maintaining the diversity of species of plant and animal species. Applying a fixed regime selects for some species, and disadvantages others. If we wish to maintain a diverse and fire-resilient fauna, flora and landscape, we need to plan for fire regimes that allow for, and even promote, variability within broad limits.

However, the presence of alien invasive species, specifically plants, creates a special fire-related hazard, which increases environmental vulnerability to inappropriate veldfires. In many biomes, occurrence of fire without control of the invasive plants present aggravates the invasion, by creating conditions favourable for the proliferation of these species.

S.6.2 Derivation of fire-ecology types

S.6.2.1 Overview

A fire-ecology type is a class of vegetation types that is relatively uniform in terms of the fire regimes (e.g. frequency, season, intensity and size) within the constituent vegetation types.

This classification begins by dividing vegetation types into one of three broad fire-ecology types:

- fire-dependent,
- fire-sensitive or
- fire-independent.

We used the information from the previous veldfire risk assessment to group the vegetation types recorded in the latest national vegetation map (Mucina and Rutherford) into 13 fire-ecology types (Figure 2).

MODIS satellite imagery for the period 2001-2008 provided information on the geographical distribution of veldfires in relation to the pattern of fire-ecology types. There was a marked trend in fire incidence from east to west and, to a lesser extent from north to south. The north-western quarter of the country where the dominant biomes are the Succulent Karoo, Desert and Nama Karoo had few if any fires. In the isolated cases where there were fires they were generally confined to certain vegetation types within these biomes.

The fire-incidence was also relatively low in the south-western quarter where the dominant biomes are the Fynbos and Succulent Karoo. The relatively low incidence of fires in the Fynbos fire-ecology type is to be expected as the typical fire return interval is 10-15 years.

The vegetation types comprising the Sour Grassland fire-ecology types had the highest mean fire incidence. The next highest mean fire incidence was the Moist Woodlands followed by the Arid Woodlands. Protected areas in grassland and woodland fire-ecology types tended to have higher fire incidence that surrounding areas.

S.6.3 Ecologically acceptable fire regimes in South African vegetation

Since changes in the key elements of fire regimes can result in changes in the species composition, vegetation structure and ecological functioning of ecosystems, alteration of fire regimes constitute a risk to biodiversity. However, most ecosystems prone to fire in South Africa have substantial resilience to such alterations. The text of the main report specifies the known effects of human caused changes in fire regimes in some of the fire-ecology types.

S.6.4 Conclusions on fire ecology and management

Veldfire management and risk reduction strategies must take account fire ecology. Land cover and land use changes in the South African rural environment are often such that the ecosystems no longer support natural fire regimes. Therefore some form of fire management, involving prescribed burning, is needed to simulate the natural regime, or to achieve other management goals.

Ecologically appropriate prescribed burning is often diverted because of lack of skills and capacity in land management institutions (owners or agencies), lack of knowledge and information, or fear of the law. Inappropriate prescribed burning, or weak or absent veldfire management can have substantial negative environmental impacts or lead to loss of ecosystem services. Examples of these impacts are: (a) bush encroachment, (b) invasions by alien plants, (c) a decrease in forage palatability and productivity, and (d) reduction in water yield. Burning too seldom is as damaging as burning too often. A build-up in fuel load increases both the risk of damage to life and property as well as the possibility severe burns that lead to soil erosion or the death of otherwise resilient organisms. The regions of high and extreme veldfire risk are all especially prone to these environmental consequences of inappropriate veldfire regime. Inappropriate veldfire regimes can, in turn, lead to intractable wildfire management problems.

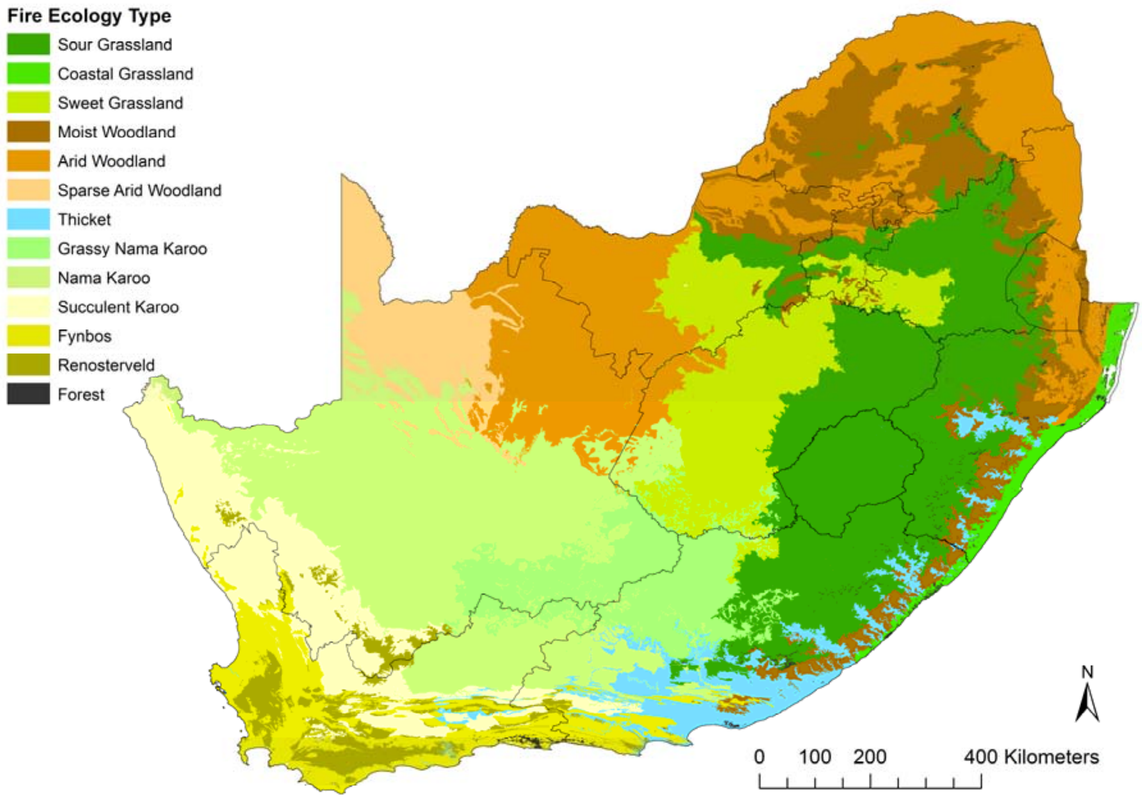

Figure 2. The distribution of the 13 fire-ecology types based on the descriptions and distribution of the vegetation types in the current national vegetation map (Mucina and Rutherford)

S.7 Veldfire risk levels in South Africa

7.1 Overall risk level

Extreme overall veldfire risk corresponds with the Sour Grassland and Moist Woodland fire-ecology types. In the Fynbos fire-ecology type such conditions only occur where there are commercial forestry plantations. In Coastal Grasslands and Arid Woodlands pockets of Extreme veldfire risk occur where there are dispersed rural settlements. In 30,6% of the country there is an Extreme veldfire risk, while it is High in 31.3%, Medium in 11,7% and Low in 26,4%. In areas of Extreme and High veldfire risk it is necessary to take precautions to safe guard lives, livelihoods, property and the environment.

KwaZulu/Natal has the largest area of Extreme veldfire risk comprising 84.1% of the province. This is followed by Mpumalanga with 70.9%. These provinces are important for commercial forestry plantations which are prone to destructive veldfires. They also many disperse rural settlements whose inhabitants are particularly vulnerable to veld fires. The Northern Cape is the province with the lowest veldfire risk: 57,3% of the area has a Low veldfire risk and a mere 0.2% has an Extreme veldfire risk.

In certain district councils (DC) more than 90% of the area has an Extreme veldfire risk. These are Alfred Nzo DC (100%) in the Eastern Cape; Thabo Mofutsanyane DC (98,7%) in the Free State; Metsweding in Gauteng (93.0%), Umgungundlovu DC (99,4%), Uthukela DC (96,7%), Amajuba DC (100%), Zululand DC (91.1%) and Sisonke DC (100%) in KwaZulu/Natal; and Greater Sekhukhune DC (93,3%) in Limpopo.

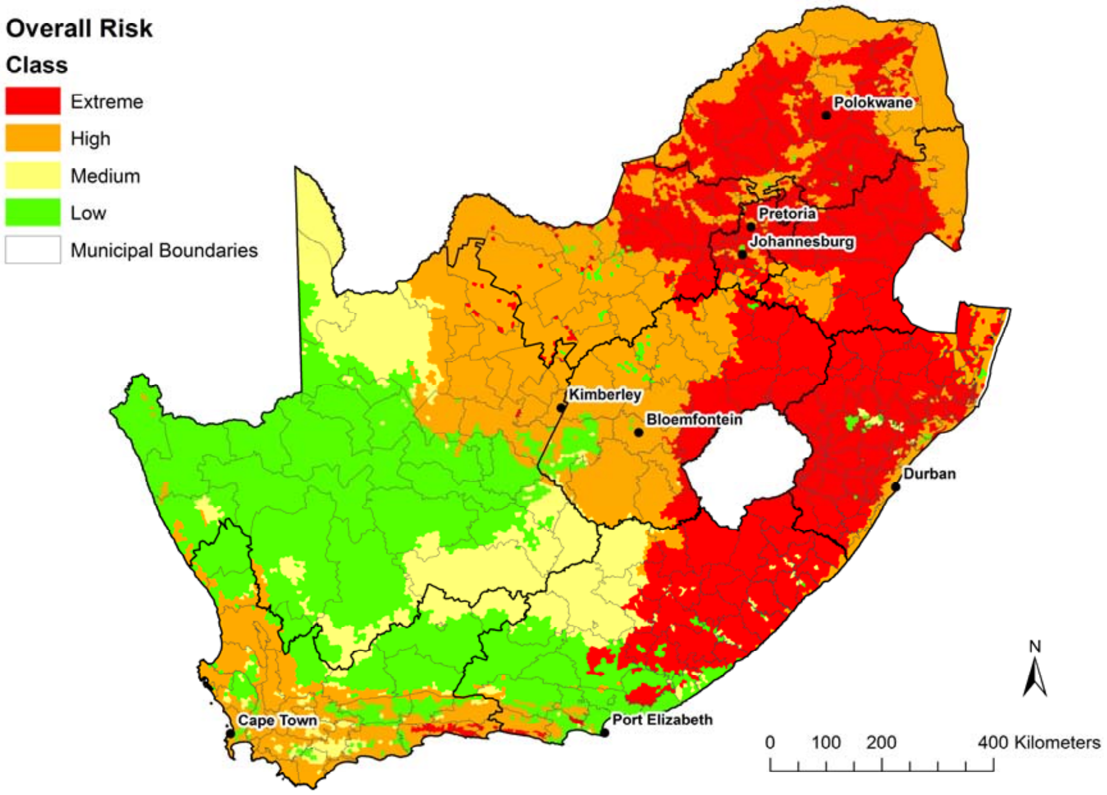

Figure 3. Overall assessment of veldfire risk levels in South Africa.

S.8 Conclusions and recommendations

S.8.1 Implementation of the National Veld and Forest Fire Act

Of the 13 fire-ecology types identified for South Africa, four have no or very low levels of veldfire risk. These are Forest, Thicket, Succulent Karoo and Nama Karoo. In these there is no requirement for the application of the National Veld and Forest Fire Act. In all other fire-ecology types, the Act should apply in full.

In the fire-ecology types with Medium fire risk, i.e. Grassy Nama Karoo, Renosterveld and Sparse Arid Woodland, fire risk management strategies of an intermediate level would be appropriate. The principal focus should be on the establishment of FPAs, since these are sparsely settled regions and the reach of local government is limited: local cooperation needs to be the basis of reasonable preparedness among land owners and integrated veldfire management, with financial and in-kind support from local government.

In the fire-ecology types and municipalities with High to Extreme fire risk, comprehensive risk management strategies are needed. This includes:

- Urgent provincial risk assessments as frameworks
- Fully developed FPAs and Umbrella FPAs
- Detailed per asset and per value fire risk assessments within municipalities and FPAs
- Comprehensive risk management planning including ecological fires management principles and plans, and the Council of Australian Government's National Inquiry on Bushfire Mitigation and Management, 2003/2004 fires season 5Rs framework:

  - Research, information and analysis;
  - Risk modification;
  - Readiness;
  - Response; and
  - Recovery
- Comprehensive response strategies for megafires (a veldfire or concurrent series of veldfires that is in the upper percentile of the fire regime).
- In areas of poverty, special support from government, coupled with FPA promotion integrated with Community Based Natural Resources Management initiatives

We recommend the following actions to promote the use of this national veldfire risk assessment:

- Widespread distribution of the report for comment
- Training of risk assessors (Fire Protection Officers and others) on the basis of a revision of the guidelines in the Department's document on guidelines for business plans of FPAs
- Scheduled implementation of the process according to priority municipalities.

S.8.2 Improving the risk assessment: requirements for information and research

There several further requirements to be met in order to position South Africa for an improvement in veldfire risk assessment and management:

- The DAFF with the National Disaster Management Centre must promote the full deployment of the National Veld fire Information System (NVIS), with links to the South African Risk and Vulnerability Atlas
- Evaluation of the development of business plans and capacity in FPAs in relation to veldfire risk levels
- Integrated veldfire management (ecological and disaster management) capacity evaluation in local government, FPAs, and Working on Fire against the 5Rs framework
- Study of historic megafires, the synoptic weather and other conditions that affect them, and the possible effect of climate change on their incidence
- The areas assessed as being in the category of Extreme risk vary greatly among each other and need further study.
- Geographical database and analysis of fire reports from various sources to assess the geographical variation in the incidence, and consequence of wildfires.
- Given the high social, economic and environmental costs of wildfires in South Africa, however, especially to vulnerable rural populations, it is advisable to invest substantially now in precautionary and rational analysis to understand better the current risks and the potential effects of climate change on them.

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Appendix 4	Tabular summary of specific veldfire risk scenarios for each fire-ecology type with assessed risk levels for the three endpoints of social, economic and environmental consequences.

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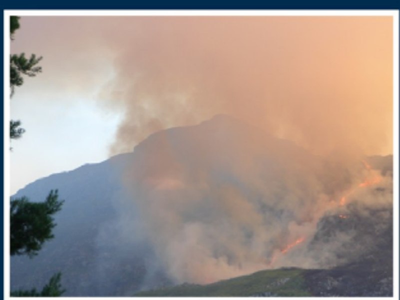

Acronyms and abbreviations

AFAC	Australian Fire Authorities Council
CRA	Comparative risk assessment
DAFF	Department of Agriculture, Forestry and Fisheries
IDP	Integrated Development Plan
IPCC	Intergovernmental Panel on Climate Change of the UN Framework Convention on Climate Change
JPOI	Johannesburg Programme of Implementation
MDG	Millennium Development Goal
NDMA	National Disaster Management Act
NDMF	National Disaster Management Framework
NEMPAA	National Environmental Management: Protected Areas Act
NFSD	National Framework for Sustainable Development
NEMBA	National Environmental Management: Biodiversity Act
PED	Poverty, environment and development (nexus)
SANBI	South African Biodiversity Institute
SDF	Spatial Development Framework
UNISDR	United Nations International Strategy for Disaster Reduction

Glossary and definition of terms

[see Appendix 1]

Statutes and statutory instruments

ACT NO	
57 of 2002	National Disaster Management Act
84 of 1998	National Forests Act
57 of 2003	National Environmental Management: Protected Areas Act
101 of 1998	National Veld and Forest Fire Act
10 of 2004	National Environmental Management: Biodiversity Act

Acknowledgements

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We thank all the participants who took part so enthusiastically in the six consultative workshops we held as well as the key informants who provided additional information. We have listed them in Appendix 2.

Our colleague, Dr Brian van Wilgen, provided valuable guidance during the study and valuable comments on the report.

The photographs in this report were taken by Dr Brian van Wilgen and Greg Forsyth.

1. Background and Introduction

The Department of Agriculture, Forestry and Fisheries (DAFF) appointed the CSIR in August 2009 to revise the national veldfire risk classification. This classification was initially developed in 2004 by Dr Fred Kruger, Greg Forsyth, Dr David Le Maitre and others to serve as a national framework for implementing the National Veld and Forest Fire Act No. 101 of 1998[1]. This classification serves as a consistent basis for setting priorities for veldfire management interventions such as the promotion of and support to Fire Protection Associations.

The first approximation of the veldfire risk classification for South Africa drew upon the scientific ecological literature available at the time and used vegetation maps to project ecological information spatially. These maps did not show current patterns of land-use. The risk used inferred information on the likelihood and consequence of critical fire scenarios.

In the initial veldfire risk classification, 13 “fire-ecology types” were assigned to each of the major vegetation types in the country, based on the dominant fire regime in each vegetation 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 fires that occur there. South Africa is divided into approximately 230 municipalities, and these were used as a basis for mapping fire-ecology types. We established the area occupied by each fire-ecology type in each municipality. We used the area of the fire-ecology type with highest wildfire risk occupying at least 30% of the area to assign a dominant fire-ecology type (and thus a likelihood of fire) to each municipality.

Wildfire risk was assessed as the combination of the likelihood and consequences of fires in each fire-ecology type. The likelihood of fire 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 fires in each fire-ecology type were estimated from a range of sources. These included fire reports, as well as newspaper accounts of fires. The consequences of fires were grouped into the following categories: catastrophic (regular loss of life and significant economic consequences of fires occur); major (extensive injuries and serious economic consequences of fires occur); moderate (localised damage and economic losses occur); minor (minor financial losses and damage occur); and insignificant (damage from fires is inconsequential).

Risk categories were defined as low moderate, high or extreme, depending on the combinations of likelihood and consequences. For example, if fires were almost certain, but of minor consequence, the risk was moderate, if they were 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. Fynbos shrublands

[1] Kruger *et al*. 2006.

which are famous for their fires were rated only as high, because most of the area is mountainous, infertile, and unoccupied, or sparsely occupied.

However in order for the national veldfire risk classification to remain valid it needs to be reviewed regularly. Since the first classification, scientific research has improved our knowledge of fire in South Africa substantially (see Section 5.1 below). The wildfire situation has evidently worsened. There have been major catastrophic fires in many areas. 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. For these reasons there have been calls for the national veldfire risk classification to be refined to more accurately reflect the ever-changing situation on the ground.

In addition, better datasets are now available; for example, a very detailed vegetation map has been released for South Africa[2] and this together with improved land cover information[3] showing the extent of transformed land, as well as other spatial information, provides the basis for a more accurate assessment of veldfire risk in South Africa.

DAFF's requirement was a revised map for South Africa showing veldfire risk ranked from low to extreme. The map was to be accompanied by a report detailing the processes involved in revising the national veldfire risk classification, and explaining the classification and its implications. Six consultative workshops were held to inform stakeholders about how the initial veldfire risk classification product was developed and to get clarity from them as to what improvements they would like to see. These workshops were held in the Free State, Gauteng, Mpumalanga, KwaZulu/Natal, Eastern Cape and Western Cape (see Appendix 2). The revision will involve research into the implementation of the improvements suggested for fire likelihood mapping as well as developing appropriate methods for evaluating the relative value of assets.

The purpose of this report is thus to facilitate strategic planning aimed at mitigating veldfire risk in South Africa, and specifically support a bioregional approach for regionally specific veldfire management. It is a policy risk assessment, not an operational risk assessment and has been designed to support regionally specific veldfire management interventions. As such, it should be viewed as a working document that should be regularly updated to incorporate additional knowledge, information and experience as they become available.

This assessment will require periodic review as information improves and conditions change. But it reflects best available information on the current conditions of veldfire risk.

[2] Mucina and Rutherford 2006.
[3] Van den Berg 2008.

2. A note on terminology

For an assessment of this kind, consistent use of terms is essential. The Glossary of Terms included with this document sets out the standards followed here (see Appendix 1).

This terminology is consistent with the definitions in the National Veld and Forest Fire Act, the National Disaster Management Act, ISO 31000, and the 2009 UNISDR Terminology on Disaster Risk Reduction, and draws on the Australian Fire and Emergency Services Authorities Council Wildfire Terminology where necessary. Where needed, we adapted these terms to fit the matter of veldfires.

Note that we speak of veldfires when referring to fire in vegetation in general, and of wildfires when referring specifically to unplanned vegetation fires.

In this work, we follow the ISO31000 and AS/NZS 4360 with respect to comparative risk assessment (see below). These standards do not require the explicit treatment of vulnerability, which is a specific requirement in other approaches, such as the National Disaster Management Framework, and the UNISDR (see below). Instead, we identify vulnerable values and assets in each of our analysis units, and use this information to guide the analysis of the consequence of veldfire events. Full details follow in the text below.

3. Context and problem

3.1 The veldfire situation in South Africa

3.1.1 Introduction

What follows here deals with the hazard of wildfires in South Africa, and their adverse consequences.

There is a great difficulty in addressing this topic, primarily because of the poor quality and coverage of the available information available[4]. For example, we know that many people are killed and injured in veldfires every year (see below), but we have no reliable statistics about this. StatsSA reports that among the non-natural causes of death – about 10% of all deaths in 2007 (the latest reporting year), over 74% are unexplained ("Other external causes of accidental injury" and "Event of undetermined intent")[5]. These are sevenfold greater than reported motor accident deaths. But these figures are in any event doubtful; 2007 statistics from the National Injury Mortality Surveillance System (NIMSS), based on mortuary data, present a different picture[6]. The NIMSS report finds that current estimates for the injury mortality burden in South Africa is calculated to be between 60 000 and 70 000 fatalities which represents 11.53% to 13.4% of the estimated 520 000 deaths

[4] For example, Ruth Bezuidenhout, Safire, presentation to the National Fire Technical group on 26 November 2009 at the Synodale Centre Pietermaritzburg.

[5] StatsSA 2007.

[6] Donson 2007.

registered in South Africa each year; other unintentional injuries accounted for 13%, and 9% were "undetermined". It is among this 22% that deaths owing to fire are classified; but the 2007 study relied on mortuaries in urban areas except for a set from Mpumalanga. We simply do not know what human consequences arise from veldfires.

Nevertheless, the anecdotal evidence, media reports and sectoral reports currently available indicate that the situation in rural South Africa, and the urban-rural interface, is serious, worsening, and affecting significantly our progress in achieving rural development goals. The sections below expand on this current evidence.

Members of the insurance industry report that the risk in the rural environment of South Africa has progressively increased over the past 10 years. Although this is not all owing to veldfire risk, veldfires are an important cause of the trend.

3.1.2 Extreme wildfire episodes

Though a national assessment, this analysis is scaled at the local municipality, and the distribution of inherent risk within the area of the local municipality.

There are some cases of extreme wildfire episodes, where wildfires exceed the boundaries of any municipality, and when many major fires break out almost simultaneously, across wide stretches of the country. The wildfires of late August and early September 2008 are such an example[7].

This period was marked by extreme dryness and strong gusty northerly to westerly winds, ahead of a major regional weather front, following a long rainless period in the interior and east of the subcontinent. By 29 August, a fire in the Sparse Arid Woodland of the Central Kalahari Game Reserve of Botswana had grown to over a million ha in extent, and eventually burnt for over a week. Numerous fires broke out across the Sour Grasslands of South Africa. By 31 August Working on Fire reported for South Africa: "Some of the most devastating veld fires of the year raged through the north eastern parts of the country [in the Sour Grassland] this weekend with wind speeds of 85km/hour recorded in some areas grounding aerial fire fighting resources and endangering ground veld fire fighting teams. Forestry plantations, agricultural land, buildings and livestock were destroyed in more than 50 veld fires in KwaZulu Natal and Mpumalanga. On Sunday a new grass fire was burning near Bethlehem in the Free State while later in the day an out-of-control fire near Piet Retief in Mpumalanga chased towards the town." Large areas of Sparse Arid Woodland, Arid Woodland and Moist Woodland were burnt in the same period. Fire response capacity was overwhelmed throughout the region.

By 8 September, 32 people were reported killed in Mozambique, and the fires there "burned down 722 houses, making 2,805 people homeless, and affected 16,000 hectares of agricultural land."

In South Africa, scores of people lost their lives in the fires, and economic losses amounted to billions of Rands.

[7] See http://www.fire.uni-freiburg.de/GFMCnew/2008/09/0901/20080829_bots.htm and other subsequent posts at the Global Fire Monitoring Centre.

In this assessment, we have factored such episodes into the specific fire risk scenarios used in the risk analysis (see below). However, such “megafire” episodes have been poorly reported to date and little researched; events of this kind need further study and proper factoring into future risk assessments.

3.1.3 Current social consequences

The information on loss of life and injury owing to veldfires is still poor, but there is much anecdotal evidence that it is a significant factor in the health profile of rural communities. Poorly documented social losses accompany these incidents, involving at least the loss of homes and livelihoods. Some indicative cases are:

- September 2001: 19 dead in a veldfire in the Kruger National Park [8]
- September 2009: 25 dead in veldfires in the Eastern Cape and KwaZulu-Natal [9]

There are also pervasive health effects from extensive, untimely fires, such as smoke pollution under conditions of atmospheric stability during winter on the Highveld of Gauteng and Mpumalanga. This contributes to South Africa’s “reversal of progress” with respect to the MDG4 (“Reduce mortality of children under 5 years”) and the increase in non-communicable diseases[10]

3.1.4 Current economic consequences

Again, there is no overall appraisal available of the economic consequences of veldfires in South Africa, but a partial analysis is possible from various sources.

The best documented losses to fire are in the forest sector. Here, losses have been increasing exponentially during the past decade[11] (see Figure 1).

[8] News24 at http://www.news24.com/: Fire victims tired to run, but flames caught them Houses, 2001-09-06.
[9] News24 at http://www.news24.com/: Houses destroyed in E. Cape fire, 2009-09-02; Veld fire death toll rises,2009-09-09.
[10] *The Lancet* 2009: “Health in South Africa”; published August 25, DOI: 10.1016
[11] van Wilgen *et al*. 2010.

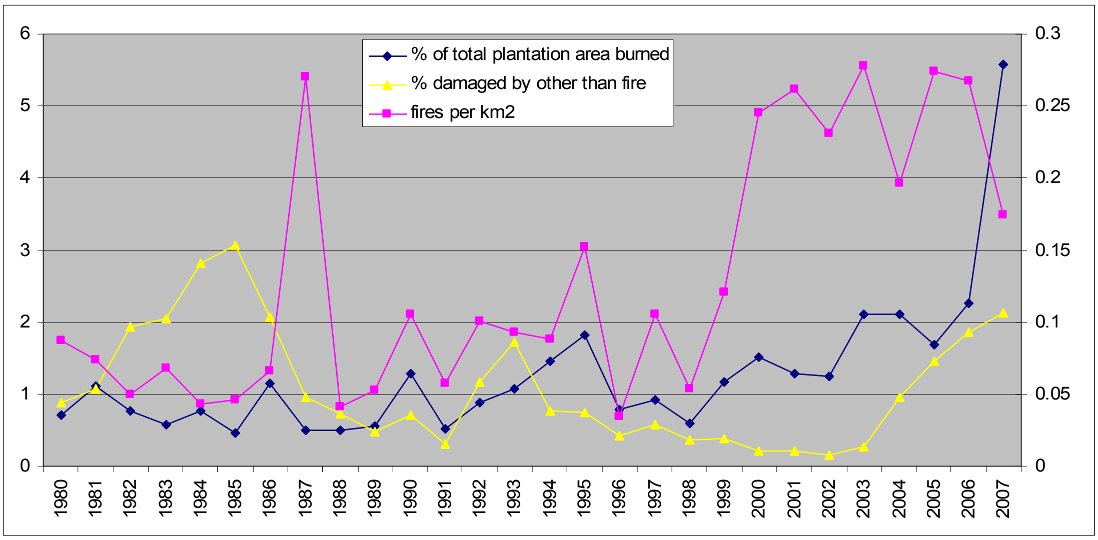

Figure 1. The best documented losses to fire are in the forest sector. Here, losses have been increasing exponentially during the past decade.

Van Wilgen *et al.*[11] conclude: "The incidence of fires in forest plantations has increased markedly in the past few years, probably due to less effective fire protection and additional sources of ignition. If these trends continue, they constitute a very serious threat to the viability of the forest industry. Our preliminary model suggests that, where trees are grown on a 30-year rotation, timber yields will decline by between 40 and 75% for scenarios where plantations are subjected between 3 and 7% of the plantation area burnt on average each year."

During the period from January to August 2007, 61,700ha of plantation forest burnt in KwaZulu-Natal and Mpumalanga, 2,9% and 9,5% of the total area of plantations respectively in these two provinces[12]. ForestrySA estimated the value of standing timber burnt amounted R1,33bn (2007 prices), and that of this, 40% would be a dead loss. More important however, were the forward effects of the disaster, with the consequent impacts on wood flows, especially sawlogs for construction timber, being felt throughout the economy. This was accompanied by closure of manufacturing capacity, loss of rural jobs, and many other adverse effects.

Other examples of the economic consequences of wildfires are:

- Power-line "downs" resulting in industrial losses[13]
- Farm and country resort infrastructure[14]
- Stock losses and loss of grazing[15]
- Loss of resources for rural livelihoods (Box 1 provides an example).

[12] ForestrySA 2007.

[13] Daily Despatch at http://www.despatch.co.za/: Mamase too visit fire-ravaged districts, 1999-09-14.

[14] News24 at http://www.news24.com/: Mamase too visit fire-ravaged districts, 1999-09-14. Black Monday to cost KZN R16m, 2002, July 30.

[15] SABC News at http://www.sabcnews.com/: Veld fires destroy Northern Cape farms, 7 January 2009.

Box 1. Use of thatch grass from Mkambati Nature Reserve by neighbouring communities and the exposure of the resource to fire[16]

Shackleton conducted a study of the socio-economic importance of Cymbopogon validus (Umqunga or Tamboekie grass) in Mkambati Nature Reserve on the Wild Coast. She established that people were travelling from 12 to 78 kilometres to harvest grass in the nature reserve. Mkambati and other nature reserves on the Wild Coast are a major source of thatch and supplies outside the reserves are extremely limited. Shackleton attributes the limited supply to grazing pressures and an increase in areas being allocated to arable plots.

Her study showed that the highest yields , 200 bundles (head loads) ha $^{-1}$ (2237 kg) were obtained from areas burnt two years prior to harvesting with substantially lower yields, 97 bundles ha $^{-1}$ (1081 kg), from one year old areas. In areas older than 2 years yields decreased to 150 bundles ha $^{-1}$ (1795,25 kg) indicating that fire is necessary but not at too short intervals. A biennial or triennial burning programme is best to promoting yields.

The grass is used for homestead roofs (new and repairs) and 80 - 120 bundles are required to thatch a homestead. Roofs are replaced every 9 – 15 years. Local people are very dependant on Mkambati as a source of thatching grass and this dependency is likely to increase.

Exposing the thatching grass resource to too frequent fires, as is the case outside protected areas, or burning too large an area at any one time both threaten this resource.

The overall effect of the current level of fire risk in rural South Africa is to constrain, if not locally depress, the opportunities for local economic development. This is because investment is inhibited by the high risk to financial returns, high costs of insurance, or reluctance of reinsurers, and so on[17].

3.1.5 Current environmental consequences

Veldfire is a natural ecological factor in most bioregions in South Africa (see Section 5.1 below). Wildfires can often be beneficial in protecting biodiversity and maintaining ecosystem services; managers of protected areas as well as production landscapes will often allow wildfires to continue, as long as they remain confined to the desired areas, for their ecosystem benefits. Managers employ prescribed burns for the same purpose.

Wildfires in South Africa cause environmental loss if untimely or extreme, or where wildfires occur on transformed or degraded land, or areas invaded by alien plant species.

Untimely fires in grasslands destroy the standing crop of grass, required by pastoralists as a fodder bank. Local communities also suffer periodically from the loss of important resources such as thatch grass, in wildfires (Box 1).

[16] Shackleton 1990.

[17] For example, Ruth Bezuidenhout, Safire, presentation to the National Fire Technical group on 26 November 2009 at the Synodale Centre Pietermaritzburg; "As water levels go up, so does risk rise for insurers", The Sunday Independent 4 April 2010.

The extreme fires of August 2007 in plantations in Mpumalanga reached intensity levels such that coarse fuels on the ground burnt entirely, with the heat destroying the structure of surface soil horizons; excessive erosion followed during the rainy season, resulting in loss of soil fertility and sedimentation of river channels and wetlands downstream (see Section 5.2.4 below).

3.2 Recent trends in risk factors

3.2.1 Factors governing fire activity in general

Fire activity is strongly influenced by four factors: fuels, climate and weather, ignition agents and people. The account below derives mainly from Flannigan and co-authors[18].

The fuel type, continuity, structure, moisture, and amount are critical elements of fire occurrence and spread. For example, for fires to spread, there needs to be fuel continuity, which means that at least 30% of the landscape may need to have fuel; thus, in many drier parts sufficient precipitation is required during the season preceding the fire season for the growth of sufficient fuels to be available to regularly carry fire on the landscape – 650 mm in the case of savannas[19].

However, although the amount of fuel, or fuel load, affects fire activity as a minimum amount of fuel is required for fire to start and spread, fuel moisture largely determines fire behaviour, and has been found to be an important factor in the extent of area burned.

Weather and climate – including temperature, precipitation, wind, and atmospheric moisture – are critical aspects of fire activity. Numerous studies suggest that temperature is the most important variable affecting wildland fire, with warmer temperatures leading to increased fire activity. Warmer temperatures increase evapotranspiration, as the ability for the atmosphere to hold moisture increases rapidly with higher temperatures, thereby decreasing fuel moisture, without precipitation. In addition, warmer temperatures may lead to a lengthening of the fire season. Precipitation is also an important variable in fire activity but timing of precipitation during the fire season rather than the amount is usually the most important aspect.

Fire activity is strongly influenced by conditions throughout the atmosphere as well as the conditions at the earth's surface. Temperature, precipitation, wind, cloudiness and atmospheric pressure depend largely on the horizontal and vertical state of the atmosphere. The strength, location and movement of surface highs and lows and associated warm or cold fronts are functions of the three-dimensional atmosphere[20].

Large-scale, recurring variability in ocean and atmosphere circulation patterns, known as teleconnections or synoptic-scale circulation patterns, occur on a multiannual to multidecadal time scale (see also Tyson 1986[21]). The El Niño–

[18] Flannigan *et al.* 2009; Bradstock 2010.
[19] Archibald *et al.* 2009.
[20] Southey 2009.
[21] Tyson 1986.

Southern Oscillation (ENSO) is an example. These teleconnections are associated with systematic variations in temperature, precipitation, air pressure, humidity, wind patterns, and dry lightning occurrence over large areas. Large-scale patterns and synchronisation of wildfire activity are related to these oscillations. Therefore, teleconnections can impact wildfires through direct effects on fire weather and indirect effects of climate on vegetation growth, seasonality, and composition.

People have lived with and exploited fire for all of our history, and our fire problems are essentially socially constructed problems. People are also by far the main cause of fires having negative impacts on the environment and society. Most fire is intentional, but because many fires are poorly controlled, some fires escape intended boundaries to become disaster events, or megafires. There has been an epidemic of megafires that have occurred around the world during the last 15 years. In addition to climate change driving this recent phenomenon, contributing human factors include biomass burning associated with land clearing, increasing available fuel loads caused by land abandonment (afforestation, revegetation), fuel build-up from historical fire suppression (e.g. Australia, western North America), and people as an omnipresent ignition source.

Human-caused fires tend to cluster around areas where human activity and fuels are coincident[22]. However, in African savannas, "Human activities – represented by grazing, roads per unit area, population density, and cultivation fraction – were also shown to affect burnt area, but only in parts of the continent with specific climatic conditions, and often in ways counter to the prevailing wisdom that more human activity leads to more fire."[23]

3.2.2 Trends in fire risk factors in South Africa

Risk factors are the underlying natural or human causes of a given level of veldfire risk.

Risk factors in plantation forests appear to have deteriorated markedly, with the results as reported above. Safire argues that, in plantation forestry, the risk levels have increased because of the strong trend toward the practice of leaving slash unburnt after clearfelling, "for conservation reasons", though forest managers are now reviewing this policy[24]. They mention other contributing factors as including neglect of silvicultural tending practices in the forests, as well as a lack of trained staff and management on Corporate estates and "managed farms"[25], and instead, a reliance on forestry contractors, who are either not resident or not familiar with the territory, or both, and thus ineffective in responding to wildfire. This is despite improvements in fire detection, according to Safire.

Safire also reports an apparent current increase in the severity of fire weather as reflected in the calculated fire danger indices and wind speed. This is possible, but

[22] Flannigan *et al.* 2009.

[23] Archibald *et al.* 2009.

[24] Ruth Bezuidenhout, Safire, presentation to the annual meeting of the Grassland Society of Southern Africa, Pietermaritzburg, 2009.

[25] Note that Safire reports that the proportional loss of forest area among its insured was one-third that of the industry as a whole, pointing strongly to improved risk management among the insured.

as likely owing to cyclical changes in weather over the regular cycle, rather than climate change (see below).

The spread of alien invasive plants continues in certain areas. The consequences are diverse, since the effect on fuel varies with the species that invades, and the density reached. In some parts, where species of pine have become dense, fire intensity may increase significantly.

In general, there are many anecdotes regarding risk arising from changes in land ownership, which were also aired during the consultative workshops in the present project. This is resulting in new owners with little capacity for fire management, or who are absent, and the trend arises from the land reform programme on the one hand, and the development of resorts and other gentrification near montane and savanna protected areas on the other. An important factor in this tend is the question of ignorance of fire, especially the neglect to recognise the recurrence of rare megafires, such as in recent Australian fire history[26]. But the problem also exists in South Africa[27]. This means that people at risk will often misperceive the level of risk that they face. (However, the reverse, social amplification of risk also occurs, triggered for example, by the occurrence of an adverse event of the risk-previously-ignored category, and such cases often have a chain of consequences triggering higher-order impacts, e.g. excessive cost of insurance[28]).

Rural populations in South Africa affect fire activity, but not simply. Van Wilgen[29] concludes: “Human population densities have direct impacts on the size and number of fires in savannas and grasslands. Fires in areas inhabited by people are much smaller due to human alteration and fragmentation of natural vegetation. The number of fires increases with increasing human population density (presumably due to increased ignition sources) but because the individual fires are smaller, less of the landscape is burnt.” And further: “If, as has been seen in other ecosystems, there were to be a move to the cities, and large parts of the landscape became depopulated we would expect to see an increase in the area burned and the size of fires, without substantial changes in the fire intensity or the fire return period. The opposite would be true if rural population densities increased. (Increased human populations can fragment the landscape and can significantly alter fire regimes).

There are complex population trends in rural South Africa. Overall, the urban population has grown to above 70% of the total, so that rural populations have declined. However, the newly urbanised have maintained their rural links, so that the number of rural households may not have declined. Influx from neighbouring countries has also created new denser rural settlements, especially in Mpumalanga and Limpopo provinces. On the other hand, the number of households in the commercial farming regions has declined, as a result of the consolidation of farms by acquisition.

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26 Griffiths 2009.

27 Kruger *et al.* 2000.

28 Slovic and Weber 2002. Note that such an “accident as signal” perception “may have immense social consequences if it is perceived as a harbinger of future and possibly catastrophic mishaps”, according to Slovic and Weber, and the current public perceptions of climate change effects may have such results.

29 Van Wilgen *et al.* 2010.

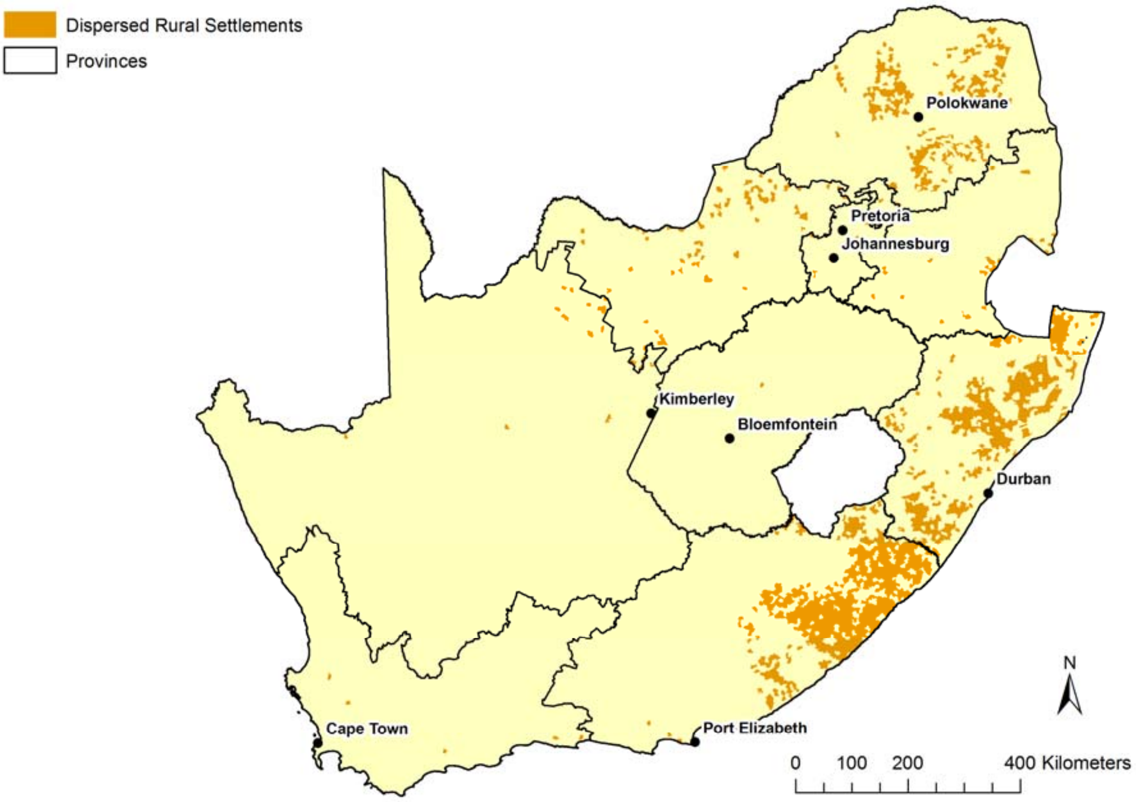


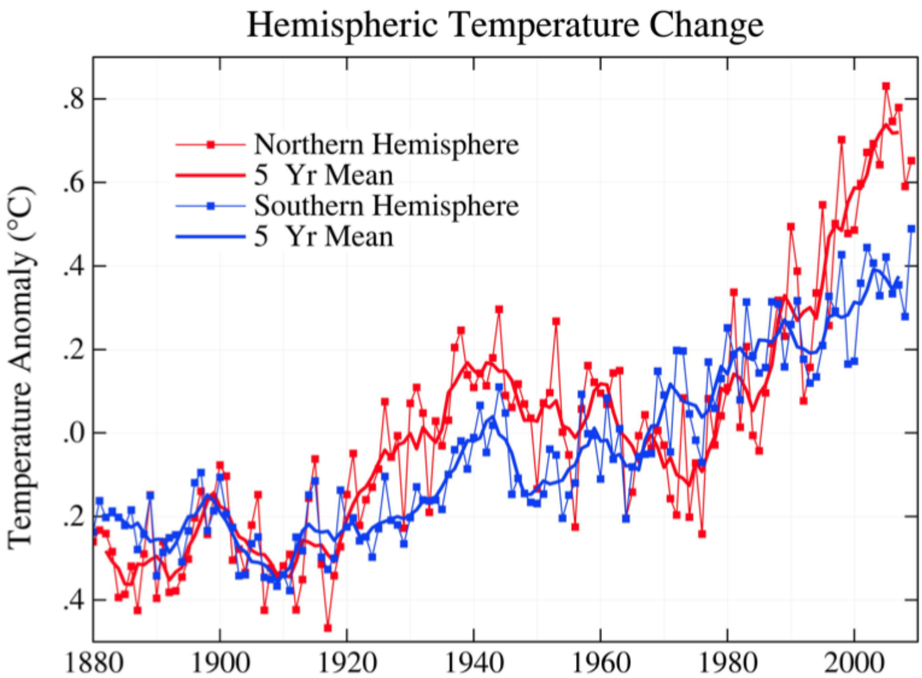
Figure 2. **Indicative distribution of the rural population in South Africa. This shows only dispersed rural settlements, which account for the larger majority of rural people.**

Summarising, the pattern and trend in rural populations have apparently had the following effects: (a) human activity remains a pervasive source of ignitions (b) poor rural security and land tenure uncertainty combine to increase the likelihood of arson (c) scattered human settlements and the growing extent of the urban-rural interface (including the poor households in informal settlements) have expanded the extent of households vulnerable to fire (d) in regions of commercial farming, depopulation has reduced the human resources available for fire management (e) land reform outcomes have had complex effects but most important is that new owners lack the know-how to live with veldfires and (e) gentrification has caused many regions to be subject to neglect arising from absentee land owners, or the segregation of resort owners from the resident communities.

Accompanying all these changes are many institutional changes, some of which have mitigated the trends in risk factors outlined above, while others have aggravated it. The successful establishment of Working on Fire and the progressive deployment of Fire Protection Associations are contributing to the mitigation of risk factors. The trend toward outsourcing of forestry work to contractors may have aggravated the trend (see above), while the catastrophic consequences of the Kruger National Park fire of September 2001 arose in part due to the new and unskilled personnel responsible for controlling that fire, and other concurrent institutional changes[30].

These trends have been accommodated in the specific fire risk scenarios developed in this study.

(a)



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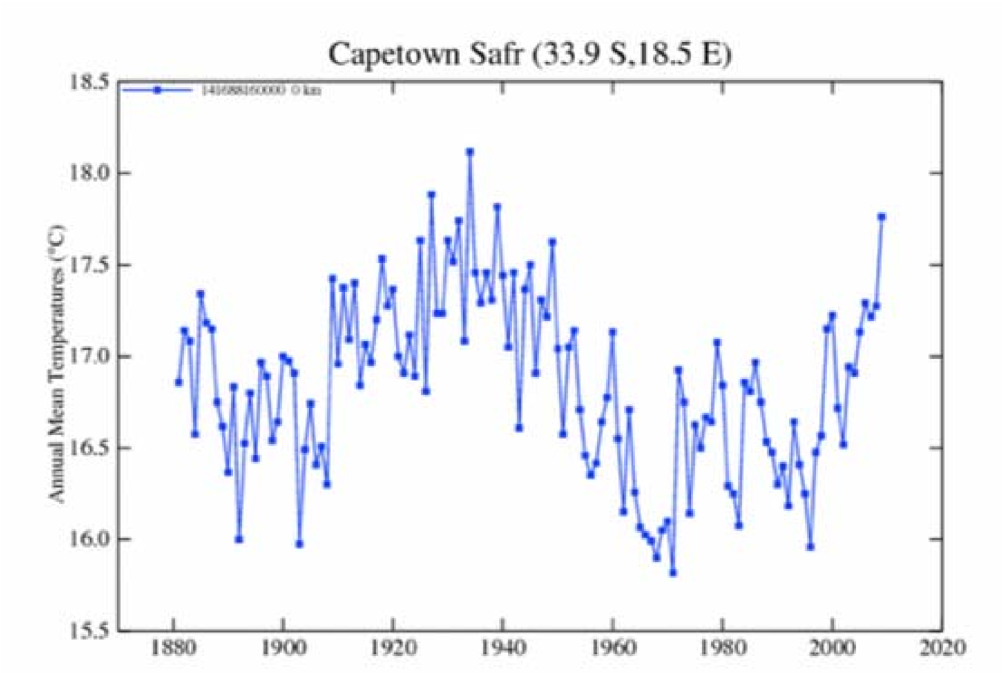

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[30] Ngobeni Commission of Inquiry. Commission of Inquiry into the Fire at the Pretoriuskop Area in the Kruger National Park that broke out on 4 September 2001. First and Final Report.

(c)

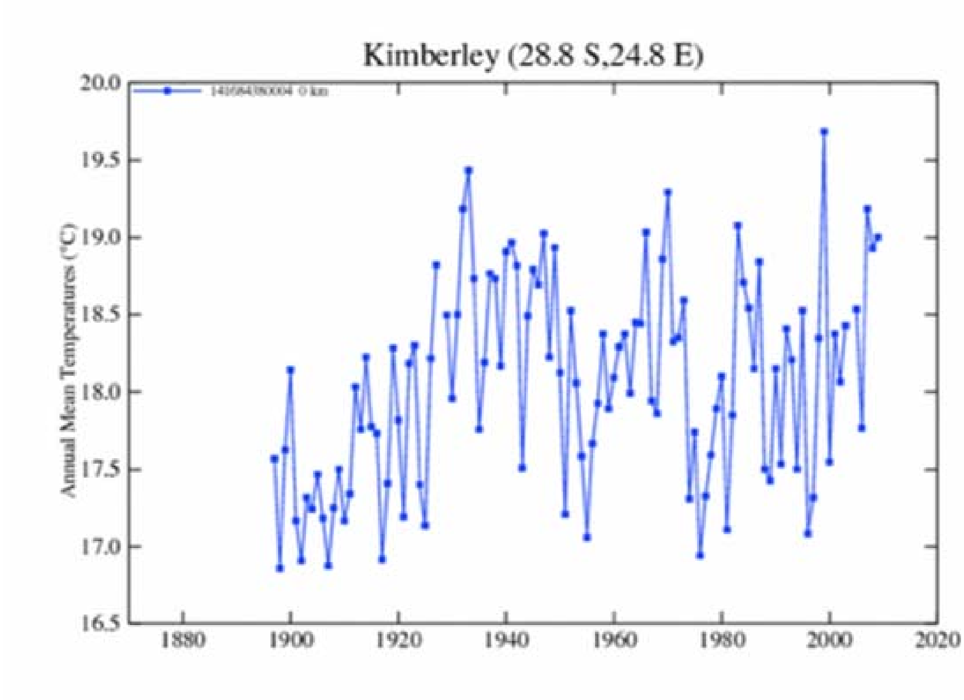

Figure 3. Global and local trends in measured surface air temperature. (a) shows an increase in mean temperature for the Southern Hemisphere during about the last 100 years. However, the long-term records used by NASA for South Africa ((b) and (c) for Cape Town and Kimberley respectively) show great interannual variability, as well as the climate oscillations reported by Tyson (op. cit.). From NASA Goddard Institute for Space Studies (http://data.giss.nasa.gov/gistemp/). The treatment of the effects of global climate change.

3.3 Treatment of the risk of climate change to veldfire management

3.3.1 Climate effects on veldfire

Changes in climate will influence the future occurrence of wildfire and the area burned through myriad pathways that involve weather conditions conducive to combustion, fuels to burn and ignition agents[31]. As humans manage fire in most parts of the world, the resulting changes in fire occurrence patterns will also be contingent on human activity, government policies, and institutional development.

Climate affects veldfire risk through its effects on all the fire activity factors discussed above. "The relative importance of climatic influences on fuel availability versus flammability can vary greatly by ecosystem and wildfire regime type. Fuel availability effects are most important in arid, sparsely vegetated ecosystems, while flammability effects are most important in moist, densely vegetated ecosystems. The direct effects of anthropogenic climate change on wildfire are likely to vary considerably according to current vegetation types and whether fire activity is currently more limited by fuel availability or flammability. In the long run, climate change is also likely to lead to changes in the spatial distribution of vegetation types, implying that transitions to different fire regimes will occur in locations with

[31] This section drawn largely from Flannigan 2009; Bradstock 2010.

substantial changes in vegetation."[32] These effects on fuels would be confounded by the CO_2 fertilisation effect in grasslands and savannas, which causes tree cover to increase at the expense of grass[33] , which may reduce wildfire occurrence, as well as responses of herbivores to changes in forage availability and quality[34].

3.3.2 Climate change and veldfire

The Intergovernmental Panel on Climate Change (the IPCC) reported in their Fourth Assessment Report as follows: "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level."[35] And further: "Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases."

Such warming may increase fire danger, unless there were to be compensatory reductions in available fuel through reduced primary production. In most countries with fire-prone ecosystems, there is concern about the inferred effects of climate change on wildland fire risk[36].

For example, the CSIRO in Australia expects that "A substantial increase in fire weather risk is likely at most sites in south- eastern Australia."[37] Substantial increases in wildfire risk are expected in the Western USA and Canada[38]. However, globally, the effect is likely to be highly variable, with fire-prone areas increasing in some areas and decreasing in others.[39]

Figure 3 above illustrates global and local trends in measured surface air temperature from 1880 to 2009. Though the global trend indicates an increase in the Southern Hemisphere of about 0.6 degrees C since about 1920, recent work by Engelbrecht[40] on the trends in surface air temperature for 1901 to 2002 show an increase of up to 1.4 degrees C over the centre of South Africa (i.e. the NE half of the Free State, and adjacent N Cape and NW Province), decreasing to about 0.8 to 1.0 degrees C near the coast. This is probably superimposed on the climate oscillation reported by Tyson, and with the many other risk factors discussed above, may have contributed to apparent recent trends of increases in wildfire risk.

The most recent authoritative global prediction of further climate change is that of the UK Meteorological Office[41]. They modelled change for the period 2070 to 2100, based on a mid-range IPCC emissions scenario A1B (i.e. with greenhouse gas emissions reaching a maximum at 2050, and then decreasing). These predictions

[32] Westerling 2009
[33] Bond *et al.* 2003b.
[34] van Wilgen 2009.
[35] IPCC 2007.
[36] Bowman *et al.* 2009; Spracklen *et al.* 2009; Westerling 2009.
[37] CSIRO 2007.
[38] Spracklen *et al.* 2009
[39] Flannigan *et al.* 2009.
[40] Engelbrecht in press.
[41] http://www.metoffice.gov.uk/climatechange/science/projections/; 14 January 2010.

show no change in summer rainfall over South Africa, except a reduction over the Desert and Nama Karoo Biomes, and no or little change in winter rainfall. The same models predict 3-5% increase in summer temperatures within the regions subject to fire risk, but up to 10% increase in winter temperatures, suggesting a lengthening of the fire season. Summer plant-available soil moisture (a predictor of vegetation productivity as well as fuel moisture content) would not change over most of the fire-risk regions, except for a 10-20% reduction in the centre. Winter soil moisture would however, be reduced 10-50% in the centre, though there would be no change in the east and the west. Such reductions in soil moisture may reduce fuel loads.

From his own regional circulation modelling, and the predictions in recent authoritative publications, Engelbrecht offers the following scenario, based on the IPCC emissions scenario A2 (greenhouse gas concentrations double their natural levels by 2050): “The subcontinent of southern African may be expected to become generally drier … The winter rainfall region of South Africa may become significantly drier as a result of frontal systems being displaced southwards by the stronger high-pressure belt. However, strong heating of the western and central interior regions … may displace the subsident regions eastwards during the warmer seasons. Most of eastern South Africa may become wetter in summer, partially as a result of this effect, which would result in increased convection and cloud-band formation over the region.”[42]

The effects of such change on fire regime would not be simple, depending on the interaction between climate and vegetation (see above) and ignition. A recent detailed global study, using statistical models derived from appropriate geographical data, predicted substantial invasion and retreat of fire across large portions of the globe, highlighting the potential for widespread impacts of climate change on wildfire. However, the maps show little predicted change in the distribution of fire-prone vegetation in Southern Africa.[43] Changes in climate and in human density and activities can substantially impact fire regimes in savanna and grassland systems. Whether this is something to be concerned about, however, is debatable. It is clear that the occurrence of high fire danger days has an impact on the probability of large fires inside protected areas, but the substantial impact that human activities have on fire size outside protected areas largely supersedes the climate driver, and large wildfires in inhabited savanna landscapes are not common[44].

“Climate only appears to have a big impact on fire in sparsely habited systems like protected areas. In these systems the consequences of large dangerous fires are not as high as they would be in more inhabited systems. However it would be wise to start looking for trends in climatic drivers of fire such as the number of high fire danger days and the total annual rainfall in these systems, as this will be an indication of possible changes in fire regimes in the future.” However, as we see from recent history (section 3.1.2), megafires occur also outside protected areas in South Africa.

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[42] Engelbrecht in press.
[43] Krawchuk *et al.* 2009.
[44] Archibald et al. 2009.

3.3.3 Climate change, veldfire and adaptive risk management

The climate-change outlook for South Africa is uncertain, as it is elsewhere. Nevertheless, the risks attached to the more extreme scenarios are sufficiently high, that a prudent policy of insurance against these risks is appropriate, if at reasonable present costs.

The IPCC concludes its chapter on adaptation: "Responding to climate change involves an iterative risk management process that includes both mitigation and adaptation, taking into account actual and avoided climate change damages, co-benefits, sustainability, equity and attitudes to risk."

Such an adaptive risk management process is appropriate in South Africa. Here, implementation of the statutory provision for a fire danger index will provide a system for institutionalising such adaptation, since the FDI will track real weather and climate variation.

For this study, we have opted not to bring climate change predictions into the risk analysis, for several reasons. First, in South Africa as in the Western US[45] and elsewhere, the past one or two decades have already experienced an increase in fire risk: we argue that the recent historical record provides sufficient information for plausible near-term future fire risk scenarios. Second, the national veldfire risk assessment reported here will need in any event to revised about five to ten years into the future, when the next assessment can be informed by the data and experience acquired in the interim.

There is one substantial uncertainty in this approach, and that is that South Africa has in recorded history (and from proxy records, for 8,000 years before) experienced a climate like that of the present, but which varies in a fairly regular 18-year oscillation[46]. This means that the recent past, even if subject to climate change, may be a poor predictor of the next 5-10 years; we have experienced a warmer than usual period (see Figure 2) and may be entering a period of cooling.

Given the high social economic and environmental costs of wildfires in South Africa, however, especially to vulnerable rural populations, it is advisable to invest substantially now in precautionary research and rational analysis to understand better the current risks and the potential effects of climate change on them.

3.4 Policy context

3.4.1 Principal instruments of policy relevant to veldfire risk assessment

3.4.1.1. <u>The Disaster Management Act and the National Disaster Management Framework</u>

The Disaster Management Act requires a National Disaster Management Framework (NDMF). This Framework is the legal instrument to address the need for consistency across the different spheres of government and multiple interest groups,

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[45] Tom Swetnam correspondence

[46] Tyson 1986.

by providing 'a coherent, transparent and inclusive policy on disaster management appropriate for the Republic as a whole' (section 7(1)).

This Framework includes, among others, Key performance area 2: Risk assessment.

The Disaster Management Act sets out in sections 20, 33 and 47 the requirements for priority setting with respect to disasters and emphasises risk assessment to guide national, provincial and municipal risk reduction efforts.

The NDMF requires a risk at national level to guide risk reduction efforts for specific known threats or disaster events and processes that:

- due to their scale and magnitude are likely to affect more than one province
- are of recurrent high and medium magnitude, occur in most provinces and may require national support and/or intervention
- occur infrequently or seasonally (for example, veld fires and flooding), have the potential to cause severe loss, and require levels of specialist support not available at provincial level
- affect neighbouring countries and have consequences for South Africa (for example, unplanned cross-border movements and events that require humanitarian or other relief assistance).

Risk reduction, in the Act, emphasises prevention and mitigation, while "disaster management" means a continuous and integrated multi-sectoral, multi-disciplinary process of planning and implementation of measures aimed at:

a) preventing or reducing the risk of disasters
b) mitigating the severity or consequence of disasters
c) emergency preparedness
d) a rapid and effective response to disasters; and
e) post-disaster recovery and rehabilitation.

In this respect, the objective is to establish a uniform approach to assessing disaster risks that will inform risk management planning and reduction undertaken by organs of state and other role players.

All national organs of state must carry out risk assessments for priority disaster risks relevant to their functional areas. Where possible, these should be undertaken interdepartmentally to avoid duplication of efforts and to ensure uniformity of findings.

The NDMF sets a national standard for assessment of priority risks, to give priority to the establishment of a uniform approach to disaster management and the provision of a national standard to guide the assessment of priority risks. Prior to the development of such a national standard:

- all proposed risk assessments planned by national and provincial organs of state must be reviewed by the NDMC prior to commissioning of the assessments

- all proposed risk assessments planned by metropolitan municipalities must be reviewed by the NDMC and the appropriate PDMC prior to commissioning of the assessments
- all proposed risk assessments planned by district municipalities must be reviewed by the appropriate PDMC prior to commissioning of the assessments
- all proposed risk assessments planned by local municipalities must be reviewed by the appropriate MDMC prior to commissioning of the assessments.

As the organ of state accountable for the implementation of the National Veld and Forest Fire Act, the DAFF requires a risk assessment for veldfire as priority risk, according to the requirements as set out in the NDMF (see below).

3.4.1.2. The National Veld and Forest Fire Act

The National Veld and Forest Fire Act where it refers to veldfire risk (e.g. Chapter 2, on the formation of Fire Protection of Fire Protection Associations, and Chapter 4, on veldfire prevention through firebreaks) requires risk assessment for its proper implementation. DAFF will employ the map and its classes, to guide the priorities for the establishment of and support to Fire Protection Associations, as an integral part of the veldfire disaster management framework.

3.4.1.3. The National Environmental Management: Biodiversity Act and bioregions

Much of the extent of the nine broad priority areas for conservation action in South Africa, as identified in the National Spatial Biodiversity Assessment 2004, coincide with regions of high fire risk[47].

Section 40 of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEMBA) provides for the designation of bioregions (which would encompass the priority areas for conservation action), and for these, the development of bioregional plans (Section 41). A bioregional plan must contain measures for the effective management of biodiversity and the components of biodiversity in the designated bioregion. Such a plan is intended to guide land-use planning, environmental assessments and authorisations, and natural resource management, by the range of sectors whose policies and decisions impact on biodiversity, so that biodiversity priorities and sustainable management of natural resources are taken into account by all of these sectors. All organs of state are bound by these plans.

For example, Local and District Municipalities must align critical biodiversity areas and the contents of the bioregional plan generally into their IDPs and by implication into their SDFs. The DAFF is obliged to take bioregional plans into account in their planning processes and in the programmes which they develop. At the same time, Section 48 provides that a bioregional plan and a biodiversity management plan may not be in conflict with any other plans prepared in terms of national or provincial legislation that are affected.

Thus, this veldfire risk assessment needs both to take account of biodiversity management, and to inform bioregional plans. This is especially important since

[47] See Department of Environmental Affairs and Tourism, “Guideline regarding the Determination of Bioregions and the Preparation and Publication of Bioregional Plans” for additional details.

many of South Africa's ecosystems are fire-dependent and lack of the appropriate fire regime is one of the major threats to the country's biodiversity[48] (see Section 5.1 below).

3.4.2 Framework instruments of policy and strategy

The priorities and programmes in which veldfire policy and management finds its place, with development strategy and disaster and biodiversity management, are contained in the Government Programme of Action (GPOA). Currently, the only relevant element of GPOA appears in Activity 1 of the Human Development Cluster (Strengthen the skills and human resource base), which includes focus 2.8.3. "Focus on non-communicable diseases, injuries, patient's rights and quality plus provide accountability" for "Improving the health profile of all South Africans". However, veldfire risk management does also address the safety and security leg of South Africa's Five Priorities [see State of Nation Address], in that successful management will contribute to people's "being safe and feeling safe".

In 2008 the government adopted the National Framework for Sustainable Development (NFSD). A key target of the Johannesburg Programme of Implementation (JPOI), which supports the Millennium Development Goals (MDGs), is to integrate the principles of sustainable development into country policies and programmes. South Africa has numerous strategies and programmes that include sustainable development considerations and in 2003 it developed a response strategy to the JPOI; but it did not have a coherent and overarching national strategy for sustainable development. The NFSD seeks to address this void by initiating a broad framework for sustainable development in the country that can serve as a basis from which to develop and consolidate a national strategy and action plan.

The five strategic priority areas in the NFSD are:

- Enhancing systems for integrated planning and implementation
- Sustaining our ecosystems and using resources sustainably
- Investing in sustainable economic development and infrastructure
- Creating sustainable human settlements

Though the NFSD refers to the Acts relevant to this risk assessment, it has no explicit elements in the priority areas that relate to this matter.

The National Strategy for Sustainable Development is now being developed, and would need to address veldfire risk management as it affects each of the five strategic priority areas, at least with respect to the rural environment.

Government policy and strategy in other areas also relate to veldfire risk management, e.g. food security.

A further important focus area is the Department of Social Development's Strategy on Population and Development, which is to promote sustainable human

[48] Van Wilgen and Scholes 1997; Bond 1997.

development by focusing on population, environment and development (PED – the PED Nexus initiative) interactions especially on local government level. IDPs are to take linkages between population, environment and development into account in order to achieve sustainable development. PED Nexus relates directly to requirements in the NDMF, e.g. disaster risk assessment and management for increased robustness of development initiatives in poor communities and areas.

3.5 Problem frame

The veldfire risks in South Africa are costly in terms of the country's sustainable development, and bear heavily on the rural and urbanising poor. The fire environment, i.e. the surrounding conditions that determine veldfire activity, varies significantly across South Africa, from one vegetation type to the next. This means that veldfire regimes and levels of fire risk co-vary, a situation aggravated by the geographical variation in assets and values exposed to veldfires.

For this reason, classifying and mapping veldfire risk requires the method called comparative risk assessment, in order to generate an ordered ranking of veldfire risk that is meaningful geographically. By this we mean that a comparative assessment among the geographically and socially (asset-wise) distributed veldfire risks is needed to guide prioritisation of risk management in a consistent and meaningful way. Such consistency is especially important in the allocation of resources to agencies through national transfers to provincial, local and community spheres.

As the organ of state accountable for the implementation of the National Veld and Forest Fire Act, the DAFF requires a risk assessment and map of risks of veldfire, according to the requirements as set out in the NDMF. This assessment should integrate with relevant provisions in this Act, for example, the fire danger rating system. It should provide an assessment at the policy level, to support operational assessments and mitigation plans in the provincial and local spheres of government. It should integrate with bioregional plans in terms of the National Environmental Management: Biodiversity Act as well as the PED Nexus approach to IDPs.

The risk assessment is required for the whole country, so that areas with no risk are identified, as well as those at risk.

The assessment is to serve the purposes of policy, not operations. Therefore, it should address inherent veldfire risk, rather than residual risk after taking account of the mitigation provided by risk management. This is to meet the objective in the NDMF, i.e. to establish a uniform approach to assessing disaster risks that will inform risk management planning and reduction to be undertaken by organs of state and other role players.

4. Assessing veldfire risk

4.1 The requirements in the National Disaster Management Framework for risk assessment.

An important requirement in the NDMF is Key performance area 2: Risk assessment**.**

In the NDMF, disaster risk refers to the chance that there will be a harmful impact of some kind due to the interaction between natural or other hazards and conditions of vulnerability.

Disaster risk assessment has the objective of establishing a uniform approach to assessing disaster risks that will inform risk management planning and reduction undertaken by organs of state and other role players.

The NDMF requires risk assessment as the first step in planning an effective risk reduction programme.

Risk assessment planning requires identification of key stakeholders, as well as consultation with them about the design and/or implementation of the assessment and the interpretation of the findings.

In the NDMF, risk assessment is a process that determines the level of risk by:

- analysing potential hazards and/or threats
- assessing the conditions of vulnerability that increase the chance of loss for particular elements-at-risk (that is, environmental, human, infrastructural, agricultural, economic and other elements that are exposed to a hazard, and are at risk of loss)
- determining the level of risk for different situations and conditions
- helping to set priorities for action.

A reliable risk assessment for a specific threat should answer the following questions:

- How frequently can one expect an incident or disaster to happen?
- Which areas, communities or households are most at risk?
- What are the likely impacts?
- What are the vulnerability or environmental and socio-economic risk factors that increase the severity of the threat?
- What capabilities or resources exist to manage the risk?
- Is the risk becoming more serious?
- Is the risk undermining development progress in the areas, communities and households it affects?
- If so, is the management of the risk a development priority?
- In the areas and communities affected by the risk, are there any other significant risks?

The NDMF includes minimum requirements for a disaster risk assessment (see Box 2, below).

The NDMF requires hazard and vulnerability assessment findings to be consolidated according to uniform classifications. It mentions the internationally recognised classification of the UN's International Strategy for Disaster Reduction (ISDR). According to ISDR, veldfire classifies as a natural biological hazard.

Box 2. Requirements in the National Disaster Management Framework for undertaking a risk assessment

The general process for assessing disaster risk always involves three basic steps:

- *Identify and describe the risk*
- *Analyse the risk*
- *Evaluate the risk.*

STEP 1: IDENTIFY AND DESCRIBE THE RISK

1. *Identify and describe a specific hazard with respect to its frequency, magnitude, speed of onset, area affected and duration.*
2. *Describe and quantify, where possible, the vulnerability of people, infrastructure (including homes and dwellings), services, economic activities and natural resources exposed to the hazard.*
3. *Estimate the likely losses resulting from the hazard's action on those that are vulnerable to indicate likely consequences or impacts.*

STEP 2: ANALYSE THE RISK

1. *Identify relevant capacities, methods and resources already available to manage the risk.*
2. *Assess the effectiveness of these, as well as gaps, inconsistencies and inefficiencies in government departments and other relevant agencies.*
3. *Estimate the level of risk associated with a specific threat to determine whether the resulting risk is a priority or not. Estimating the level of risk is done by matching the likelihood of a hazard event with its expected impact or consequences. This process allows different threats to be compared for the purpose of priority setting.*

STEP 3: EVALUATE THE RISK

The risk analysis helps prioritise disaster risks when there are multiple threats to assess. However, when several threats are assessed at the same level of risk, limited resources and budgets require that they be prioritised even further. This process, called 'risk evaluation', is necessary because it is not possible to address all risks at the same time.

One useful approach for comparing different types of risks evaluates the seriousness, manageability, urgency and growth of a particular risk to determine whether it ranks higher as a priority than other risks. Each of these can be further evaluated in terms of 'High', 'Medium' and 'Low' to compare several different threats that have been assessed to have the same level of risk.

Vulnerability should be assessed as social, economic, political, environmental or physical (infrastructural) vulnerability. As vulnerability factors are often the major drivers of disaster risk, rather than external hazard processes, it is critical to identify these during a risk assessment. This provides important insights for developing vulnerability reduction interventions that lower the levels of disaster risk.

4.2 Comparative risk assessment

4.2.1 Introduction

Comparative risk assessment (CRA) is a set of procedures, i.e. a protocol, for the simultaneous assessment and ranking of diverse risks. The term distinguishes this protocol from the procedures employed for univalent risk assessment, where risks arising from the exposure of, usually, humans to for example a toxic compound are assessed through a dose-response relationship; i.e. an "objective characterization of the distribution of possible outcomes"[49].

CRA is a protocol designed to accommodate scientific knowledge, rational belief, and human judgement. It "attempts to unify the methods and assumptions used for the diverse risk factors that have traditionally been assessed in individual scientific and social science disciplines"[50].

CRA is part of an overall protocol within a framework for risk management (see below). Risk assessment is "the identification, quantification, and characterization of threats to human health and the environment. Risk management centres "around processes of communication, mitigation, and decision making"[50].

CRA "can be conceptualized as a multi-attribute evaluation procedure"[51], with the following characteristics:

- It is transdisciplinary, i.e. an integrative form of research comprising extra-scientific experience and practice; a unity of knowledge beyond disciplines; whereby the result, as a rule, exceeds that of the contributions of the individual sciences[52].
- It culminates in explanatory risk descriptions for priority risks. These descriptions contain the understood causal relationships that underlie the risk, in such way as to aid communication and management.
- Both the public and the experts are necessary participants in the process that assessment is inevitably subjective, and that understanding public perceptions is crucial to effective decision making[53].

Importantly, "risk analysis is a political enterprise as well as a scientific one, and public perception of risk also plays a role in risk analysis, bringing issues of values, process, power, and trust into the picture"[50]

[49] Slovic and Weber 2002.
[50] Ezzati 2003.
[51] Schutz *et al.* 2006.
[52] Kötter and Balsiger 1999.
[53] Slovic *et al.* 1980.

Paraphrasing Fischhoff and co-authors, CRA is one tool that makes it possible to ask people for complex judgements about difficult societal problems and receive orderly, interpretable responses[54].

4.2.2 The method applied for the veldfire risk assessment

The field of risk analysis focuses on issues of risk assessment and risk management. The former involves the identification, quantification, and characterisation of threats to human health and the environment. The latter, risk management, centres around processes of communication, mitigation, and decision making[55].

The field has now been standardised to a significant degree. In this work, we used the standard approach to risk assessment grounded in ISO 31000[56] and formulated for CRA according to the AS/NZS 4360 standard[57]. This approach complies with the requirements in the NDMF, and with emerging international best practice in wildfire risk assessment. For example, the 2004 Australian National Inquiry on Bushfire Mitigation and Management recommended: "The Inquiry considers that the Australian Risk Management Standard—AS/NZS 4360:1999—should be applied in relation to bushfire by all relevant agencies in all jurisdictions."[58] In addition, the latest terminology of the UNISDR complies with these standards[59] .

Adapted for this work, the procedure involved the following steps:

- Context: problem definition and structuring (as reported above)
- Evidence-based knowledge building
- Comparative risk assessment and risk characterisation
- Risk prioritisation
- Development of risk management strategies.

The text below outlines the methods for each of these steps.

This procedure does not correspond fully with the procedure set out in the NDMF (see Box 2 above). However, all the measures required in NDMF Step 1 ("Identify and describe the risk") are included in the procedure followed here, and our risk analysis provides for part of Step 2 ("Analyse the risk").

We do not address the following parts of Step 2 in NDMF.

1. Identify relevant capacities, methods and resources already available to manage the risk.
2. Assess the effectiveness of these, as well as gaps, inconsistencies and inefficiencies in government departments and other relevant agencies.

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[54] Fischhoff *et al.* 1978.
[55] Slovic and Weber 2002.
[56] ISO 31000 2009.
[57] Standards Association of Australia 2009.
[58] Ellis *et al.* 2004. Standards Association of Australia 1999, AS/NZS 4360:1999 Risk Management.
[59] 2009 UNISDR.

The reasons are:

1. the present risk assessment is for policy purposes, as set out in section 3.4.1 above, and the output is to guide full risk-management plans in the provincial and local government spheres, as well as in FPAs
2. it is at these local scales that managers will identify individual assets and their vulnerabilities, the risks to them that arise from veldfire hazard, and thus establish the gaps in capacity that need to be filled
3. the present assessment provides the framework for consistency in risk management in these other three spheres that is required by the NDMF
4. and finally, addressing Step 2 fully would require resources and time to the extent that the national assessment would be much delayed, this delaying the risk management procedures in these other three spheres.

4.3 Building the knowledge base

Several sources of information provide a sound evidence base for the NDMF requirements, through the lens of the problem framed in 3.5 above. These are both for analysing potential hazards and assessing the conditions of vulnerability, as well as the formal process of risk analysis required for determining the levels of risk in different situations. The first are treated in the situation and trends assessment in sections 3.1 to 3.3 above. The second follows in the sections below.

During the past 5-10 years there has been substantial progress in our knowledge of fires in vegetation. This has arisen largely for three reasons: the need to understand the potential effects of climate change on fire and hence biodiversity (and the effects of fire on the atmosphere), the progress in the earth observation systems that allow a comprehensive examination of patterns and trends in fire, and the need to improve fire-management policies to conserve biodiversity and ecosystem processes while managing risk. But the research has also been motivated by the apparent increase in megafires over recent decades.

This new body of knowledge available for this project had three main parts: first, a wide series of papers reporting on the fundamental factors governing fire activity and subject to environmental change, at the global and continental scales; second, regional African studies of the determinants of fire activity; and third, local studies of fire and fire management, almost all in fynbos and savanna. Finally, there is a growing body of useful literature on comparative risk assessment, consulted in detail for this project.

A second important body of knowledge should come from fire reports. This is especially important in the risk analysis. However, reporting in South Africa is still poor, despite attempts to implement a National Veldfire Information System. For this information we have relied on (a) reports from specific investigations, such as by ForestrySA[60], the report on the 2000 Cape Peninsula fires[61], and the reports for the Ngobeni Commission of Enquiry for the September 2001 megafire in the Kruger National Park, scientific papers reporting fire histories for protected areas or

[60] ForestrySA 2007.

[61] Kruger *et al.* 2000 op. cit.

regions[62], press reports, and contributions through the consultative workshops (see below).

Finally, the geographic information available in South Africa that is useful to this assessment has expanded considerably. This information includes several kinds (a) the "mesozone" scale layers of socio-economic information used in the National Spatial Development Perspective (b) the 2001 National Land Cover map, which has a large set of polygons classified by extant land cover, allowing the mapping of vulnerable crops, the exclusion of transformed land, and other applications as set out below (c) human settlements maps, and (d) the new national map of vegetation types.

Box 3. Mesozones as used in the National Spatial Development perspective for geographical analysis

The South Africa Geo-spatial Analysis Platform (GAP)

GAP was developed specifically to address the problem of spatially incompatible 'large area statistics' and other limitations associated with indicators and related maps that portray the geography of need, development and sustainability in terms of an absolute, container view of space[63]. The underlying mesoframe methodology – developed by the Council for Scientific and Industrial Research (CSIR) Built Environment unit [64] – overcomes the problem of spatially incompatible 'large area statistics' by re-scaling and assembling a variety of census, satellite imagery and other data sources in terms of a common set of meso-scale analysis units. This consists of 25 000 irregularly shaped mesozones (approximately 49km^2 or 7 km by 7 km in size). The demarcation of mesozones was determined using various types of boundaries (political, economic and biophysical). In particular, they were demarcated so as to nest within important administrative and physiographic boundaries, and to be connected to a digital road network for South Africa. A primary consideration was that these boundaries should correspond with travel barriers such as rivers and 'breaklines' between sparsely and densely populated areas.

4.4 The standard approach to comparative risk assessment

4.4.1 Definition and interpretation of risk

The key starting point is the definition of risk. Here, the definition, from AS/NZS 4360, is: "The exposure to the possibility of such things as economic or financial loss or gain, physical damage, injury or delay, as a consequence of pursuing a particular course of action. The concept of risk has two elements, i.e. the likelihood of something happening and the consequences if it happens."

That is, for veldfires,

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[62] Brown et al. 1991; Seydack *et al.* 2007; Forsyth 2008; van Wilgen 2009; van Wilgen *et al.* 2010.

[63] Couclelis 1991

[64] Naudé *et al.* 2007

Risk = a function of the likelihood and the consequence to a vulnerable asset of a given fire risk scenario, i.e. hazard.

Section 4.4.3 outlines how we determined likelihood and consequence, and hence risk level, again following AS/NZS 4360.

This assessment is of inherent risk, not residual risk. Here, inherent risk means the risk diagnosed under current conditions, i.e. without risk reduction other than that instituted in current management regimes. This means, for example, that for a given plantation forest management unit, or for the forest industry as a whole, we assume a risk analysis based on present conditions, with current fire management in place, and ignoring variations among units regarding management.

Residual risk would be the risk diagnosed for a given case once the required risk management is in place.

This methodology is consistent with the procedure specified for risk assessments by FPAs in the preparation of their business plans (in Department of Water Affairs and Forestry Guidelines for the Establishment and Management of Fire Protection Associations in Terms of the National Veld And Forest Fire Act No. 101 Of 1998 as amended).

4.4.2 Identifying assets and hazards

4.4.2.1. Overview

We analysed the consequences of a veldfire event in terms of the three endpoints, social, economic, and environmental consequences. Choosing a measure for different endpoints is both complex and judgemental[65]. We approached this, first through consultation in workshops, and then, by examining the available reports on fires in South Africa over about the last 10 years., as well as by using spatial data that represented the location of and variation in proxy measures of assets, values and their vulnerabilities, as set out below.

4.4.2.2. Vulnerable social assets

We used life and health as measures of social assets, i.e. we simply took the exposure of people to the hazard of veldfires as the endpoint measure. However, we assumed social vulnerability to be a function of the proportion of people living below the mean living level (MLL; 2004 data) (see Figure 4) per mesozone (see Box 3). This measure correlates strongly with the distribution of dispersed rural settlements (see Figure 2). Thus, in mesozones where more than 25% of people were below the MLL, we shifted the assessed risk level one grade higher than in equivalent mesozones where people were better off. This was only in regions where there is a real risk of veldfire (see Appendix 3 and Figures 14-17).

65 Slovic and Weber 2002.

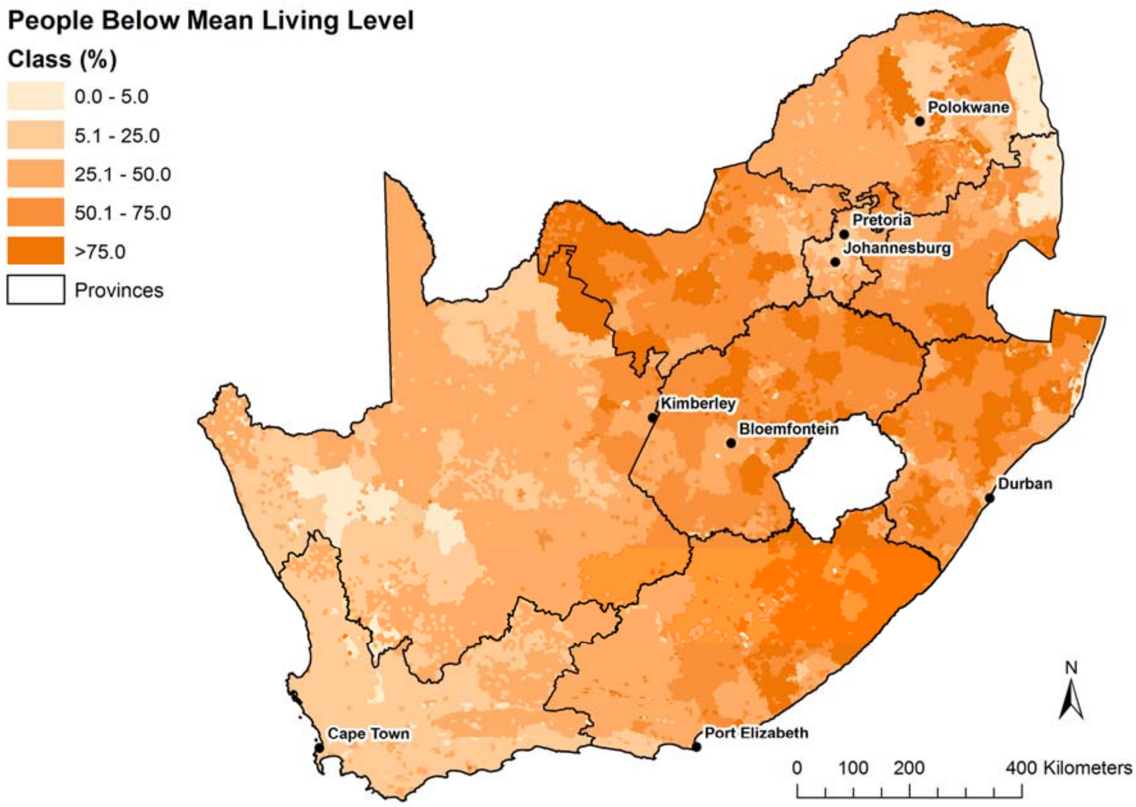

Figure 4. Distribution of poor households as measured by the proportion of the population below the mean living level in each mesozone. Derived from 2004 national census published by StatsSA.

There is general concern about the vulnerability of communities at the urban-rural interface. We did not however include this in the present risk assessment, mainly because such vulnerability is not readily applied at the national scale, and the assessment of risk at that scale is best done locally, with local knowledge and consultation.

4.4.2.3. Vulnerable economic assets

We identified economic assets that are vulnerable to veldfires from the available reports for damaging wildfires. These are all aspects of the ecotourism and agro-forestry components of the rural economy, an economy which varies strongly across South Africa. We used information from fire reports on losses in fires as well as the map of agro-forestry gross value added (Figure 5) to guide the assessment of economic consequences of specific-risk scenarios.

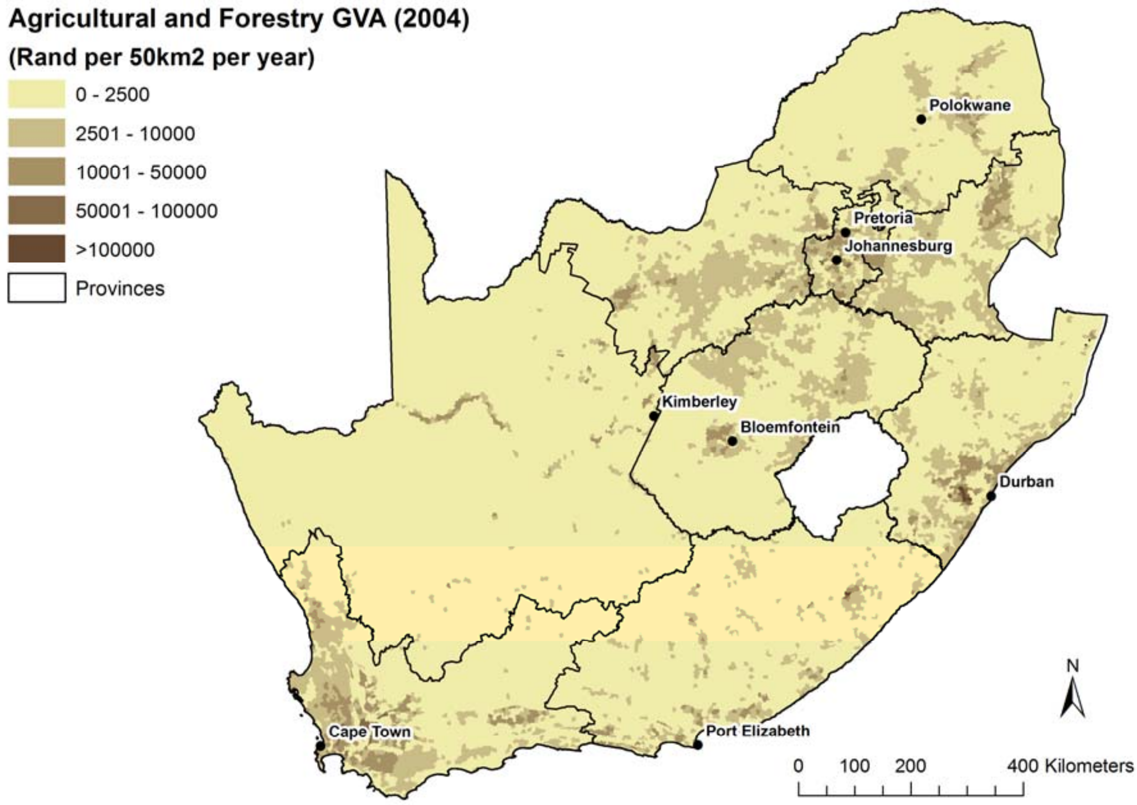

Figure 5. Agro-forestry gross value added to the local economy in each mesozone[66].

These assets included infrastructure (such as power lines), industrial facilities (e.g. sawmills), fodder, livestock, homesteads, resorts, and plantation forests. We excluded dryland crops, such as maize, since these seldom suffer loss. In addition, certain harvestable natural resources, such as thatch-grass stocks, are lost in fire, to the detriment of local communities. These resources now are largely confined to protected areas and commercial farms; we provide for this in the specific risk scenarios where appropriate.

Each specific fire-risk scenario lists vulnerable economic assets.

4.4.2.4. Vulnerable environmental assets

Most if not all ecosystems in areas of fire risk are resilient to veldfire, being fire-dependent or fire-independent (see 5.1 below). Thus, in most cases, we did not rate ecosystems as vulnerable to veldfires. This applies even where the conservation status of ecosystems has been rated in biodiversity assessments as being vulnerable to factors other than fire.

66 Naude *et al.* 2007.

Natural Forests, Thicket, and Sparse Arid Woodland are fire-sensitive. However, to our knowledge, fires penetrate these types only rarely, and the ecosystems recover in the long inter-fire periods. We therefore also rated these types as not being vulnerable; this assessment may change in future, depending on the course and outcomes of climate change.

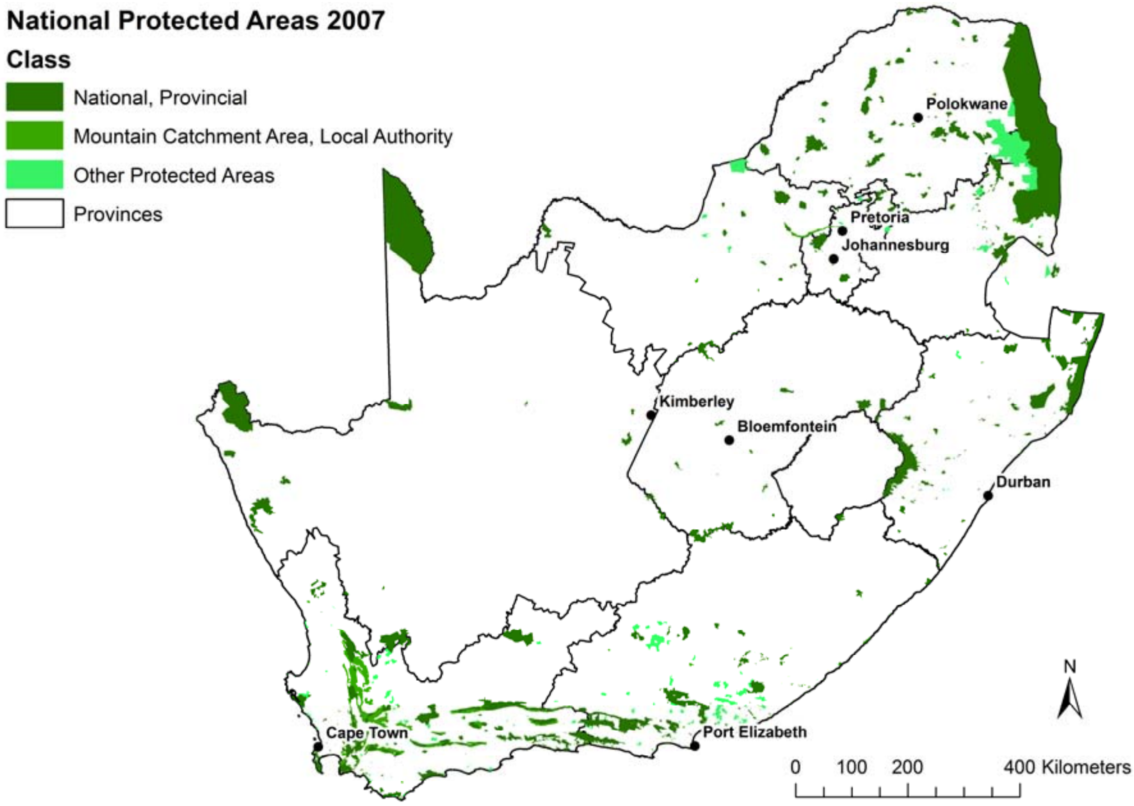

Figure 6. Distribution of protected areas classified according to the National Environmental Management: Protected Areas Act[67].

Figure 6 depicts the location of protected areas in South Africa. Most occur in areas prone to veldfires. Once more, where relevant, we take account of the vulnerability of such areas in the specific fire risk scenarios, taking account of the resilience to fire of the ecosystems contained in these areas.

Ecosystems, such as fynbos, that are vulnerable to invasion by alien plant species after fire, present a special case of veldfire vulnerability. Here too we did not treat plant invasion as being a factor in vulnerable environments, but leave such an assessment to local-level veldfire risk assessment. This is because alien plant

[67] Copy of the current national protected areas database provided by S. Holness (South African National Parks Board, pers. comm., February 2010).

invasions after fire depend on the state of alien plant control at a given place at the time of a fire, information not available for the present assessment. The Working for Water Programme has commissioned the National Invasive Alien Plant Survey, which may be useful in the next veldfire risk assessment.

Environmental values are vulnerable where fires occur in forest plantations. This is the case where intense blow-up fires occur in plantations with high ground fuel loadings, or where there are fires with long residence times in heavy ground fuels of slash after clearfelling. In such circumstances, the fire will often destroy the structure of the surface soil horizon, causing accelerated erosion, and consequent loss of soil and catchment values[68]. We take account of this in the fire risk scenarios and the risk assessments attached to these.

There are dense invasions of invasions by species of pine, which may burn like plantation forest with the same environmental consequences, but assessment for such cases awaits the National Invasive Alien Plant Survey.

4.4.2.5. <u>Specific veldfire risk scenarios</u>

In order to perform the veldfire risk analysis, we first developed specific veldfire risk scenarios.

These are each a written description of the specific risk that contains all the necessary information, to make a justifiable risk evaluation, described in a way that is meaningful and unambiguous.

These describe the main source of danger against which to take precaution. These scenarios are plausible descriptions of possible wildfire events, which define the kind of event that must determine a cost-effective but affordable risk management strategy that would be the desired standard or norm for a given situation. It should be normative in the sense that if the strategy were implemented, people would feel reasonably safe in that environment, and economic development would proceed under conditions of manageable risk, while environmental values are protected and ecosystem services sustained.

Thus, the specific veldfire risk scenarios define possible extreme events that would cause much harm to people, property, and the natural world, without risk management.

We derived these scenarios from information provided by key informants, news and other reports, and expert experience.

Each scenario specified the following:

- Context: the fire-ecology type, its state, and a broad indication of land use.
- A description of assets and values vulnerable to fire: social, economic, and environmental
- Time of year

[68] Scott 1993; Scott *et al.* 1998.

- Prevailing weather conditions
- Fuel type structure and state
- Terrain
- Fire behaviour.

Appendix 3 contains these descriptions.

4.4.3 Risk analysis

The risk analysis tables (Tables 1-3, adapted from AUS/NZS 4360) provide the algorithm according to which risk is analysed and for each separate risk, and assigned a risk level ranging in four classes from low to extreme. Tables 1 and 2 provide linguistic scales for the ranking of the perceived and informed judgements of the likelihood and consequence of a risk scenario, in a given environment, by the panel involved in the analysis (and in a way that the analysis may be tested in a wider audience).

The quasi-numerical scale of likelihood in Table 1 is subordinate to the linguistic scales. This avoids the difficulties of communicating statistical probabilities[69] while also allowing participants to debate the information on probabilities and their judged inferences of scenario likelihoods.

The assignment of likelihood proceeds in the assessment panel by setting the question: "In any one municipality with this fire-ecology type. What is the likelihood that this would occur?"

Table 3 provides a categorical classification of risk levels. Here, the scaling is done in the assignment to cells of levels from low to extreme.

This analysis by linguistic scale and agreed categories addresses the risk perception problem: the "… complex interplay between emotion and reason that is essential to rational behaviour ..";   "… logical argument and analytic reasoning cannot be effective unless it is guided by emotion and affect … Rational decision making requires proper integration of both modes of thought. Both systems have their own sets of advantages, as well as biases and limitations."[70]

We conducted this algorithmic analysis for each combination of specific fire risk scenario, fire-ecology type and asset type, in a two-level expert panel process. A core panel of two, with considerable experience of fire ecology and the fire regime across South Africa, completed a draft analysis, and a second panel, equally expert, reviewed this draft. We consulted together until we had resolved any anomalies. This means that the overall assessment reflects an expert view, and would need to be subject to wider review in good time.

[69] Hoffrage *et al.* 2000.

[70] Slovic and Weber 2002.

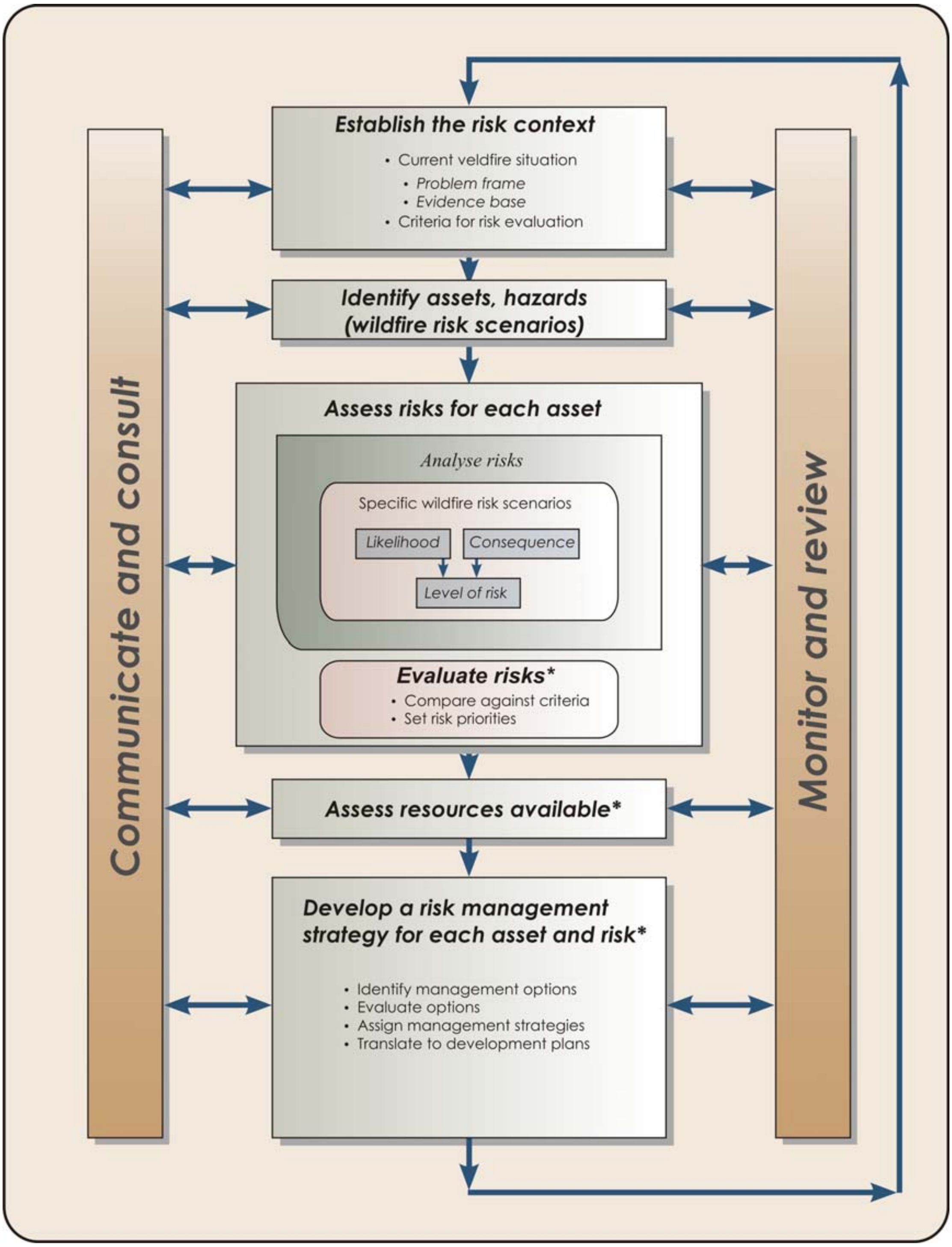

Figure 7. The standard risk management framework, adapted from AS/NZS 4360. Boxes marked with an asterisk indicate the steps not included in this assessment, other than to provide indicative recommendations.

Table 1. Qualitative and quantitative indicators of likelihood i.e. the likelihood that a specific fire risk scenario would come to reality.

Likelihood rating	Indicative frequency	Description
Almost certain	once in 2 years	Is expected to occur
Likely	once in 5 years	Will probably occur
Possible	once in 10 years	Might occur at some time; as likely as not
Unlikely	once in 20 years	Could occur at some time
Rare	once in 100 years	May only occur in exceptional circumstances

Table 2. Qualitative measures of consequence of a specific fire risk scenario.

Level of consequence		**Consequence end points**		
		Social consequence criteria	**Economic consequence criteria**	**Environmental and ecological consequence criteria**
1	Catastrophic	Death of one or more persons in the scenario	Depressed economy of the Municipality. Extensive and widespread loss of assets. Major impact across a large part of the community. Long-term external assistance required to recover.	Permanent loss of species or habitats within the area or of water catchment values and other ecosystem services (and not assessed as an economic consequence).
2	Major	Extensive injuries to people in the scenario, requiring emergency hospitalisation and affecting work capacity; or, evacuation required.	Serious financial loss, affecting a significant portion of the community. Requires external funding (e.g. from Disaster Management funds) to recover.	Habitat destruction, temporary loss of species, or temporary loss of catchment values and other ecosystem services (and not assessed as an economic consequence), requiring many years to recover.
3	Moderate	Medical treatment required but full recovery possible.	Localised damage to property. Short-term external assistance required to recover.	Serious impact on the environment that will take a few years to recover.
4	Minor	Minor injuries only – first aid treatment required.	Minor financial loss. Short-term damage to individual assets. No external assistance required to recover.	Discernable environmental impact. Assets recover rapidly.
5	Insignificant	No injuries	Inconsequential or no damage to property	Minor impact on the environment

Table 3. Levels of risk, assessed as the product of likelihood and consequence.

Likelihood Rating	Consequence Rating				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Possible	Low	Medium	High	High	Extreme
Unlikely	Low	Low	Medium	High	Extreme
Rare	Low	Low	Low	Medium	High

4.4.4 Summary of protocol followed

Box 4 is an algorithmic statement of the manner in which we implemented the whole procedure.

Box 4. Summary of the protocol followed in the comparative risk assessment

1. Risk identification

a. Resolve vegetation types as the base ecological template.

i. Check against literature and other sources of knowledge for uniformity of fire regime within a bioregion or vegetation type; compare with the prior, 2004 fire-ecology types and explain anomalies if any.

ii. Derive fire-ecology types (which may be aggregates or subdivisions of bioregions or aggregates of vegetation types).

iii. Describe fire-ecology types in terms of ignition sources, fuel (loads, structure and dynamics), fire weather, climate and terrain, as well as sustainable or "normal" fire regimes.

iv. Assign fire-ecology types to mesozones (Box 3). Where a mesozone includes more than one fire-ecology type selected the fire-ecology type that has the highest fire incidence provided that it occupies more than 10% of that mesozone.

b. Develop an asset typology.

i. This yields a list of groups of assets or values exposed to fire hazard or dependent on proper fire management.

ii. The list should be a set of proxies, i.e. assets or values are vulnerable or fire-dependent and which would be good measures of potential consequence. Examples follow below:

1. Social: scattered rural households; peri-urban households,

2. Economic: rural infrastructure (power lines, communications, etc), plantations forests, livestock and fodder banks, and

3. Environment: values that reflect ecosystem services enjoyed, e.g. freshwater supply, harvestable natural resources, etc;

c. Locate and map assets for each fire-ecology type.

i. The assets for each end point (social, economic, environmental) exposed to fire, in each mesozone in each fire-ecology type.

ii. Do "hot-spotting" to aggregate mesozone clusters with equivalent asset types and levels, and classify.

- *iii. Locate the clusters within municipalities within each fire-ecology type.*
- *d. Fire-risk predictors.*
  - *i. Develop guides or algorithms per fire-ecology type for predicting the likelihood of a given specific fire risk scenario.*
- *e. Formulate specific fire risk scenarios (Appendix 3)and match to resolved fire-ecology types.*
  - *i. Work from the literature, reports, and workshop contributions.*
  - *ii. Formulate the fire risk scenarios as normative events.*
  - *iii. Specify the following parameters qualitatively, categorically, or quantitatively:*
    - *1. Fire weather scenario,*
    - *2. Fuel conditions,.*
    - *3. Fire behaviour, and*
    - *4. Fire size.*

2. Risk analysis

- *a. To be conducted for each specific risk scenario in each municipality where the relevant scenario is possible, BUT only for the higher-risk scenarios.*
- *b. The geographic unit of assessment is the mesozone (Box 3).*
- *c. Assess the likelihood and consequence of each specific fire risk scenario and determine the risk level (Table 3) for social, economic and environmental endpoints.*
- *d. Assign risk levels for each end point*
- *e. Calculate the percentage of the four risk of risk; extreme, high, medium and low, occurring in each municipality for each end point.*

3. Risk description

- *a. Develop a typology for the assessed risks.*
- *b. Nominate type.*
- *c. Formulate a narrative explanation for each type of risk.*
- *d. The narrative should allow risk managers to evaluate the risk and an appropriate risk treatment in response to it.*
- *e. Each narrative should specify the cause and sources of the risk..*

4.5 Consultation

4.5.1 Workshops and workshop records

There is a well established policy context for this risk assessment (see above), the outcome of lengthy recent consultations on the various frameworks and instruments of policy set out in this report; the requirements for consultation therefore differ from those at the local scale, where intense consultations are needed to mobilise and inform stakeholders and reveal their risk perceptions and experiences. In this project, the consultations needed to focus on the context for the assessment, and the approach to the analysis, while also eliciting relevant information and judgment from the participants on their experiences with veldfire risk.

We arranged a series of consultative workshops to review the current veldfire risk classification[71] together with major stakeholders drawn from representatives from private industry, training institutions and national, provincial and local government. In particular we focused on inviting representatives from the forestry, agricultural, environment, disaster management and insurance sectors as well as academics. Representatives of large fire protection associations were also invited as well as representatives of the Working on Fire Programme (see Appendix 3) and also to get clarity from them as to what improvements they would like to see made.
The purposes of the workshops were:

- To gauge the participants' responses on the desirability of the investigation
- To inform the stakeholders how the initial veldfire risk classification product was developed and get clarity from the stakeholders as to what improvements they would like to see. Any improvements required will need to be adapted to the availability of suitable information.
- To review experience gained from the application of the current national veldfire risk map.
- Identify the way it has been used (e.g. prioritizing fire protection association (FPAs), guiding FPA business plans and insurance policies).
- Establish what has worked well and what needs to be improved.
- To gauge their responses on approach and method, including comments on the choice assessing inherent and residual risk, quantification and definitions of terms.
- To gain contributions on the veldfire situation in South Africa in terms of assets vulnerable to veldfires and specific (normative) veldfire risk scenarios
- To obtain guidance on the revision of the risk map, with the objectives of:
- Improving guidelines on risk-related provisions in the National Veld and Forest Fire Act (e.g. landowner's preparedness); and
- Contribute to the formulation of the veldfire component of the National Disaster Risk Management Framework.

Each of the six consultative workshops was of a day's duration. Not every sector was represented at every one of the workshops but together the workshops included representatives of the main interest groups. In total 85 people, including the study team, participated in the workshops. In addition we consulted by telephone and e-mail a small number of key informants for supplementary information and views (see Appendix 3).

During the first part of each workshop participants were provided with background material while the second part of the presentation focused on gathering information from the participants.

[71] Kruger *et al.* 2006.

4.5.2 Correspondents

In addition to information from the workshops, we corresponded with several key informants for supplementary information, as follows:

- ForestrySA: fire reports and economic losses
- The Institute for Commercial Forestry Research: the Integrated National Forest Protection Strategy
- Safire (insurance industry): fire losses and risk trends
- The National Disaster Management Centre: risk assessment procedures and standards
- Conservation agencies: supplementary information on wildfire events.

5. Findings

5.1 Ecological information and fire types

This section outlines best available knowledge of fire ecology in South Africa, to inform the risk analysis as well as the choice among various risk reduction strategies.

We describe the data sets we used and then the fire-ecology types developed for this assessment. The content is based on the information contained in the previous assessment[72] and includes additional knowledge and datasets derived from research work published since then.

This review provides the evidence that fire is an important, and often vital, ecosystem process that maintains many South African terrestrial ecosystems and the ecosystem services important to our wellbeing.

We explain how we classified the major ecosystem types in the country into fire-ecology types, the typical fire regimes that characterise these types, and the environmental consequences of changes to these fire regimes that may be brought about by changes in veld and forest fire management.

5.1.1 Fire ecology

5.1.1.1. Introduction

Fire in the ecosystem is an ecological process and part of our environment. It has a fundamental role in sustaining biodiversity. However, if fire is mistimed, occurs too frequently or too seldom, or is of insufficient or excessive intensity, it may result in ecosystem degradation[73].

Fire ecology is the science of the interaction between fire, the other components and processes of the ecosystem, and society. There is a substantial body of knowledge on fire ecology in South Africa, though it is focused mainly on the grassland, savanna, and fynbos biomes[74].

Without fire, many of our ecosystems would look quite different, because fires rejuvenate grasses and fynbos shrublands and prevent the development of dense woodlands and forests[75]. Since the ancient grasslands and fynbos contain most of the biodiversity in South Africa, national biodiversity conservation depends to a very large degree on the conservation of these biomes, including the judicious management of fire, which includes prescribed burning.

[72] Kruger *et al*. 2006.
[73] Gill 1975.
[74] Edwards 1984.
[75] Bond 1997.

The evidence for such fire-dependence comes from experiments where fires have been deliberately excluded, as well as other manipulations of the fire regime. These show that fire exclusion increases the density and size of woody plants where the annual rainfall is more than 300 mm but less than 725 mm[76]. Where the annual rainfall exceeds 725 mm (or 525 mm in winter rainfall areas) forests will develop when fire is excluded. Indigenous forests tend to have fuel properties that do not promote fire, assisting their survival in the fire-prone landscape[77].

Grasslands are particularly fire prone because all the elements for fire ignition and spread are provided every year: fine, dry leaves and culms for fuel, dry warm conditions in late winter, and sources of ignition. Indeed, the evolution of grasses and their natural association with frequent fires are believed to be the factors that led to the decrease in woody plants and the increasing dominance of grasses about 6-8 million years ago[78].

Most of South Africa has strongly seasonal rainfall and a dry season which lasts for five or more months. The eastern half of the country receives enough rainfall for the grasses to produce enough fuel to support a fire every year or two[79]. This means that veldfires are frequent and inevitable. Originally most fires were caused by lightning but our ancestors learned to light and manage fires more than a million years ago, exploiting and augmenting the natural causes of fires to manage the vegetation for their own purposes[80]. Today, more than 90% of fires are lit by people, either deliberately or accidentally.

The general public often believes that fires are universally bad and should be prevented and controlled. In many cases people have been taught this in school and the message is also reinforced by the frequent use of negative language like "fires have destroyed 100ha of fynbos…" in newspapers and news bulletins. However, both facts and traditional knowledge contradict this generalization. Fires are needed to renew ecosystems and sustain the rich plant and animal biodiversity in most vegetation types. But fires can and do kill people and domestic and wild animals, and destroy crops, grazing and houses, and alter vegetation ecology and biodiversity. The harm fires can do is what makes the deliberate use of fire in land management controversial. Although fire is a natural and necessary factor in the ecology of most of the vegetation types, its role remains contentious, and there are ongoing debates about how to use fire in ecosystem management.

Thus, in the South African climate fires are inevitable in many ecosystems. Therefore a clear understanding of where, and under what conditions, fires are desirable, and where and when they should be avoided, is necessary in order to develop appropriate fire management strategies. We also need to understand if and how we can prevent and contain those fires we do not want, and get the fires we do want to burn under conditions that will result in maximum benefits and minimum costs.

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[76] Bond *et al.* 2003a; Higgins *et al.* 2007; Rutherford and Westfall 1996.
[77] Van Wilgen *et al.* 1990.
[78] Bond *et al.* 2003b.
[79] Edwards 1984; Everson 1999.
[80] Brown *et al.* 2009.

5.1.1.2. The role of fire in the ecology of natural ecosystems

Early ecologists classified certain South African ecosystems as "fire sub-climaxes", meaning that the development of the vegetation to its "full potential" under the prevailing climate is prevented by repeated burning[81]. Research and the understanding gained during the past 40 years has shown unequivocally that fire is a natural ecological factor, and has been for millions of years, even before human intervention[82]. Fires have been a frequent presence in most southern African landscapes for millions of years. Indigenous species would not have persisted if they could not cope with fire. It is therefore just as unreasonable to say that any particular grassland could be a forest if only it did not burn, as to say that a desert could be a forest, if only it received more rain! Furthermore, modern ecologists reject the implied hierarchy of ecosystem "value" that "climax" vegetation is always the desired end state. Current interpretations of the role of fire recognize that it has been a major factor in the evolution of plant species in fire-prone areas, and that many component plant species (including large numbers of endemic species) require fire to persist[83]. Maintaining fire as an ecosystem process is therefore an important aspect of ecosystem management; conversely, excluding fire can damage ecosystems.

There are many examples of plant and even animal species that are fire dependent – they require fire to complete their life histories. The adaptations they exhibit range from tolerance (for instance, in species that survive fire by resprouting) to dependence (for instance, a requirement for fire to stimulate flowering, seed release, or germination)[84]. Examples include:

- *Sprouting* – a large proportion of plants in fire-prone areas have the ability to sprout after fire, either from below-ground roots or bulbs, or from buds protected by a fire-resistant bark. This trait is not confined to fire-prone ecosystems but is particularly common in them[85].
- *Serotiny* – some plants (for example, proteas) hold their seeds in "fire-proof capsules" built from the remains of the flowers. Examples include many proteas[86]. Fire typically kills the parent plants, but this releases the seeds and they germinate during the following rainy season. Fires are essential for such species – without fire, the plants lose vigour and die. The seeds cannot successfully germinate and establish in the dense, old vegetation, they require the competing plants to be removed by fire. Some animals, such as tortoises, use a similar strategy. They lay their eggs underground before the fire season and the eggs hatch after the fire season has passed. This enables the species to survive even though the individuals often are killed by fires.
- *Smoke-stimulated germination* – the seeds of many plant species are stimulated to germinate by chemicals contained in the smoke[87]. A "smoke extract" is sold commercially to help gardeners to get seeds of fynbos species to germinate.

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81 Phillips 1936.
82 Bond *et al.* 2003b; Bond and Keeley 2005.
83 Bond and van Wilgen 1996; Bond 1997.
84 Le Maitre and Midgley 1992.
85 Bond and Midgley 2001.
86 Lamont *et al.* 1991.
87 Brown 1993.

- *Fire-stimulated flowering* – many species are stimulated to flower, often *en masse*, following fires[88]. Fires thus offer the best opportunity for seed production and germination of these plants. Some birds, such as the wattled plover, require the burned areas as nesting sites, and have eggs camouflaged as charcoal.
- *Flammability* – some plants may even have evolved properties that make them more prone to burning, such as the ability to produce lots of dead material, and high flammable oil contents in their leaves[89]. This may have given them an evolutionary advantage through "killing their neighbours", and creating space for their own progeny to thrive.
- *Dependence on fire-induced nutrient flushes* - Some animals, such as Roan antelope, calve in the middle of the dry season, when green grass is scarce. The females need the protein flush that follows a fire to provide enough milk for their calves.

5.1.1.3. Fire regimes

Following AFAC (see Appendix 1) we define a "fire regime" as the history of fire in a particular vegetation type or area including the frequency, intensity and season of burning; it is the combination of elements that typifies fires in a given region, under assumed natural conditions. Table 4 provides a brief description of the elements of fire regimes as they apply to South Africa.

Table 4. Elements used to describe fire regimes in natural vegetation in South Africa. Each of these elements is characterised by both an average value, and by the variation around this statistical mean.

Element of fire regime	What does it measure?	Examples and comments
Frequency (better defined as the fire return interval)	How often do fires occur? (i.e. the interval between fires on the same spot).	Fires occur and recur in the same place almost every year in some little-grazed moist grassland ecosystems, less frequently in moist grasslands and woodlands (2-5 years), perhaps 5-10 years in arid woodlands and savannas, 10-20 years in fynbos, and almost never in deserts and inside wet forests
Season	At what time of the year do fires occur? (Interpret the calendar from a plant's point of view: dry season, early, mid, and late-wet season)	Hot, dry summers (November to April) are the fire season in the south-western Cape, while the dry winters (May to October) provide suitable conditions in most other areas; seasonality within the dry season is also driven by fire-inducing weather systems (e.g August and later in the east)
Intensity	How fiercely do fires burn? This is defined as the rate at which energy is released from fires. People talk of 'cool' and 'hot' fires, but this does not refer to temperature	The "fire line intensity" calculated by multiplying the heat content of the fuel (about 18 MJ/kg) by the mass of fuel (kg/m^2) and the rate of spread of the fire (m/s) As a rule of thumb, flame lengths are a good indicator of fire intensity: the longer the flame, the more intense the fire.
Severity	How severe are the effects of a fire? This is usually a function of the duration (residence time) of a fire and its intensity	The longer a fire burns on a given spot, and the closer the fuel to the ground, the more severe its effects on plants, seed banks and the soil. Head fires (burning with the wind or upslope) and backfires (burning against the wind or down slope) of similar intensity can have different residence times, severities and effects.

[88] Gill 1975; Le Maitre and Midgley 1992.

[89] Bond and Midgley 1995.

Type	The type of fires that occur	Fires can be head fires (burning with the wind, or upslope), or backfires (burning against the wind, or downslope). In addition, they can be surface fires (just above the ground surface), crown fires (in the canopies of trees) or even underground fires (in peaty layers of the soil).
Size	The area covered by a given fire (hectares, or in defined size classes)	Ecosystems usually experience many small fires and a few big ones. Typically it is the big ones that matter, as they burn up to 90% of the total area of all fires in a given period.
Source of ignition	The cause of fires	While the cause of a fire has no direct ecological significance, changes in the dominant sources of ignition can cause shifts in fire season and frequency.

Fire regimes are **statistical** descriptions. A fire regime is not defined by a single fire, or even two or three, but by the long-term average of many fires. Thus, it is characterised by a distribution of values, which is typically summarised with a mean and some measure of variation (such as a range, or a standard deviation, or an upper and lower confidence limit).

The key point is that fire regimes are ecological drivers - they shape the functioning, structure and composition of the ecosystem[90]. **If the frequency, intensity, type, season or size of fires diverges from the natural range of variation under which the ecosystem evolved, the ecosystem structure and processes will change.**

In some cases the change can be rapid such as when too-frequent fires exterminate tall protea shrubs, changing a tall fynbos shrubland into short-shrubland in just one or two fires. In others it can take a long time such as changes in the shape and size of a forest patch with strongly fire-resistant dominant trees.

5.1.1.4. <u>The hazard of inappropriate fire regimes</u>

Fire regime alteration can be defined as the extent to which the prevailing patterns of fire diverge from the ecologically acceptable ranges of variation in key fire regime elements for that ecosystem type. This creates an ecological hazard.

In turn, what is defined as ecologically acceptable is usually based on what is inferred to be ‘natural’, i.e. the regime under which that ecosystem evolved.

Alteration of key elements of a fire regime may cause current or long-term conditions that threaten the persistence of native plant and animal populations associated with that fire regime. Thus, altering one or more fire regime elements may stress an ecosystem by significantly changing its composition, structure or function, which in turn, can establish a trajectory toward a fundamentally different ecosystem type and fire regime.

Where these changes lead to a reduction of the benefits we derive from the ecosystem (‘ecosystem services’, such as pasturage, or water yield), we say that the ecosystem is ‘degraded’. In the context of this report, “inappropriate” fire regimes can be defined as those regimes that are altered in such a way as to depart from

[90] Gill 1975.

ecologically acceptable ranges associated with the continued conservation of a particular ecosystem type.

The results of numerous long-term fire experiments show that the exact return period between fires, and the time during the dry season when fires are ignited, hardly makes any difference to the outcome, unless they are taken to extremes. For instance, in grasslands and savannas, annual burning differs from burning every two to five years, and both differ from no burning at all: but between these limits, natural variation due to climate fluctuation and herbivory (grazing and browsing) masks any measurable difference.

Fynbos ecosystems, unlike savanna and grasslands are sensitive to certain changes in fire recurrence intervals[91]. They have species which survive fires only as seeds and take several years to flower and produce sufficient seeds to re-establish viable populations after fires. However, the minimum intervals between fires can be longer than the time needed for the fynbos to accumulate sufficient fuel to burn. In these cases managers need to ensure that fire recurrence intervals are not too short for these species to survive because the only a small change in the fire interval is needed to result in local extinction.

Similarly, fires in the wet season have different outcomes to fires in the dry season, but dry season fires hardly differ among themselves. As a result, the rules for lighting or permitting fires have become much less restrictive. Thus, the ecological hazard of altered fire regimes arises only with substantial departures from the ecological norm. Table 5 specifies typical acceptable fire regimes for each type. Alternations of these regimes would be environmentally hazardous.

There is also good evidence that natural fire regimes vary in return period, season of ignition, intensity and size of fire and that this is important for maintaining the diversity of species of plant and animal species[92]. Applying a fixed regime selects for some species, and disadvantages others. If we wish to maintain a diverse and fire-resilient fauna, flora and landscape, we need to plan for fire regimes that allow for, and even promote, variability within broad limits.

However, the presence of alien invasive plants creates a special fire-related hazard, which increases environmental vulnerability to inappropriate veldfires. In many biomes the occurrence of fire can exacerbate alien plant invasions by creating conditions favourable for the proliferation of these species (Table 5).

5.1.2 Derivation of fire-ecology types

5.1.2.1. Overview

A fire-ecology type is a class of vegetation types that is relatively uniform in terms of the fire regimes within the constituent vegetation types.

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[91] Le Maitre and Midgley 1992; van Wilgen *et al.* 1992; van Wilgen *et al.* 1994; Bond and van Wilgen 1996; Bond 1997.

[92] Van Wilgen *et al.* 2003; van Wilgen 2009.

This classification begins by dividing vegetation types into one of three broad fire-ecology types[93]:

- fire-dependent,
- fire-sensitive or
- fire-independent.

This classification is based primarily on the role of fire in the regeneration of the species comprising those ecosystems.

Fire-dependent describes ecosystems where fire is necessary for the regeneration of most plant species but where inappropriate fire regimes can alter the species composition, vegetation structure or ecosystem function or a combination of these.

Fire sensitive ecosystems are those that do not require fire for regeneration but which occur among fire-prone ecosystems and can be adversely affected by the inevitable fires, especially if they are too frequent or severe.

Fire independent ecosystems also do not require fires for regeneration and occur in environments where fires are very rare or absent, usually because there is little or no fuel for fires.

In the previous assessment we used the Low and Rebelo[94] vegetation classification which included six biomes and 96 vegetation types. The new vegetation map[95] has 435 vegetation types, including types (e.g. wetlands, alluvial vegetation) which transgress vegetation type or biome boundaries and so cannot be assigned to one vegetation or fire-ecology type. We also have access to data on fire incidences which we can use to describe fire regimes and refine our previous approach. The following sections briefly describe how we derived the fire-ecology types.

5.1.2.2. Vegetation data

The concept of the biome, a large ecological unit which is characterized primarily by similar vegetation composition and structure, dynamics and ecological drivers (e.g. the fire regime) is the basis of the current ecological classification of vegetation in South Africa. At the time of the previous veldfire risk assessment, the only biome definitions that were also available as a geographical information system (GIS) data set were those defined by Low and Rebelo[96]. For the present assessment we used the national vegetation map compiled by Mucina and Rutherford[97] and their collaborators.

The classification for this vegetation map is hierarchical and recognizes 9 biomes plus the Azonal vegetation types (Box 5; Figure 8: the SANBI biomes), each of which contains bioregions which, in turn, contain vegetation types. Some of the biome definitions have changed from those used for the previous assessment and a few new biomes have been added. The most important changes from the veldfire perspective are the following:

93 Bond 1997, Bond *et al.* 2003a, Kruger *et al.* 2006.
94 Low and Rebelo 1996.
95 Mucina and Rutherford 2006.

- Azonal vegetation types: this new category was introduced because certain ecosystem types (e.g. wetlands) span vegetation type and even bioregion and biome boundaries. Their fire ecology ranges from relatively fire-dependent to more fire-sensitive. These are generally small patches or narrow strips and are thus affected by the fire regimes in the adjacent vegetation types.
- Indian Ocean Coastal Belt – this new biome was grouped with the grassland biome in the previous vegetation map. It comprises the coastal grasslands and woodlands of the Indian Ocean coastal strip from the Kei River valley to the Mozambique border. The climate has no definite dry season and has high humidity all year round. Most of this biome was classified as the coastal grassland fire–ecology type in the previous analysis.
- The Albany Thicket – this biome now comprises the thicket vegetation types that occur from the Little Karoo to just west of the Kei River mouth. The thicket vegetation eastwards from the Kei River valley, as defined by Low and Rebelo (1996) is now included in the Savanna biome.

Box 5. Biomes of South Africa (Mucina and Rutherford 2006):

- ***Forest*** *– the smallest biome, characterised by a dense to closed overstorey of tree species with a variable understorey, is typically confined to sheltered habitats embedded in fire-prone vegetation; it and reaches its maximum extent on the coastal forelands and slopes of the Outeniqua and Tsitsikamma mountains*
- ***Grassland*** *–characterised by dominance of grasses, with woody vegetation generally rare or confined to sheltered situations*
- ***Savanna*** *– characterised by two layers, an overstorey of woody plants and an understorey of grasses; densities of woody plants vary from very scattered to dense. Includes a very wide range of vegetation types ranging from closed woodlands to sparse arid woodland in the Kalahari*
- ***Indian Ocean Coastal Belt*** *– a mixture of grassland and woody vegetation ranging from open grassland to closed woodland interspersed with numerous forest patches; extensive wetlands occur in this biome on the Zululand costal plain*
- ***Albany Thicket*** *– characterised by a large, often spiny, woody plants, a ground layer of herbs and a range of succulent species; some forms of thicket are dominated by succulent shrubs.*
- ***Fynbos*** *– typically dominated by shrubs with perennial herbaceous species beneath; renosterveld is dominated by fine-leaved, evergreen shrubs and can have a relatively high grass cover; fynbos has a greater variety of shrub forms and a rich flora of fine-leaved herbaceous species; grasses are uncommon in fynbos except in the eastern regions*
- ***Nama Karoo*** *- short, sparse, evergreen or deciduous shrubs with an open canopy and herbaceous species between or beneath the canopies; grass cover is higher in the east and south-east, especially in higher-lying areas*
- ***Succulent Karoo****– short, evergreen or deciduous shrubs with an open canopy and a rich variety of succulents, annual herbs and geophytes in the gaps between the shrubs*
- ***Desert*** *– sparse perennial dryland vegetation and riparian woodland found in areas with an annual rainfall of 70-80 mm or less*
- ***Azonal*** *– ecosystem types with similar species composition, structure and dynamics but often extending across different vegetation types or even biomes. Examples include: wetlands, riparian or estuarine vegetation and salt marshes or pans.*

A biome is too heterogeneous a unit to be used to derive fire-ecology types except for the arid, fire-independent Succulent Karoo and Desert Biomes, where fires do not occur. The next unit in the hierarchy is the bioregion which is based largely on vegetation and ecological characteristics and the geographical distribution of the constituent vegetation types. Although some of the bioregional differences can be related to fire-ecological characteristics, the bioregions generally do not relate directly to fire-ecology types, especially in the grassland and savanna biomes. This meant that we needed to find a way of relating the vegetation types directly to fire-ecology types.

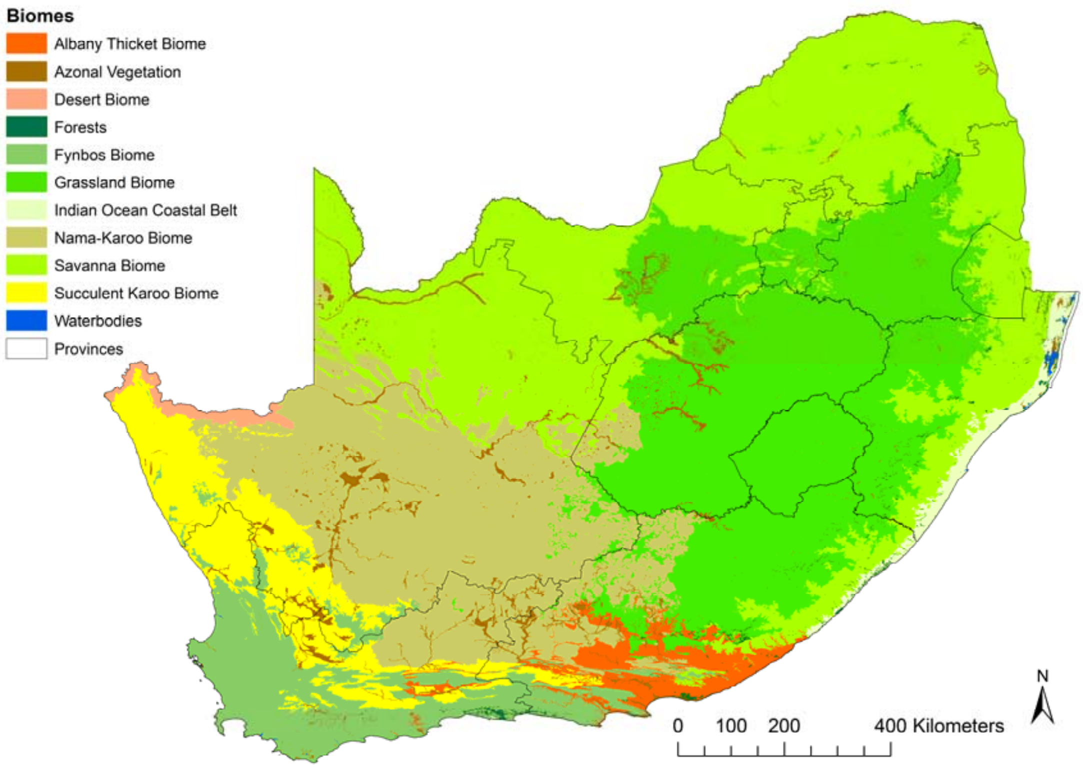

Figure 8. Biomes of South Africa as defined in the national vegetation map (Mucina and Rutherford 2006). Azonal vegetation includes valley bottom and river floodplain vegetation on alluvial deposits, wetlands, pans, sea-shore vegetation, salt marshes and estuaries. Waterbodies include lakes, estuaries and large dams.

We derived the fire-ecology types used in the original assessment from the vegetation descriptions from Low and Rebelo[96], information from the fire ecology literature and expert knowledge.

The first step was to compare the previous fire-ecology types against the new vegetation types based on matching their geographical distributions, the descriptions of the vegetation types, and the classification used in the previous assessment. We applied this approach to the new vegetation types except for the vegetation types belonging to the Azonal biome (Figure 8). In this case we assigned the individual

96 Low and Rebelo 1996.

polygons (map units) of each Azonal vegetation type to the fire-ecology type of the vegetation type that was adjacent to it. Figure 9 depicts the results of this matching exercise.

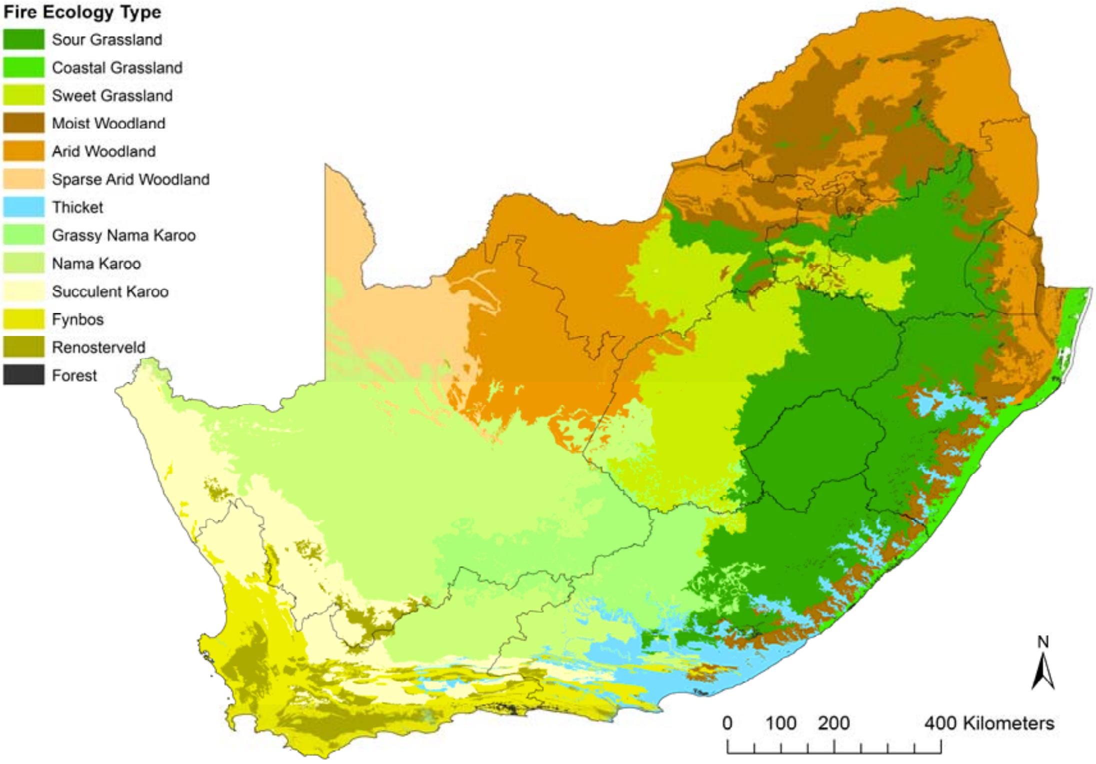

Figure 9. The distribution of the different fire-ecology types based on the matching the descriptions and distribution of the vegetation types in the current national vegetation map (Mucina and Rutherford (2006) with the vegetation types used previously (Low and Rebelo 1996) and the sour, sweet and mixed grasslands based on Acocks veld types map (Tainton 1999).

The new fire-ecology types generally match those used in the previous classification very well. The differences are minor and are mainly due to the more detailed mapping done for the current national vegetation map which also included many more vegetation types and smaller minimum mapping units[97].

5.1.2.3. Fire incidence in the different fire-ecology types

We used MODIS satellite observations supplied by S. Archibald[101] to measure fire incidence for the period of nine years between January 2000 and December 2008.

The MODIS satellite passes over South Africa twice a day and records information which is used to infer both the current fire activity (whether or not a fire is present at a given place) and whether a given spatial unit (a pixel of 500 x 500 m or 25 ha) has been recently burnt or not[98].

[97] Mucina and Rutherford 2006.

[98] Archibald *et al.* in press.

The burnt pixel information has been used to derive fire incidence i.e. how frequently each pixel was burnt during the nine-year period. Pixels which had invalid data due to cloud cover or instrument failure more than twice a year on average were excluded from the dataset. The burnt-area information has been estimated to capture about 75% of the total burnt area and fire incidence in southern Africa with the accuracy decreasing as tree cover increases. Fires that burn less than about two-thirds to half a pixel are unlikely to be detected. Many fires in the rural areas are the size of individual fields (less than 1-2 ha) and so are unlikely to be detected although the cumulative signal of a number of small fires within a pixel could change that pixel to a burnt status.

We determined the mean fire incidence (i.e. mean number of fires per pixel over the nine years) for each biome, bioregion and vegetation type (see Section 5.1.2.5). We mapped these results and compared these with the results of the previous classification to evaluate the fire-ecology type classification. We excluded areas in the National Land Cover 2000 dataset mapped as transformed[99]. Transformed land cover types include tree plantations, all forms of cultivated lands, improved grassland (cattle pasture) and all forms of urban areas, mines and quarries.

5.1.2.4. Defining and assigning fire-ecology types

In the previous assessment we developed a fire-ecology type classification with 14 types for natural vegetation[100], grouped according to their fire regime and responses to fire as described earlier:

- Fire-sensitive: Forest, Grassy Nama Karoo
- Fire-dependent: Fynbos, Renosterveld, Coastal Grassland, Sweet Grassland, Sour Grassland, Sparse Arid Woodland, Arid Woodland, Moist Woodland
- Fire-independent: Succulent Karoo, Nama Karoo, Thicket

We previously singled out Wetlands as a fire-ecology type. Wetlands are particularly sensitive to changes in fire regimes even in fire dependent types such as the grasslands. This means they always need to be burnt with care when a fire is being planned in areas where they occur. The different wetland types generally could not be assigned to just one fire-ecology type because wetlands vary widely in their fire ecology and similar types occur in different vegetation types. In general, the fire-regimes in wetlands will be affected, or even determined, by the regimes in the vegetation types that they are embedded in or adjacent to. We used this spatial relationship to assign individual wetlands to fire-ecology types and thus merged wetlands into the associated fire-ecology type.

In addition to these natural types we recognized two managed land-cover types as being particularly sensitive to fires: Plantation Forests, and Cultivated Lands. The effects of fires on the two types of land cover, and their effects on fire risks are dealt with in the section on assets that are vulnerable to fires.

The previous classification of the grasslands and savannas was based largely on the known distinctions between those where sweet (i.e. always palatable) grass species

[99] Van den Berg *et al.* 2008.
[100] Kruger *et al.* 2006.

are dominant in the grass layer, and those where the dominant grasses are sour grasses which are seasonally unpalatable. We have followed this classification because it works well in most areas and is well understood by farmers and other land managers who deal with fires.

Sour grasses are dominant on the Highveld, the higher-lying areas of the bushveld, the coastal grassland of the east coast and in the fynbos. Sweet grasslands generally occur in the dry parts of the country including the Lowveld, north-western part of the Northern Province and in the Lowveld. Sour grasslands typically occur in high rainfall (>650 mm) areas with frequent frosts in winter and relatively infertile soils. Sweet grasslands occur in low rainfall areas with a low frost occurrence and relatively fertile soils. Some grasslands are characterised by a mixture of sweet and sour grasses and occur in areas which are transitional between sour and sweet grasslands. Mixed grasses are also characteristic of the renosterveld vegetation that forms part of the fynbos biome and is classified as a fire-ecology type (Table 5). Soil fertility is an important factor in the Woodlands as well where different suites of trees are found on relatively fertile and infertile soils.

The poor palatability of the sour grasses results in the accumulation of ungrazed grass which provides abundant fuel, sufficient to be able to carry fires in most years in high rainfall areas. Sour grasses are generally deliberately burnt to clear the dead material and prevent it from suppressing the growth of the grasses in the next growing season. These differences between sweet and sour grasslands are evident in their fire regimes, with sour grasslands accumulating high fuel loads and being able to burn annually whereas sweet grasslands generally burn less frequently and mainly after wet years when there is abundant grass growth. Thus sour grasslands could be a fire hazard every year whilst sweet grasslands may only carry fires every few years. We have decided to retain the previous fire-ecology types but discuss the particular vegetation types or areas where there are important differences between the observed and expected fire regimes for those fire-ecology types.

Table 5. The fire-ecology types and crop types in South Africa, with fire regime characteristics and areas. Observations on the susceptibility to invasion by alien plants are also included. Note: the areas given below include transformed areas. Information taken from vegetation descriptions in Mucina and Rutherford (2006) supplemented with information from: Granger (1984), Bond (1997), O'Connor and Bredenkamp (1997), Scholes (1997), van Wilgen and Scholes (1997), Everson (1999), Stuart-Hill and Tainton (1999), Trollope (1999), Bond and Archibald (2003), Bond *et al.* (2003a, 2003b) and Uys *et al.* (2004).

Fire-ecology type Area (km^2), and % of total land area	Fire-regime type	Typical acceptable fire regime	Notes
Moist Woodland 114462 (9.03)	Fire dependent	Fires in the dry winter season, at intervals between 1 and 4 years	These woodlands should be subjected to periodic fire, whether by means of prescribed burning or otherwise, and may be at risk of fire exclusion. Fire exclusion for more than 3 years alters grass composition and for >5 years can alter forb composition and promote bush encroachment. Factors that may lead to fire exclusion include a fear of legal or other consequences, and a lack of management capacity. Fires facilitate invasions by alien plants which can recover by sprouting and have fire stimuated germination. Invasions can increase fuel load and fire intensities, potentially leading to water repellency and soil loss.
Sour Grassland 230790 (18.21)	Fire dependent	Fires in the dry winter season, at intervals between 1 and 4 years	These grasslands require frequent fire, and may be at risk of fire exclusion. Fire exclusion for more than 3 years alters grass composition and for >5 years can alter forb composition and promote bush and scrub encroachment. Factors that may lead to fire exclusion include a fear of legal or other consequences, and a lack of management capacity. Fires facilitate invasions by alien plants which can recover by sprouting and have fire stimuated germination. Invasions can increase fuel load and fire intensities, potentially leading to water repellency and soil loss.
Arid Woodland 235994 (18.62)	Fire dependent	Fires in the dry winter season following periods of above-average rainfall. Typical fire-return intervals between 3 and 10 years	These woodlands can be subjected to infrequent fire, whether by means of prescribed burning or otherwise, and may be at risk of fire exclusion, or a reduction in fire intensity. Low intensity fires will favour woody species; high intensity fires are needed to control bush encroachment following overgrazing (and the fertilisation effect of higher CO_2 levels in the atmosphere); fuel loads unlikely to sustain frequent high intensity fires in the dryer areas. Factors that may lead to fire exclusion include a fear of legal or other consequences, and a lack of management capacity, while low intensity prescribed burns may be practiced to maintain control of fires. Grasslands are also at risk if there is a shift in fire season (brought about by conducting prescribed burns during "safe" but ecologically inappropriate times of the year). Fires can facilitate invasions.
Fynbos 56193 (4.43)	Fire dependent	The majority of fires in summer or early autumn, at intervals between 10 and 20 years.	Fynbos is a shrubland vegetation that requires regular fire. Major changes in vegetation structure and composition can be caused by excessively frequent fires (<8 years apart) or excessively infrequent fires (>30 years); species with canopy-stored seeds require summer-autumn fires for optimal recruitment; fire intensity not well understood but may affect species composition. This biome also at serious risk from invasion by alien shrubs and trees, which may lead to increases in fire intensity. Serious risks to the conservation of this vegetation may arise from growing human populations (leading to more frequent fires), a shift in fire season (brought about by conducting prescribed burns during "safe" but ecologically inappropriate times of the year), and increases in fire intensity (leading in many cases to severe erosion) brought about by invasion by high-biomass trees and shrubs. Fires facilitate invasions by alien plants which can recover by sprouting and have fire stimuated germination, seed release and seedling recruitment. Invasions by woody species can increase fuel load and fire intensities, potentially leading to water repellency and soil loss.

Fire-ecology type Area (km^2), and % of total land area	Fire-regime type	Typical acceptable fire regime	Notes
Sweet Grassland 107372 (8.47)	Fire dependent	No real need for fires, but they do occur in the dry winter season, at intervals between 3 and 10 years.	Fire ignition and spread are limited in these grasslands because the sweetveld grasses are palatable all year round and heavily grazed by livestock and a range of other herbivores. Prescribed fires are only needed when sufficient fuel accumulates over a large enough area to sustain a fire. This typically occurs in high rainfall years when the additional moisture promotes grass growth. Stocking rates should be managed to reduce fuel loads and minimise the need for fires. Changes in fire frequency and season can alter community composition and structure. High intensity fires will be needed where bush encroachment needs to be controlled because of overgrazing, but the high fire danger conditions required for high intensity fires will make prescribed burning a high risk. Well-trained and experienced teams will be needed to manage this type of fire. Fires can facilitate invasions.
Coastal Grassland 14796 (1.17)	Fire dependent	Fires in the dry winter season, at intervals between 1 and 4 years	See Sour Grassland. Some of these coastal grasslands are characterised by specialised woody plant species and a species rich flora of herbaceous species. The grasslands of southern KwaZulu-Natal and Pondoland in the Eastern Cape have a rich flora of fire sensitive woody species. High fire frequencies may affect these species and expert advice should be obtained when defining desired fire regimes. Fires faciliate invasions by alien plants which can recover by sprouting and have fire stimulated seed germination.
Grassy Nama Karoo 72293 (5.70)	Fire sensitive	Fires are rare, and restricted to periods following exceptionally high rainfall leading to high grass fuel loads	Fires are possible in grassy Nama Karoo in following wet years, when sourveld grass fuels will accumulate. Fire occurrence is strongly determined by the amount of grass fuel left after grazing, and the veld should be burnt only when sufficient fuel is present – usually after being rested for a year. The recommended fire season is during the winter (June to August). High intensity fires – head fires - are required to reduce or eliminate shrubs. Effects of fires on biodiversity are not known, and therefore the effects of any shifts in fire regime cannot be predicted at this stage. Fires do not appear to facilitate invasions by alien shrubs but invasions by alien grasses can generate additional fuel, increase fire frequencies and further facilitate invasions.
Renosterveld 28282 (2.23)	Fire dependent	The majority of fires in summer or early autumn, at intervals between 5 and 20 years.	Renosterveld is a fire-prone and probably fire-dependent shrubland vegetation, and requires regular fire. An increase in fire frequency may promote grasses and alter species composition and vegetation structure; elements of the vegetation may be sensitive to fire intensity because of the high proportion of fine-seeded species. This biome also at risk from invasion by alien shrubs and trees which lead to increases in fire intensity. The most serious risks to the conservation of this vegetation types arises from severe fragmentation, which inhibits the spread of fires, and in smaller patches may lead to fire exclusion. Fires facilitate invasions by alien plants which can recover by sprouting and have fire stimuated germination. Particularly susceptible to invasion by alien grass species which, in turn, can result in increased fire frequencies. Invasions by woody species can increase fuel load and fire intensities, potentially leading to water repellency and soil loss.
Natural Forest 4715 (0.37)	Fire-sensitive	Do not normally burn, but can do so in exceptionally hot and dry conditions. Fire return periods between 50 and 200 years; margins frequently scorched during fires in surrounding vegetation.	This type refers to the evergreen closed forest, such as the Afro-Montane forests. Forest patches seldom burn, but may be at risk if they are fragmented by clearing, allowing grasses and other flammable elements to invade, thus introducing fires. Most forest species can survive fire, but fires alter the habitat; forests are vulnerable to fires which burn in the surrounding vegetation, frequent fires will degrade the ecologically important forest margin vegetation exposing the interior to further fires. Forest margins are vulnerable to species which invade after fires have damagaed the margins. Flammable species such as *Chromolaena odorata* increase the vulnerablity of the forest margins and patches to fire.

Fire-ecology type Area (km^2), and % of total land area	Fire-regime type	Typical acceptable fire regime	Notes
Nama Karoo 217913 (17.19)	Fire-independent	Does not burn.	Seldom burns, due to insufficient fuel. No lasting harm if it does occasionally burn. Fires do not appear to facilitate invasions by alien shrubs but invasions by alien grasses can generate more fuel, increase fire frequencies and further facilitate invasions.
Sparse Arid Woodland 53043 (4.18)	Fire dependent	Climatic factors dominate, fires not an ecological requirement, but do occur in the dry winter season, at intervals between 3 and 10 years	These woodlands can be subjected to infrequent fire, but fires will only be possible after occasional periods when higher rainfall allows for grass fuels to build up. Low intensity fires will favour woody species; high intensity fires would be needed to control bush encroachment following overgrazing and higher concentrations of CO_2 in the atmosphere; fuel loads unlikely to sustain frequent high-intensity fires in the dryer areas. There is a risk that low-intensity fires will be practiced for safety reasons. Extensive wildfires must be minimised because this will deprive farmers of the grass and browse needed for their livestock. Fires can facilaitate invasions.
Succulent Karoo 87790 (6.93)	Fire-independent	Does not burn	Fires are unlikely in this fire-ecolgy type, but invasions by alien grasses may bring in sufficient fuel to support fires. If this happens, there are severe risks to the many rare and endemic succulent plant species. Fires do not appear to facilitate invasions by alien shrubs but invasions by alien grasses can generate fuel, increase fire frequencies and further facilitate invasions.
Thicket 43276 (3.41)	Fire-independent (some grassy [eastern] forms are fire sensitive)	Does not burn	Thicket vegetation dominated by succulent plants does not burn, but is at risk when it is fragmented by clearing, allowing grasses and other flammable elements to invade, thus introducing fires. Most thicket species are unable to survive fires, and fires will then eliminate these species, leaving degraded vegetation. Rare fires are possible in succulent-poor, grassy forms of thicket. High intensity fires may be needed in the grassy forms because these are susceptible to bush encroachment. Fires can be lit during the winter months but summer burns may be needed to control bush encroachment. As almost no research has been done on the effects of fire in grassy thicket forms, the risks of inappropriate fire regimes are poorly understood. Fires do not appear to facilate invasions.
Wetlands (<1) Wetlands are not mapped as a distinct fire-ecology type in this classification. We have retained the description in this table because there are special considerations which apply when planning fires in areas with wetlands	Fire-influenced or fire sensitive	Seasonal grassy or reedy wetlands burn every 1-3 years. Peat bogs burn every 50-200 years	Wetlands, paradoxically, often have an intense and frequent fire regime. This is because many South African wetlands are seasonal. The large amount of biomass (such as reeds or grass) that grows when they are flooded is typically unpalatable, and in the dry season, forms an ideal fuel bed. Reedbed fires are frequently the cause of electrical power outages, when the high flames reach the low-hanging transmission lines. Many of the ecological risks that have been ascribed to over-frequent burning (nutrient depletion, soil erosion) often do not apply to wetlands, such as when they occur on fertile soils, at the bottom of hillslopes. In tropical Africa, these ecosystems (called *dambos)* are burned annually, and probably have been for centuries with no apparent harm. Other forms of wetlands (peat bogs, perched seeplines, mangrove forests) may be much more susceptible to inappropriate fire regimes, but are only likely to burn in exceptionally dry years, or if they have been drained.

Fire-ecology type Area (km^2), and % of total land area	Fire-regime type	Typical acceptable fire regime	Notes
Plantation forests (1.5)	Fire-sensitive	Can burn in the dry season. Fires actively suppressed wherever possible. Data from South African plantations show that 12 584 ha of pine and 6 881 ha of eucalyptus including other hardwoods burn per year. This translates into a fire return period of 55 years for pine and 100 years for eucalyptus	Plantations of pines, eucalypts and wattles burn on occasion in South Africa. In economic terms, these fires result in a loss, and managers seek to prevent them wherever possible. The vigorous programmes of fire exclusion and fire suppression also have knock-on effects on the surrounding vegetation (usually grassland or fynbos), where fire exclusion leads to the local extinction of fire-dependent species, and succession to more wooded landscapes. Fires facilitate invasions that can increase fuel load and fire intensities, potentially leading to water repellency and soil loss.
Crop agriculture (13)	Fire sensitive	Can burn in the dry season. Fires normally actively suppressed wherever possible, except for sugar cane which is burned prior to harvesting.	With the exception of sugarcane (which is burnt prior to harvesting), crops are not managed using fire. Occasional wildfires can be detrimental to crops.

Across South Africa rainfall is a key determinant of vegetation growth and, thus, of the accumulation of litter for fuel for fires[101]. The occurrence and extent of fires in sour and sweet grasslands has been found to be positively correlated with the amount of rainfall during the previous growing season. This is particularly important in the fire-ecology types with sweet grasses which otherwise burn rather rarely, namely the Sweet grasslands, most Arid Woodlands, Sparse Arid Woodlands and Grassy Nama Karoo.

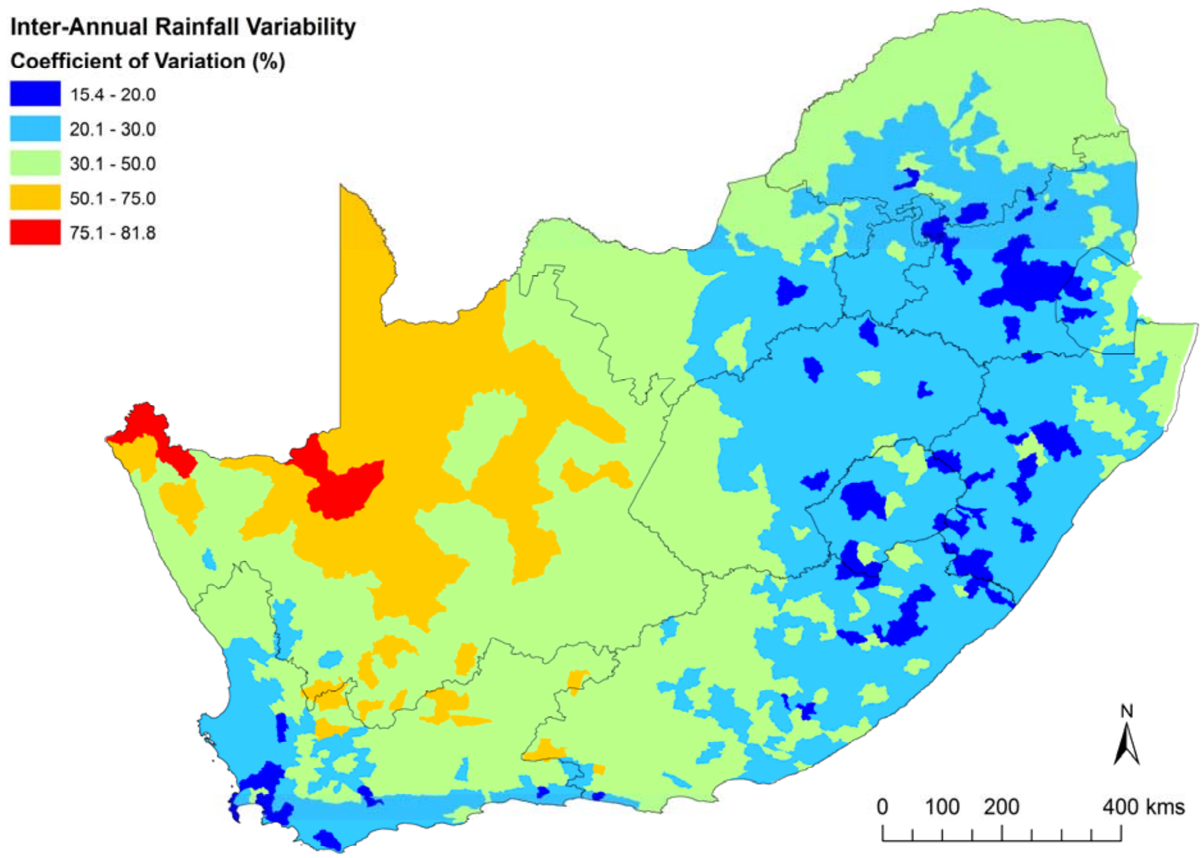

Figure 10. Coefficient of variation of the annual rainfall which is a measure of how variable it is relative to the long-term mean[102]

In South Africa the variability of the rainfall increases as the rainfall decreases so that the driest areas have the most variable rainfall (Figure 10). The variability in the rainfall has even greater effects on the annual net primary production, a measure of the biomass growth of the vegetation in a year (Figure 11). In much of the Sparse Arid Woodland fire-ecology type in the Northern Cape (e.g. the Kalahari) the coefficient of variation of the rainfall is greater 50% whereas the coefficient of variation of the net primary production is more than 75%. It is also more than 50% for most of the Northern Cape compared with less than 25% in much of KwaZulu-Natal. The rapid response of the grasses in the Kalahari to above average rainfall explains why fires are periodically a problem in the Sparse Arid Woodlands but may not occur for many years if the annual rainfall is close to or below the mean.

[101] Stephenson 1998; van Wilgen *et al.* 2004; Midgley *et al.* 2006; Archibald *et al.* 2009.

[102] Schulze *et al.* 2008.

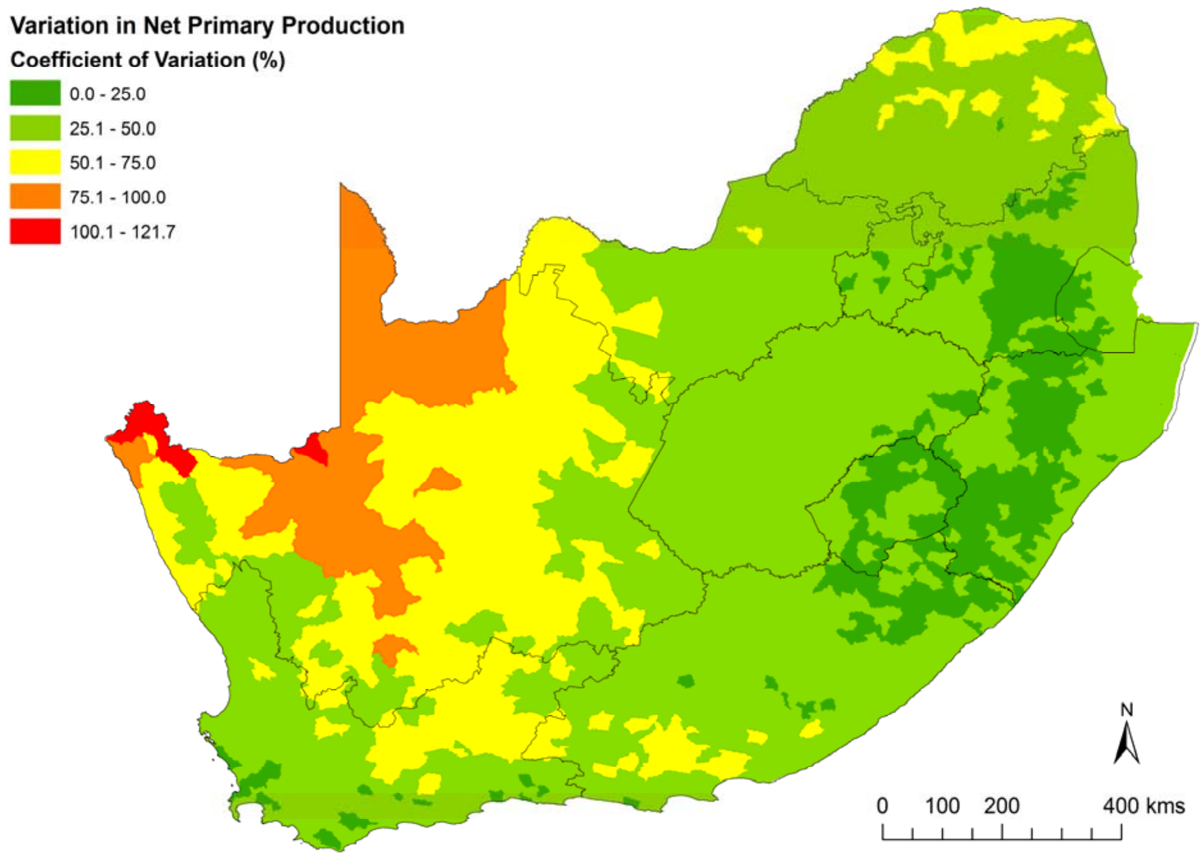

Figure 11. Coefficient of variation of the net primary productivity of the vegetation of South Africa[103]

5.1.2.5. Fire incidence and fire-ecology types

This section describes the spatial patterns in fire incidence and compares them with the fire regimes in the fire-ecology types (Table 5) and highlights some important differences. There are uncertainties about the completeness and accuracy of the data, especially for small fires and in moderate to dense woodlands. This means that it is more important to look at the relative incidence and broad trends than the absolute value of the fires per pixel in a given location.

There was a marked trend in fire incidence from east to west and, to a lesser extent from north to south (Figure 12). The north-western quarter of the country where the dominant biomes are the Succulent Karoo, Desert and Nama Karoo had few if any fires. In the isolated cases where there were fires they were generally confined to certain vegetation types within these biomes.

The fire-incidence was also relatively low in the south-western quarter where the dominant biomes are the Fynbos and Succulent Karoo. The relatively low incidence of fires in the Fynbos fire-ecology type is to be expected as the typical fire return interval is 10-15 years so there would be relatively few fires in the nine year period that was analysed. The highest fire incidence was found in the mountain areas, particularly the eastern Langeberg, and the incidence increased from west to east across the biome. The very low fire incidence on the

[103] Schulze et al. 2008.

western and southern coastal lowlands was due the exclusion of most of these areas from the analysis because of the high proportion of cultivated lands. The raw data show that these extensively cultivated areas actually burnt quite frequently because the farmers burn the stubble remaining after harvesting the wheat crops, particularly on the West Coast.

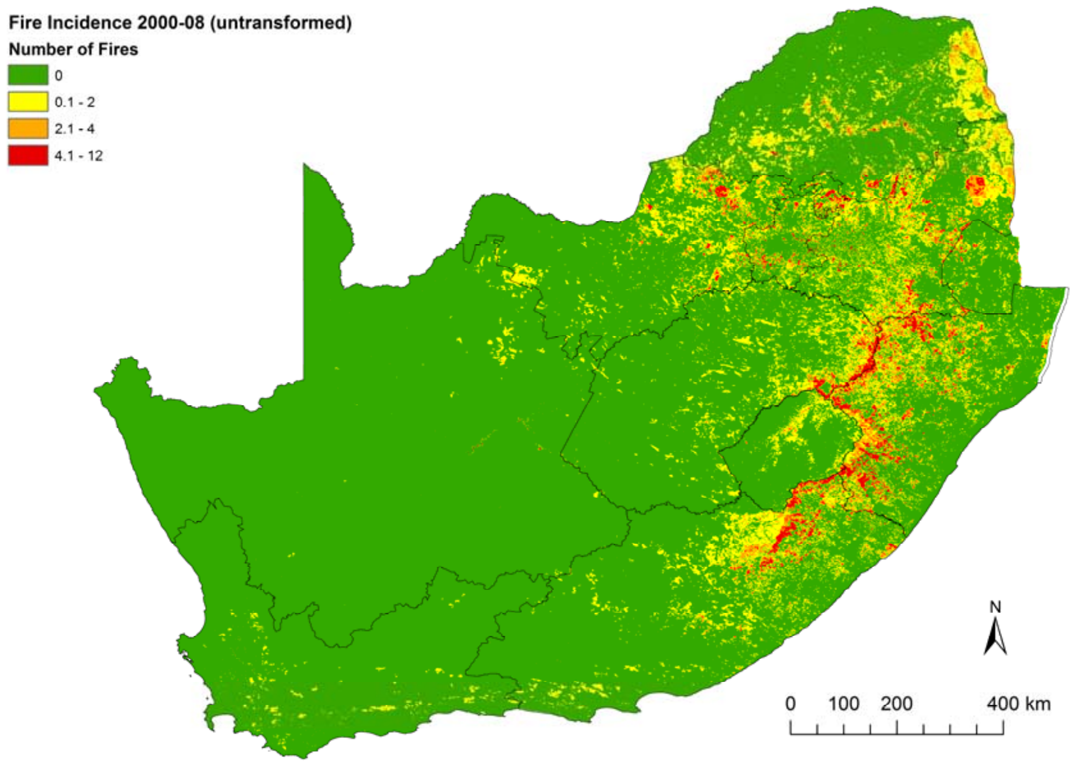

Figure 12. Map of fire incidence derived from data on the area burnt in fires from January 2000 to December 2008. The fire incidence is the total number of times each spatial unit (i.e. 250x250 m pixel) was burnt over that time period[104]. Fire incidences in transformed areas (tree plantations, cultivated lands and urban areas) were excluded from the calculations using data from the national land cover dataset[105] .

The highest fire incidence was found in the Sour Grassland and Moist Woodland fire-ecology types of the Drakensberg escarpment (from the Eastern Cape to southern Mpumalanga) and the mountain ranges of Mpumalanga and Limpopo provinces (e.g. Drakensberg, Waterberg, Strydpoortberg, and Soutpansberg). The mean fire incidence in these fire-ecology types is generally > 0.50 fires (0.06/yr) per pixel (Figure 12). The Sour Grassland fire-ecology types associated with the Drakensberg Wetlands had a mean of 3.21 and 2.58 fires for the Northern and Southern Drakensberg Highland Grassland vegetation types respectively. The Drakensberg Wetlands themselves had the highest fire incidence of all with 4.98 (0.55/yr) fires per pixel. The only other Sour Grassland fire-ecology type with more than 3.00 fires per pixel was the Wakkerstroom Montane Grassland. The Pilanesberg Mountain Bushveld in Northwest province had a mean fire incidence of 4.85 (0.54/yr) (Figure 12). This was very high for the Moist Woodland fire-ecology type and was probably due to prescribed burning in the Pilanesberg Game Reserve. The low fire incidence in the grasslands of Lesotho was in marked contrast to the high fire incidence on the South African side of the border, particularly along the Drakensberg. The reasons for this are not entirely clear, but may be associated with the marked

104 Fire incidence data supplied by S. Archibald, December 2009.

105 Van den Berg 2008.

rain shadow in these areas which, together with the very cold climate, may keep grass fuel mass low. Some of the area on the South African side of the border area falls inside protected areas and the fire incidence may be altered by prescribed burning. The KwaZulu-Natal Drakensberg also has the highest incidence of lightning strikes in South Africa and this may also contribute to the high fire incidence.

Most Arid Woodland, Coastal and Sweet Grassland fire-ecology types had between 0.01 and 0.50 fires per pixel. The high fire incidence in the mopane woodlands in north-east Limpopo province and in the eastern lowveld, all in the Arid Woodland fire-ecology type, stands out very clearly. Most of the vegetation types in this area fall within the Kruger National Park where management practices may have altered the fire regime. The prominent patch of high fire incidence in eastern Mpumalanga is located in the western Kruger National Park between the Sabie and Crocodile Rivers. The grass layer in this area is either sour or mixed grass but the high fire incidence was probably due to prescribed burning in the park. The overall fire incidence in the lowveld was markedly higher than in the adjacent Arid Woodland areas or in the similar woodlands in the Limpopo River valley.

Fires in the Sparse Arid Woodlands are expected to occur only after growing seasons with enough rainfall for the grasses to grow sufficient biomass to provide the fuel needed for them to burn. The period from 2000 to 2007 was characterized by dry years, which would have resulted in a relatively low fire incidence. A longer record should include one or more wet years (such as 2008 and 2009) and an increase in the fire incidence in this fire-ecology type. Some of the Arid and Sparse Arid Woodland areas with a relatively high fire incidence in the north-eastern Northern Cape, and adjacent North-West province, appear to be irrigated lands with seasonal crops (e.g. maize) that are burnt after the annual harvest. These irrigated areas should have been excluded from the analysis but the complex mosaic of irrigated lands and large the pixel size of fire-incidence resulted in some of these records still being included in the assessment.

The vegetation types comprising the Sour Grassland fire-ecology types had the highest mean fire incidence (1.34 fires per pixel, Figure 13.). The standard deviation (a measure of the variation) was 1.03 fires per pixel per year, emphasizing the wide range in mean fire incidence between different sour grassland vegetation types. The next highest mean fire incidence was the Moist Woodlands followed by the Arid Woodlands. The standard deviations were generally greater than the mean fire incidence in all the fire-ecology types because of the large proportion of the pixels with no incidence of fire (Figure 13). A longer record of fire incidence should increase the number of pixels with at least one fire and reduce this variability.

We also compared the fire-incidence records for the untransformed land cover types (i.e. natural vegetation) with those in the transformed areas for each fire-ecology type (Figure 13). This is important because it gives a better understanding of where fires are most likely to occur or originate more frequently. This helps identify potential sources of fires that can affect the ecology of the natural vegetation and where fires in natural vegetation my pose a risk to crops or tree plantations.

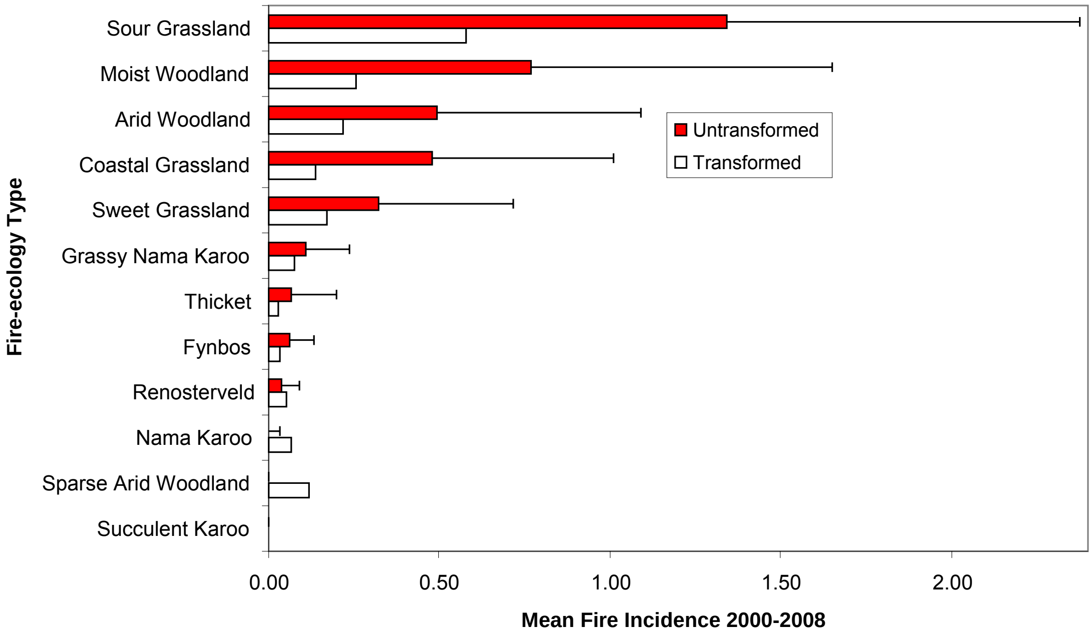

Figure 13. The mean fire incidence in each fire-ecology type ordered from highest to lowest. The error bar represents one standard deviation based on the range of mean fire incidence between the vegetation types which comprise each fire-ecology type. The data for the untransformed (natural) and transformed areas (e.g. cultivated lands, tree plantations, urban areas) are shown separately for each fire-ecology type.

The transformed areas in each fire-ecology type are burnt fairly frequently but less often on average than the untransformed areas except in the Renosterveld, Nama Karoo and Sparse Arid Woodland. In these areas the main difference is found in the cultivated lands where the relatively high fire incidence is due to the farmers burning the stubble in their wheatlands (particularly in the Renosterveld) or irrigated lands planted with maize or other short-duration crops (Sparse Arid Woodland, Nama Karoo).

5.1.3 Ecologically acceptable fire regimes in South African vegetation

As discussed briefly earlier, changes in the key elements of fire regimes can result in changes in the species composition, vegetation structure and ecological functioning of ecosystems. Table 5 provided information on the prevailing fire regimes. This section goes into greater detail of the known effects of human caused changes in fire regimes in some of the fire-ecology types.

The practice, in some sourveld areas, of putting in autumn (early dry season) burns to stimulate an out-of-season flush of green fodder has been regarded as detrimental, but the evidence for this is mixed[106]. It has been an apparently sustainable practice over vast areas of Africa and Australia for thousands of years. Where there is some residual moisture in the soil, and the patches burned are neither too small (to avoid over-concentration of grazers, who immediately move onto the burned patches), nor too big (so that some forage remains in the landscape if a flush does not appear), it has not been proven to be harmful, and in many circumstances is beneficial, and simplifies fire management by spreading the burning over a longer period and providing 'natural' fire-breaks.

[106] Everson 1999; O' Connor *et al.* 2004.

In savannas (which includes a wide range of mixed tree-grass ecosystems, from arid open parklands to nearly-closed moist woodlands), the main fire issue relates to its effects on the number and size of woody plants in the savanna mixture, which in turn determines the productivity and quality of the grasses. Frequent, high-intensity fires suppress trees and thus promote grasses, while protection from fire, and lower intensity fires (often associated with high levels of grazing, and correspondingly lower grass fuel loads) allows woody plants to increase, the widespread "bush encroachment" phenomenon[107]. For fire to effectively control trees and shrubs, it needs to reach a sufficient intensity to kill the aboveground parts, often enough that they cannot grow beyond the effective kill-height of the fire, and thus over-top and out-compete the grasses. This requires flames about 2 m tall (i.e. a fire line intensity over about 3 MJ/m/s), about once every three to five years: the time it takes for a sapling to grow taller than 2 m. The combination of hot, frequent fires and steady pressure from browsing animals (such as goats, elephants, giraffe, or kudu) is particularly effective in bush control. Once bush encroachment is in its advanced state, it is very hard to accumulate sufficient fuel to reverse it.

Shrublands (including fynbos and renosterveld) are fire-maintained vegetation types in which fires are needed to ensure the persistence of the often extremely diverse set of species they contain. Fynbos is by-and-large unpalatable, and therefore not grazed. Fire is used for purposes of biodiversity conservation, water catchment management, and fire hazard reduction. While renosterveld has some value as grazing, it has been reduced to tiny fragments of its former extent through conversion to crop agriculture. 'Thicket', found mostly in the Eastern Cape, is also a kind of shrubland, but is largely too succulent to be flammable, and seldom burns. However, it is often found in a mosaic with grassland, which does burn, and fire is probably instrumental in maintaining this pattern.

Indigenous forests are not extensive in South Africa, and covering less than 1% of the landscape even before they were over harvested during the period 1700 to 1900. They occur in a matrix of fire-prone surrounding vegetation (either grassland or fynbos), and are normally confined to "fire refugia" – places in the landscape protected by the topography from frequent fire[108]. Indigenous forests can and do burn: the great fire of 1865[109] is said to have reduced the former extent of the Knysna Forest by half, and initiated formal forest conservation in South Africa. Most 'undisturbed' forest patches in South Africa have evidence of charcoal in their soils, indicating that they do burn, but infrequently. Even with diligent protection (especially of the forest margin, which when intact is a natural firebreak), rare fires in exceptionally dry years will be sufficient to satisfy any ecological fire requirement, and no deliberate burning policy is recommended.

Arid landscapes in South Africa include the Karoo fire-ecology types (grassy Nama Karoo, Nama Karoo, and Succulent Karoo in this analysis). Fire is not an important issue in their management, since except for the grassy Nama Karoo (a form transitional to grasslands), fuel loads are normally insufficient to support fires[110]. Occasional fires (once a decade) are unlikely to do lasting harm although farmers in the Sutherland area argue that fires have severe adverse effects on the Renosterveld-Grassy Nama Karoo mosaic in these areas. Fires are believed to promote unpalatable plants and reduce the grazing capacity for decades afterwards and the farmers actively extinguish any fires that occur in the area. However, the adverse

[107] Trollope 1999; Govender *et al.* 2006.
[108] Geldenhuys 1994.
[109] Brown, J.C. cited in Beinart 2003; although the fires were extensive, the damages reported by Brown are probably an exaggeration.
[110] Bond 1997; Vorster 1999.

effects may actually be due to them allowing their livestock to graze these areas; the animals probably selective browse the regenerating palatable species, leaving only the unpalatable species behind.

5.1.3.1. Causes of inappropriate fire regimes

There are a number of factors that can lead to the establishment of inappropriate fire regimes. These are summarised in Table 6.

Table 6. Factors that contribute to the establishment of inappropriate fire regimes in South Africa.

Factor	Reason for potential negative influence on fire regimes	Potential manifestations of the problem
Lack of appreciation of role of fire.	People do not always fully understand the role of fire in ecosystems, or have preconceived ideas about fire. They seek to eliminate fire or reduce its frequency, or change the fire season to one when it is easier to control.	Fire protection, leading to fuel build-up and high-intensity wildfires. Lengthening of fire-return periods. Fires tend to be applied in "safe" seasons when escapes from prescribed burns would be minimised, and tend to be of low intensity.
Fear of legal liability	Prescribed burning programmes are not carried out when necessary due to fear of criminal or civil litigation resulting from loss of life, injury or damage to property and crops	A decrease in prescribed fires, and a corresponding increase in wildfires. While this is not always undesirable in an ecological sense, it can result in increased damage to property and crops, and promote invasion by alien species.
Global climate change	Climate is a significant determinant of fire behaviour, both through its influence of the growth of plants (fuel production), and on weather.	Possible increases (or decreases) in the frequency and intensity of fires, and shift in season (especially in the winter rainfall areas).
Human land use pressure	More intensive land use fragments the habitat, preventing the spread of fires. Dense human populations increase the risk of ignition, particularly in situations of land use conflict.	An increase in the incidence of fires, both due to accidental ignitions and arson. Habitat fragmentation leads to a decrease in mean fire size.
Lack of management capacity	Inability to conduct prescribed fires, or to combat unwanted wildfires.	A decrease in prescribed fires, and a corresponding increase in wildfires. Increased spread of alien species in areas where effective control requires the application of prescribed fire.
Crop production	The establishment of fire-sensitive crops in the landscape will lead to inappropriate levels of fire suppression in the surrounding vegetation	A decrease in the number of fires.
Ecosystem conversion	The replacement of "fire-resistant" vegetation types with flammable vegetation can introduce fires into fire-sensitive vegetation types. The reverse is also possible. Bush encroachment can reduce fire incidence – see text.	The introduction of fires into indigenous forest patches and thicket ecosystems.
Bush encroachment	Increase in woody plant recruitment and density leading to suppression of grasses, reduced fire intensities and further encroachment	A decrease in the number of fires
Invasive species	Invasive species can change the fuel properties of vegetation, leading to changes in the fire regime. The reverse is also possible. [Safire reports that wattle plantations burn much less than otherwise.]	Increases in fire intensity (often to damaging levels) where invasion of fire-prone ecosystems leads to increases in biomass and fuel loads. The introduction of fire to previously fire-free areas (for example following the invasion of Karoo areas by flammable grasses[111])

[111] Rahlao *et al.* 2009.

5.1.4 Conclusions on fire ecology and management

Veldfire management and risk reduction strategies must take account of fire ecology.

Fire is a natural and inescapable ecological factor in South Africa. Those ecosystems and species that were exposed to fire during their evolution are adapted to fire, and often require it to complete key stages in their life cycle. Land cover and land use changes in the South African rural environment have meant that ecosystems often no longer support natural fire regimes. Therefore some form of fire management, involving prescribed burning, is needed to simulate nature, or to achieve other management goals.

Thus, the hazard of wildfires may be increased or decreased, depending on the quality of veldfire management in any one area. Equally, the bad environmental consequences of wildfire may be aggravated where veldfire management is poor, as indicated in Table 6 above.

Ecologically appropriate prescribed burning is often diverted by factors such as lack of skills and capacity in land management institutions (owners or agencies), lack of knowledge and information, or fear of the law. Inappropriate prescribed burning or weak or absent veldfire management can have substantial negative environmental impacts or lead to loss of ecosystem services. Examples of these impacts are (a) bush encroachment, (b) invasions by alien plants, (c) a decrease in forage palatability and productivity, and (d) reduction in water yield. Burning too seldom is as damaging as burning too often. A build-up in fuel load increases both the risk of damage to life and property, and the possibility of high intensity or severe burns that lead to soil erosion or the death of otherwise resilient organisms. The regions of high and extreme wildfire risk are all especially prone to these environmental consequences of inappropriate veldfire regime. Inappropriate veldfire regimes can lead to intractable wildfire management problems.

Programmes of prescribed burning will not necessarily eliminate the risk of dangerous wildfires, but they can substantially reduce it. Recent evidence from the Kruger National Park suggests that attempts to manipulate the fire regime through imposing prescribed burning, or fire suppression, over the past 50 years have had little real effect on the actual area that burns each year, although it can affect the size and timing of individual burns, and thus their intensity or threat level. Rather, the total fraction of the landscape that burns is related to rainfall, which determines how much grass there is to burn - size of areas burned in three southern African parks is dominated by the amount of rainfall in the immediately preceding summer[112]. In the Cederberg wilderness in the Western Cape, a policy of “no fires” (suppressing all fires that occurred) still resulted in many wildfires[113]. When this policy was replaced by one of prescribed burning in an attempt to reduce the incidence of large wildfires, the number and size of wildfires was found to be unaffected despite regular prescribed burning for 14 years. An analysis of the fires in the Swartberg Mountains in the all-year rainfall region of the Western Cape also found that the key factors were high temperature and summer rainfall and management policies had little effect. Fire managers in conservation areas now prefer to apply “adaptive management”, where fire management is based on best available knowledge, the policy is always provisional and is adapted according to evaluations of the programme against its stated objectives, and predetermined “thresholds of potential concern”. At the same time it

[112] Midgley *et al.* 2006.
[113] Brown *et al.* 1991.

must always satisfy safety requirements. The fire management policy is adapted, without any stigma about having been 'wrong' in the past, as new evidence or understanding develops. Attempts to 'command and control' fire regimes are becoming less common.

In summary, therefore, integrated veldfire management requires knowledge of fire ecology and the environmental variation across South Africa. Good local ecological knowledge is needed for the design of appropriate veldfire management strategies. Compliance with biodiversity and natural resource management policies, as well as effective management of wildfire risk, is dependent on appropriate veldfire management strategies.

5.2 Risk analysis and maps of risk levels

5.2.1 Geographical distribution of assets and values

In order to perform the veldfire risk analysis, we first developed specific veldfire risk scenarios for each fire-ecology type described in section 5.1. Detailed descriptions of these specific veldfire risk scenarios are contained in Appendix 3.

We determined the likelihood that a fire scenario would come to reality using the qualitative and quantitative indicators of likelihood listed in Table 1. We then determined the consequences of each of the fire risk scenarios using the qualitative measures contained in Table 2. In both instances we did this for each of the three endpoints; social, economic and environmental. The level of risk for each fire scenario was then assessed using the product of likelihood and consequence as given in Table 3 and categorised as being Extreme, High. Medium or Low. This was done for each of the endpoints; social, economic and environmental, and these were mapped using mesozones as the unit of mapping (see Figures 14, 15 and 16).

The highest value for any of the three endpoints per mesozone was used to assign an overall risk value to that mesozone (see Figure 17). For example if the risk levels were; Extreme social, Major economic and Medium environmental then that mesozone was assigned an overall risk level of Extreme. The risk levels assigned to each of the fire risk scenarios are given in Table 7.

Finally the percentages of overall veldfire risk in the four classes; Extreme, High, Medium and Low were determined for each province, district municipality and local municipality and are summarised in Appendix 4.

Table 7. Summary of the veldfire risk levels assigned to the fire risk scenarios applicable to the 13 fire-ecology types (see Appendix 3).

Fire-ecology type	Scenario	Likelihood	Risk Levels			
			Social	***Economic***	***Environment***	***Overall***
Climate dependant						
1) Forest	*Not applicable*	Rare	Low	Low	Low	Low
2) Thicket	*Not applicable*	Rare	Low	Low	Low	Low
3) Succulent Karoo	*Not applicable*	Rare	Low	Low	Low	Low
4) Nama Karoo (including Desert)	*Not applicable*	Rare	Low	Low	Low	Low
5) Sparse Arid Woodland	Kgalagadi National Park	Possible	Medium	Medium	Low	Medium
Fire dependant						
6) Moist Woodland	Lowveld protected area	Likely	Extreme	High	Low	Extreme
	Waterberg farmland	Likely	Extreme	High	Low	Extreme
7) Arid Woodland	Kuruman	Possible	High	High	Low	High
8) Grassy Nama Karoo	Eastern Cape Midlands (Cradock)	Possible	Medium	Medium	Low	Medium
9) Coastal Grassland	Mkambati (Pondoland)	Likely	High	Medium	Low	High
	Zululand coast	Likely	High	High	Low	High
	Eucalyptus. plantation on Zululand coast	Possible	High	High	High	High
10) Sour Grassland	Mpumalanga highveld and escarpment	Likely	Extreme	Extreme	Medium	Extreme
	South-Eastern Seaboard	Likely	Extreme	Extreme	Medium	Extreme
	Pine plantations on Mpumalanga escarpment, KZN midlands and Zululand	Possible	Extreme	Extreme	High	Extreme
11) Sweet Grassland	Free State	Possible	High	High	Low	High
12) Fynbos	Boland mountain fynbos	Possible	High	Medium	Low	High
	Jonkershoek pine plantation	Possible	High	High	High	High
	Southern Cape mountain fynbos	Possible	High	Medium	Low	High
	Southern Cape pine plantation	Possible	Extreme	High	High	Extreme
13) Renosterveld	Touwsrivier	Possible	Medium	Medium	Low	Medium

5.2.2 Social (end point) risk levels

For the social endpoint, the area mapped as Extreme veldfire risk corresponds broadly with the distribution of the Sour Grassland and Moist Woodland fire-ecology types. These landscapes are often well populated, as opposed, for example, to the rugged terrain of the fynbos. In these fire-ecology types deaths and serious injury related to veld fires occur annually. Small areas of Extreme veldfire risk appear in the Fynbos fire-ecology type and these are associated with commercial pine plantations. Areas of High veldfire risk occur in the Arid Woodland and Coastal Grasslands where there are many scattered rural communities that are particularly vulnerable to wildfires. People living here are often subsistence farmers and there lives and livelihoods are regularly exposed to veldfires. Reasons for this include that they live surrounded by vegetation that is in a cured state during the dry season and often their homesteads are fire prone having, for example, highly flammable thatched roofs. They are also not well serviced local municipality fire brigades. The social risk of fire has also been rated as High in the Fynbos fire-ecology type as deaths and serious injury do occur from time to time but not every year.

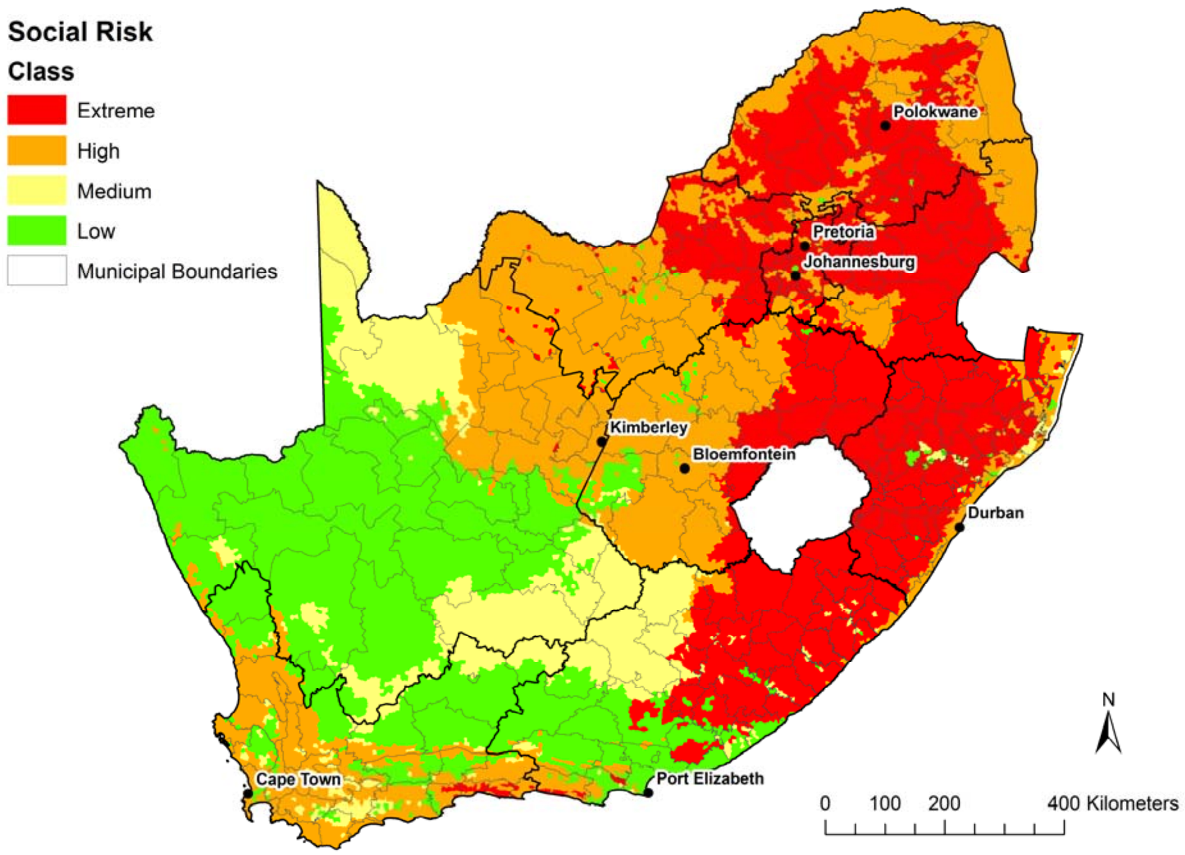

Figure 14. Veldfire risk levels in South Africa for the social endpoint.

5.2.3 Economic (end point) risk levels

Veldfire risk levels for the economic endpoint are once again Extreme in the Sour Grassland and Moist Woodland fire-ecology types situated in the eastern part of the country. These landscapes are mostly accessible, have well dispersed economic infrastructure, and carry most of the vulnerable plantation forests of South Africa. The economic assets in these fire-ecology types include rural industries, recreational resorts, emergent farmers, livestock, fodder banks, plantation forests and the infrastructure relating farming, protected areas and plantation forests, power lines and telecommunication infrastructure, fodder banks.

Plantation forests occur in region with mean rainfall exceeding about 700m per year, largely in the Sour Grassland fire-ecology type but also to a lesser extent in the Fynbos fire-ecology type. Because of high fuel accumulation and flammability, these plantation forests are especially prone to fires in dry, hot windy weather. Sour Grasslands are extensively farmed by both commercial and emergent farmers and their livestock and fodder banks are vulnerable to wildfires.

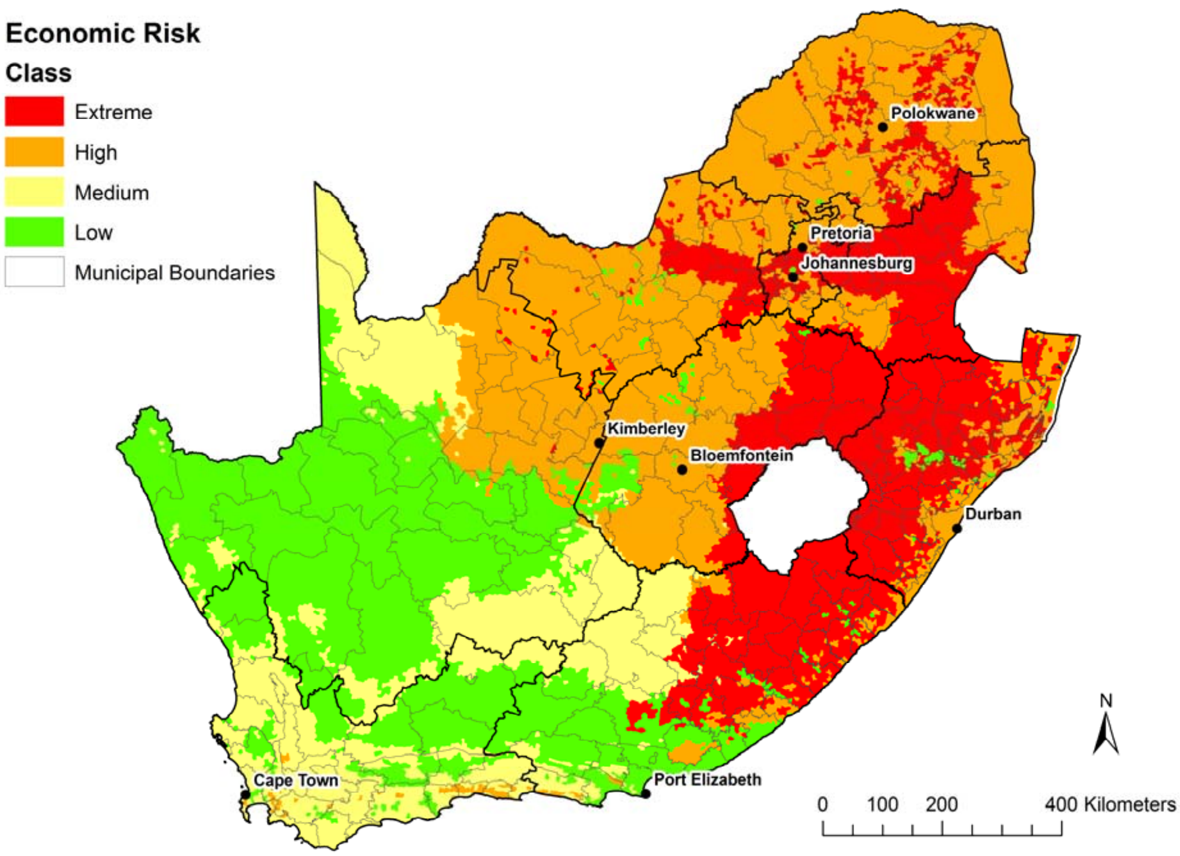

Figure 15. Veldfire risk levels in South Africa for the economic endpoint.

5.2.4 Environmental (end point) risk levels

Risk levels for the environmental endpoint are Low within most fire-ecology types as much of South Africa vegetation is fire-adapted and able to recovery rapidly from veldfires provided there are no complicating factors such the veld being invaded by woody alien plants or having commercial timber plantations as these factors increase the fuel load markedly.

Invasion of grasslands and shrublands by tall trees and shrubs increases the amount of plant material (fuel load) that can burn. Typical fuel loads in grass and shrublands are around 0.3 - 4 tonnes per hectare, while invaded sites have up to 10 times more fuel (10 - 25 tonnes per hectare[114]. While ecosystems in South Africa are normally quite resilient to regular burning, these increased fuel loads lead to higher intensity fires, often with high residence times, and a range of detrimental effects. Physical damage to the soil can occur, resulting in increased erosion after fire. For example, 6 tonnes of soil per hectare was lost following fires in pine stands compared to 0.1 tonnes per hectare following fire in adjacent fynbos in the Western Cape[115]; and 37 tonnes per hectare was lost following fires in pine stands compared to 1.8 tonnes per hectare in adjacent grassland in the KwaZulu-Natal Drakensberg[116]. Some information is also available on erosion after fire in invaded fynbos sites on the Peninsula[117].

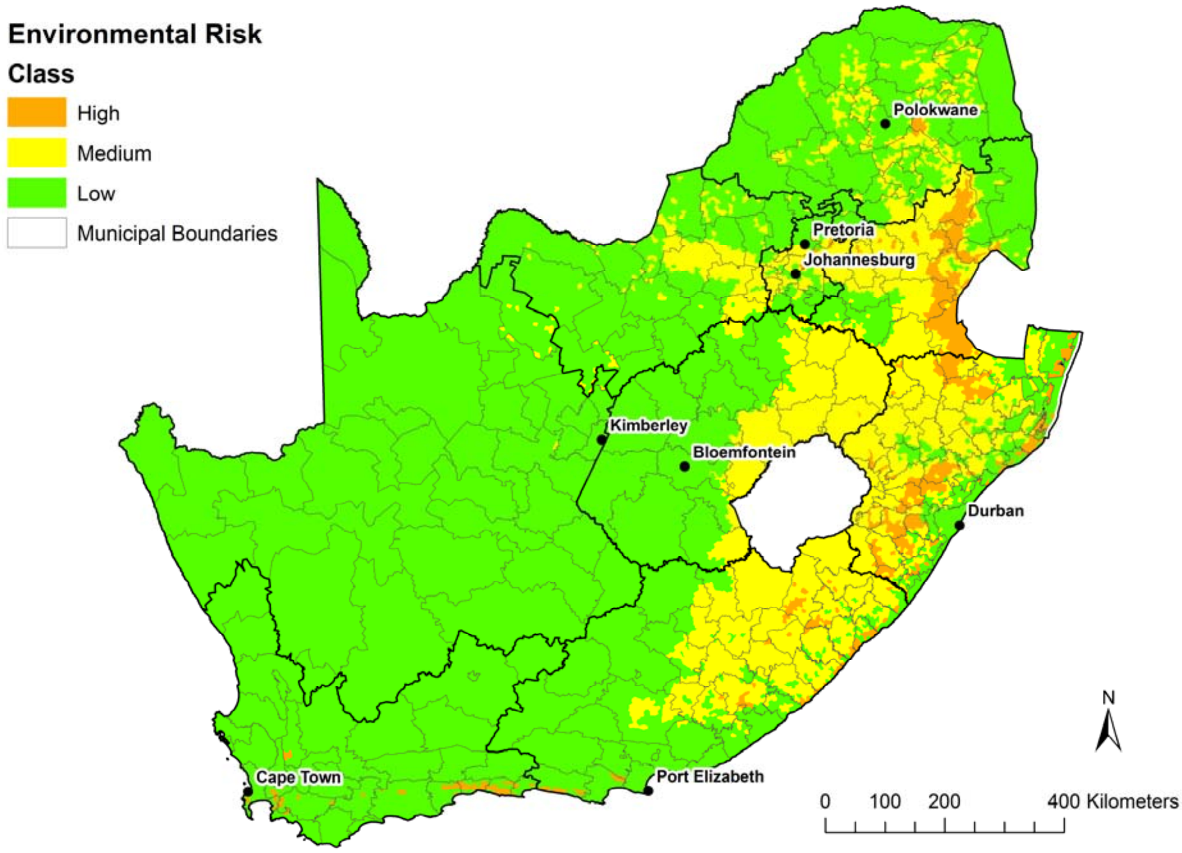

Figure 16. Veldfire risk levels in South Africa for the environmental endpoint.

[114] van Wilgen and Scholes 1997; van Wilgen and Richardson 1985.
[115] Scott *et al.* 1998.
[116] Scott and van Wyk 1990; Scott and Schulze 1992; van Wyk 1986.
[117] van Wilgen and Scott 2001.

5.2.5 Overall risk level

The highest risk value for any of the social, economic or environmental endpoints per mesozone was used to assign an overall risk value to that mesozone. Extreme overall veldfire risk corresponds with the Sour Grassland and Moist Woodland fire eco-types while in the Fynbos fire eco-type such conditions only occur where there are commercial forestry plantations. In Coastal Grasslands and Arid Woodlands pockets of Extreme veldfire risk occur where there are dispersed rural settlements. In 31,3% of the country veldfire risk is Extreme, while it is High in 30.6%, Medium in 11,7% and Low in 26,4%. In areas of Extreme and High veldfire risk it is necessary to take precautions to safe guard lives, livelihoods, property and the environment.

KwaZulu/Natal has the greatest area of Extreme veldfire risk covering 84,1% of the province with the next greatest being Mpumalanga with 70.9%. These provinces are important for commercial forestry plantations which are prone to destructive veldfires. They also many disperse rural settlements whose inhabitants are particularly vulnerable to veld fires. The Northern Cape is the province with the lowest veldfire risk: 57,3% of the area has a Low veldfire risk and a mere 0.2% has an Extreme veldfire risk.

More than 90% of certain district councils (DC) have an Extreme veldfire risk. These are Alfred Nzo DC (100%) in the Eastern Cape; Thabo Mofutsanyane DC (98,7%) in the Free State; Metsweding in Gauteng (93.0%), Umgungundlovu DC (99,4%), Uthukela DC (96,7%), Amajuba DC (100%), Zululand DC (91.1%) and Sisonke DC(100%) in KwaZulu/Natal; and Greater Sekhukhune DC (93,3%) in Limpopo.

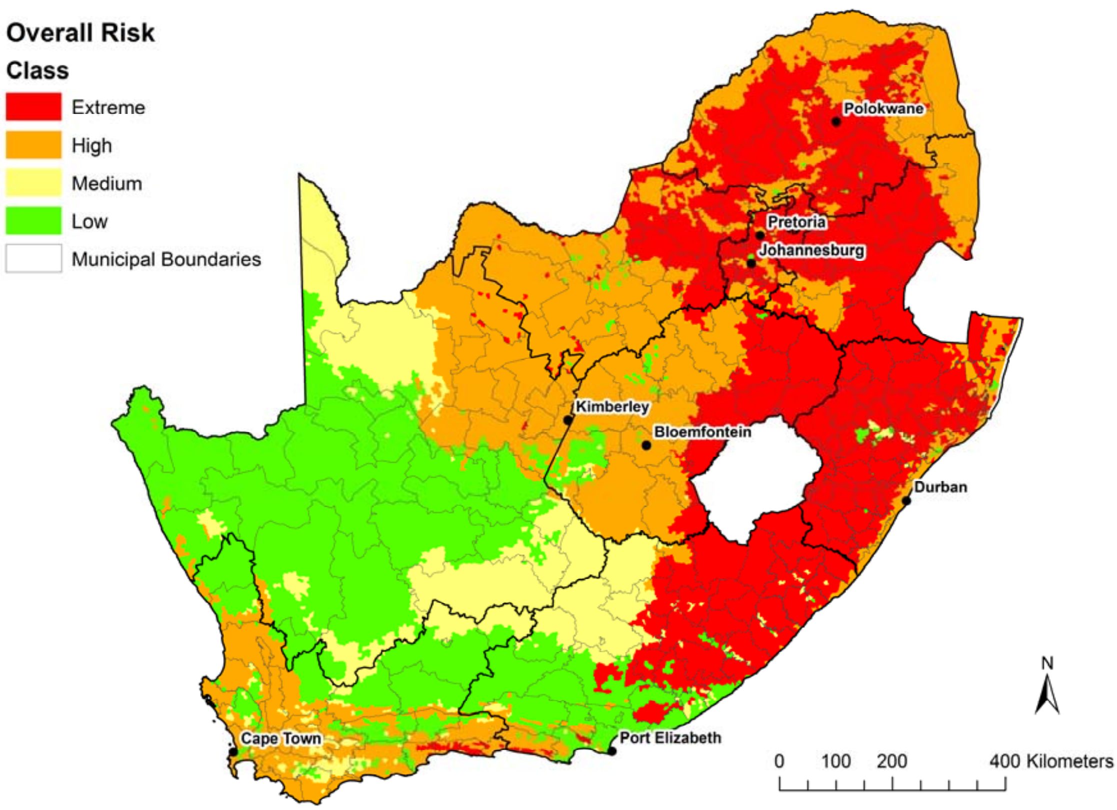

Figure 17. Overall assessment of veldfire risk levels in South Africa.

6. Conclusions and recommendations

6.1 Implementation of the National Veld and Forest Fire Act

Of the 13 fire-ecology types identified for South Africa, four have no or very low levels of veldfire risk. These are Forest, Thicket, Succulent Karoo and Nama Karoo. In these there is no requirement for the application of the National Veld and Forest Fire Act.

In all other fire-ecology types, the Act should apply in full.

In the fire-ecology types with Medium fire risk, i.e. Grassy Nama Karoo, Renosterveld and Sparse Arid Woodland, fire risk management strategies of an intermediate level would be appropriate. The principal focus should be on the establishment of FPAs, since these are sparsely settled regions and the reach of local government is limited: local cooperation needs to be the basis of reasonable preparedness among land owners and integrated veldfire management, with financial and in-kind support from local government.

In the fire-ecology types and municipalities with High to Extreme fire risk, comprehensive risk management strategies are needed. This includes:

- Urgent provincial risk assessments as frameworks
- Fully developed FPAs and Umbrella FPAs
- Detailed per asset and per value fire risk assessments within municipalities and FPAs
- Comprehensive risk management planning including ecological fires management principles and plans, and the Council of Australian Governments National Inquiry on Bushfire Mitigation and Management, 2003/2004 fires season 5Rs framework
    - Research, information and analysis;
    - Risk modification;
    - Readiness;
    - Response; and
    - Recovery
- Comprehensive response strategies for megafires (a veldfire or concurrent series of veldfires that is in the upper percentile of the fire regime).
- In areas of poverty, special support from government, coupled with FPA promotion integrated with Community Based Natural Resources Management initiatives

We recommend the following actions to promote the use of this national veldfire risk assessment:

- Widespread distribution of the report for comment
- Training of risk assessors (Fire Protection Officers and others) on the basis of a revision of the guidelines in the Department's document on guidelines for business plans of FPAs
- Scheduled implementation of the process according to priority municipalities.

6.2 Improving the risk assessment: requirements for information and research

There several further requirements to be met in order to position South Africa for an improvement in veldfire risk assessment and management:

- The DAFF with the National Disaster Management Centre must promote the full deployment of the National Veld fire Information System (NVIS), with links to the South African Risk and Vulnerability Atlas
- Evaluation of the development of business plans and capacity in FPAs in relation to veldfire risk levels
- Integrated veldfire management (ecological and disaster management) capacity evaluation in local government, FPAs, and Working on Fire against the 5Rs framework
- Study of historic megafires, the synoptic weather and other conditions that affect them, and the possible effect of climate change on their incidence
- The areas assessed as being in the category of Extreme risk vary greatly among each other and need further study.
- Geographical database and analysis of fire reports from various sources to assess the geographical variation in the incidence, and consequence of wildfires.
- Given the high social, economic and environmental costs of wildfires in South Africa, however, especially to vulnerable rural populations, it is advisable to invest substantially now in precautionary and rational analysis to understand better the current risks and the potential effects of climate change on them.

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