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Veld fire reporting and mapping techniques in the Kruger National Park, South Africa, from 1941 to 2011

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Fire has long been regarded as a major determinant of ecosystem structure and function within African savannas. Improvements in fire detection, mapping and recordings of fire activity over the past few years have made it possible to provide more reliable information on the occurrence, spatial extent and intensity of fire. The Kruger National Park (KNP) has a long and well-documented history of fire management policies implemented and an accompanying fire incident record for the park. Since 1941 the KNP has gone through seven key fire reporting and mapping eras, each with its own strengths and weakness. During this time period there were three key changes that improved veld fire monitoring in KNP, namely (1) moving from hand-written to electronic reporting and mapping procedures, (2) mapping of fires as polygons and not as burn blocks and (3) use of satellite images to improve the accuracies of boundaries of burnt areas. This paper outlines the succession, improvements and details the changes that have taken place in veld fire reporting and mapping techniques over seven decades in the KNP, in response to the needs articulated by the fire community, research and management in the park.

Keywords: fire mapping, fire monitoring, fire reporting, fire scars, satellite images

Introduction

National parks and conservation areas throughout the world are facing increasingly complex challenges in understanding and conserving their valuable resources. This is due not only to the heterogeneous nature of large ecological systems but also to a changing global environment, changing expectations of visitors and expanding neighboring communities. The contemporary situation is vastly different from that experienced by most parks and conservation areas when established many decades ago (Stevenson-Hamilton 1993, Levin 1999, Venter et al. 2008).

The Kruger National Park (KNP) has embraced the paradigm that spatial and temporal heterogeneity at the landscape scale imparts environmental vitality for the long term. This paradigm is based on the notion that ‘heterogeneity must be good for biodiversity’ (Mentis and Bailey 1990, Levin 1999) and is practiced by KNP managers as a forward-thinking experiment (Biggs and Rogers 2003, Rogers 2003). The basic premise is that if a variety of natural landscapes, structures and communities are preserved, then biodiversity will be safeguarded, a key mandate of South African National Parks (Venter et al. 2008).

Within savanna ecosystems, fire is a key ecosystem disturbance and driver and, as such, is extremely important in shaping the savanna landscape and associated faunal and floral diversity (Bond and van Wilgen 1996). Often likened to a ‘generalist herbivore’ (Bond 1997), the impacts of fire on flora and fauna communities through the large-scale removal of biomass is a key management issue within many conservation areas in Africa and South Africa (Biggs and Potgieter 1999).

The KNP fire history has been well documented (Brynard 1971, van Wilgen et al. 2000, Trollope et al. 2003, van Wilgen et al. 2003, 2004) and can be briefly characterised into five major eras. Between 1941 and 1956 there was no official veld burning policy and a laissez-faire philosophy was applied where occasional and limited fires were set in autumn, mainly to provide new fodder for grazing. From 1957 to 1980 a command-and-control fire strategy where regular prescribed burning, aimed at burning every 3 years in spring after the first rains, on fixed areas of around 4 000 ha (‘burn blocks’) was introduced (van Wilgen et al. 2003). From 1981 to 1991, a ‘flexible rotational’ burning practice was implemented. This was flexible because the season of burn varied but the fire return interval remained the same.

After nearly 40 years’ implementation of a rotational block burning program, during which managers set fires and suppressed lightning and fires lit by refugees crossing the park from Mozambique, the policy was changed in 1992 to adopt the so-called ‘natural’ burning practice. This new policy stipulated that all lightning-ignited fires were to burn freely whereas other fires were to be suppressed (Govender
seven decades of fire reporting and mapping techniques in KNP and the evolution of the various techniques associated with advancement in methodologies and technologies.

Study site

One of the largest proclaimed and officially protected natural areas in the world, the KNP was established in 1926. The park covers approximately 2 million ha, occupying almost 2.5% of the total land surface area in South Africa (Figure 1). It is situated in the north-eastern region of South Africa and is separated from adjoining Moçambique by the Lebombo mountain range in the east and from Zimbabwe by the Limpopo valley in the north. It is elongated with a total length of approximately 320 km and a mean width of 65 km (Joubert 1986, 2007). Elevations range from 260 m above sea level (asl) on the eastern plains to 839 m asl in the south-western areas of the park. The park’s mean annual rainfall is approximately 500 mm, but variations about the mean can be marked from year to year. There also exists a rainfall gradient from around 350 mm in the north to around 750 mm in the south. The climate of KNP is characterised by two distinct seasons. The wet season, which extends from October to March, is hot and humid owing to the influx of warm, moist air from the Indian Ocean. The daily maximum and minimum temperatures at this time of the year average around 34 and 21 °C, respectively. The dry season, which extends from April to September, is characterised by the presence of anticyclonic conditions over the interior of South Africa. The mean daily temperatures during the dry season vary from 10 to 27 °C, respectively (Gertenbach 1980).

The park is distinctively divided in two by its geology, with granitic sandy soils occurring on the western half of the park and basaltic clay soils on the eastern half. The two major formations are divided by a narrow belt of shale in the eastern half (Joubert 1986, 2007). There are two major river systems (the Nkomati system in the south and...
the Limpopo system in the north) with six perennial rivers (the Crocodile, Sabie, Sand, Olifants, Letaba and Luvuvhu) that drain through the park. The Limpopo River forms part of the northern boundary (Joubert 1986). The vegetation of the park is characterised as an open-wooded savanna, dominated by trees in the genera *Acacia* (*Senegalia* and *Vachellia*), *Combretum*, *Sclerocarya* and *Colophospermum*. The flora of the park comprises ±2 000 taxa, including over 400 tree and shrub species and over 220 grass species. The fauna of the park includes 148 mammal, 53 fish, 35 amphibian, 118 reptile and ±500 bird species.

**Veld fire reporting and monitoring eras**

The first official recording of veld fires in the KNP was in 1941 and continues to date. Over the past seven decades, the reporting and mapping system of fires in the park has improved and each era has its own strengths and associated weaknesses with the techniques used (Table 1). Outlined below are details of the reporting and mapping techniques that were used in each of the monitoring eras.

### 1941–1956

**Reporting system**

Given the vast area that had to be covered by as few as eight rangers (responsible for approximately 240 000 ha each), there was no systematic reporting of fires by the rangers. A temporal database for this era is therefore not available (Pienaar 1990).

**Mapping system**

A single A4 rough sketch of the approximate fire location and extent of all fires for the entire era was produced for annual reports at the end of each year (Figure 2). This spatial representation of fires is the only record of fires mapped and monitored during this time period.

### Table 1: Summary of fire monitoring in the respective fire management eras and the associated strengths and weaknesses of each monitoring system in the Kruger National Park, South African. Details are outlined in the text

<table>
<thead>
<tr>
<th>Fire management era</th>
<th>Block or point burns</th>
<th>Fire monitoring era</th>
<th>Monitoring approach</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laissez faire (1926–1956)</td>
<td>Not known</td>
<td>1941–1956</td>
<td>No systematic fire reporting or mapping</td>
<td>A single hand-drawn A4 sketch of the total annual burnt area in KNP. Submitted in annual reports</td>
<td>No associated metadata such as date, cause and extent of fire is available with the map</td>
</tr>
<tr>
<td>Fixed rotational (1957–1980)</td>
<td>Block and perimeter burns</td>
<td>1957–1980</td>
<td>Hand-written system. Fires were reported and mapped as individual block fires</td>
<td>Increased effort in the recording of fire metadata, such as date and cause of fire, weather conditions during the fire and post fire effects of vegetation</td>
<td>No electronic capturing of the spatial extent of the burnt area. Either the block burnt or not. A single fire was recorded as multiple individual blocks that burnt</td>
</tr>
<tr>
<td>Flexible rotational (1981–1991)</td>
<td>Block and perimeter burns</td>
<td>1981–1991</td>
<td>Same as above</td>
<td>Same as above with more detail on climatic and fuel conditions) under which the fire burnt. Pre- and post-fire effects were also recorded.</td>
<td>Same as above</td>
</tr>
<tr>
<td>Lightning (1992–2001)</td>
<td>Point burns ‘natural’ ignition</td>
<td>1992–2001</td>
<td>Same as above</td>
<td>Improvement in accuracy of mapping the burnt area boundary by using landscape features such as rivers and the road network to assist in delineation the boundary of the burnt area.</td>
<td>Fire maps were still hand drawn and only in the late 1990s were they captured electronically</td>
</tr>
<tr>
<td>Integrated fire management (2002–2011)</td>
<td>Point burns</td>
<td>2002–2003</td>
<td>Electronic reporting and mapping system introduced. Mapping and recording of individual fires as polygons replaced the burn block system of fire monitoring</td>
<td>Spatial extent of individual fires was mapped with landscape features (e.g. rivers and roads) forming boundaries to burnt areas. GPS locations of ignition points were recorded</td>
<td>Method of on-screen digitising of burnt areas was too time consuming, tedious and subject to human bias and error</td>
</tr>
<tr>
<td></td>
<td>Point burns</td>
<td>2004–2011</td>
<td>Same as above</td>
<td>Introduction of satellite images to map fires</td>
<td>Specialised training required to map fires. Pixel size of image limits the burnt area that can be detected and mapped</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Information required from rangers was reduced to three key measures. Development of an automated mapping system to reduce human bias in delineating the boundary of burnt area. Accuracy of fire mapping was supplemented by satellite images (MODIS)</td>
<td></td>
</tr>
</tbody>
</table>
The number of rangers in the park gradually increased to their present number of 26, with the last three ranger sections being formed in the late 1970s. With more ranger sections and rangers, the area covered by a single person was reduced and allowed for more intensive reporting and monitoring of fires. The establishment of a network of graded firebreaks subdivided the park and created approximately 400 ‘burn blocks’ with an average size of 4 000 ha, ranging from 50 to 23 800 ha (van Wilgen et al. 2000). With increased manpower and greater access to remote areas within a section, fires were now monitored as part of the ranger’s activities. Written reports for fires on a block–by-block basis from rangers were sent to Scientific Services in Skukuza. These reports were captured in digital format and information such as the commencement date of the fire, location (a designated block number) within the park, the cause of the fire (arson, meaning the cause was due to illegal trans-migrants or poachers, management, firebreak and lightning) and a brief description of the climatic condition (air temperature, relative humidity, wind speed and direction) during the fire and the pre- and post-fire condition of the vegetation in the block was recorded.

Mapping system
A schematic representation of the fire boundary was illustrated in the aforementioned fire report. An estimate of the extent of the fire was outlined using landmarks such as the block boundary, windmills, major rivers and roads.

1957–1980

Reporting system

Figure 2: Hand-drawn A4 rough sketch of the extent of fires in 1950. This method was used between 1941 and 1956.

Figure 3: An example of a schematic hand-drawn map of a fire that burnt between 1% and 20% of the burn block N011 in Punda Maria, KNP. This method was used to capture burnt areas from 1957 to 1980.
to provide an estimated outline of the boundary of the fire within the block. Figure 3 is an example of these sketch maps that were produced by the rangers. No attempt was made by the ranger to determine the detailed boundary of the burnt area within the block and the boundary of the burnt area was usually drawn from memory. Towards the latter end of this time period, from 1977 onwards, all individual schematic burnt area maps produced by rangers for a particular fire season were transferred on to a 1:100 000 map of the park that was located at Scientific Services in Skukuza.


Reporting system

During this time period the park was divided administratively into 22 sections, each with its own senior ranger and supporting field rangers. The area of responsibility for a single ranger and the additional staff was now reduced to approximately 86 000 ha. Nevertheless the written fire reports for each individual fire were still submitted to Scientific Services in Skukuza. However, the details contained in the fire reports increased significantly to include season of fire, detailed pre-fire conditions of the vegetation (grass height, greenness and moisture content, tree and shrub foliage cover, and soil moisture), climatic conditions (relative humidity, cloud cover, speed and direction of the wind, and air temperature), post-fire effects (tree and shrub damage, and small and large animals affected), pyrodiversity, fire intensity and an estimated percentage of the area burnt. The fire reporter (usually the ranger of the section) estimated all of the above information and measurements were not standardised. This fire report was submitted to Scientific Services in Skukuza and ultimately was captured in an electronic database in the late 1990s.

Mapping system

During this era the mapping system remained unchanged from the previous era and still no effort was made to capture the spatial extent of individual fires. If a fire covered more than one burn block, such a single fire was captured as separate fires, one per burn block.

1992–2001

Reporting system

No changes from the previous era were made to the type of data that was reported on for each fire. However, during this era many fires were not confined to a single burn block and fires could burn for many days under varying climatic conditions due to the removal of many firebreaks and consolidation of smaller burn blocks into larger burn areas. Consequently, the format of the written reports was changed to accommodate fires that burnt over many days under different weather conditions and through more than one burn block. In 1997 steps were also taken to capture all fire data (from 1957 to 1997) in a standardised format. It was noted that the quality of the data improved with each decade. Some of the fires recorded had the date of fire, a block location and an estimate of the percentage (ranging from 1 to 100%) of the block that burnt. Other fires had only a date and block location recorded. Of all fires recorded in the park in the 1950s, 69% of the fires recorded had to have burn percentages simulated. This decreased to 64%, 61% and 8% during the following three decades, with the most accurate fire data being collected in the last two decades (1990s and 2000s). In order to allocate a reasonable estimate of the burn block that was burnt, we simulated the missing percentages by randomly choosing percentages (as multiple of 10, same as most of the ranger recorded percentages) from the distribution formed by the percentages assigned by rangers in that same fire year. The percentages delivered in the first random selection were saved as the simulated percentages burnt for any future use.

Mapping system

The accuracy of the boundaries of burnt areas obtained from rangers was improved by providing each of the 22 ranger sections in the park with enlarged A4 maps derived from a 1:100 000 map with layers of major and minor rivers and road networks (Figure 4). During this era the fires were also recorded on a 1:100 000 map at Scientific Services in Skukuza via daily radio reports made by the section ranger.

In the latter part of the 1990s serious effort was made to capture electronically all paper-based fire maps (1:100 000 and individual ranger maps) and reconcile the burn block boundaries as these were subdivided, lumped or otherwise changed over the years (van Wilgen et al. 2000). The maps from 1957 to 1999 were electronically digitised and stored in a spatial database using the ArcView 3.2 geographic information system (GIS). During this process of capturing the fires in a GIS database, it was evident that many of the reported fires during the 1950s, 1960s and 1970s had not been captured spatially and, if they were, the burnt area may not have been accurately recorded. In was also noted that during the 1950s, 1960s, 1970s and 1980s 56%, 89%, 63% and 16% of fires recorded respectively had no spatial representation of the burnt area. Since 2000 the spatial extent of all fires has been mapped electronically.

2002–2003

Reporting system

An electronic reporting system with an online help system was implemented during this time period. Two additional reporting measures were added to the individual fire reports. Firstly, a unique fire identity that consisted of the date of the fire (YYYYMMDD), followed by a three-letter unique section code (e.g. SKZ – Skukuza) and finally by a single digit (or letter) called the terminal. The terminal exists to distinguish between fires occurring in the same section on the same day. Generally, the terminal is 1 unless there was more than one fire in a section on the same day, in which case each separate fire is allocated a different terminal (2, 3, 4 etc.) (Figure 5). The second additional datum recorded was the location of the ignition point of the fire. This was obtained either from a GPS reading or by estimating the coordinates off a map and was recorded as the Universal Transverse Mercator (UTM) Northing and Easting in metres. All other reported information remained the same but the data collected were not subjective and were standardised. This was done by using observable features in the landscape, for example if the fire was classed as having a moderate effect on the vegetation then
the observable feature in the landscape would be ‘smaller trees and shrubs (less than 3 m high) affected, leaves wilted or burnt away, bark slightly scorched’.

Mapping system
In an attempt to streamline and improve the mapping of the burnt areas by rangers, on-screen digitising of burnt areas on standard maps for each section was attempted. All rangers were given the software and training to map fires electronically by using the draw tool in the Microsoft Powerpoint program. The second option was to print the standardised map, delineate the outline of the burnt area on the map and send the map to Scientific Services in Skukuza. GIS layers such as the burn block, drainage lines and other infrastructure were indicated on the map to improve the accuracy of the burnt area boundary (Figure 5).

2004–2006
Reporting system
The level of detailed information of each fire requested from the ranger was reduced. The reason for this was two-fold; firstly, if required, climatic conditions occurring during the fire could be more accurately sourced from local weather stations and, secondly, the pre- and post-fire observation

Figure 4: Method of capturing the spatial extent of fires between 1992 and 2001, using a 1:100 000 map as a background for the Punda Maria section in the KNP. The burn blocks are in black and the extent of the burnt area is shaded
of vegetation had proved to be biased due to the lack of standardisation in observations and therefore not reliable. For more than 20 years this fire information was being collected and not used in any form of fire analysis. In the interest of improving fire reporting efficiency, the only information that a ranger was now required to report on was the start and end date of the fire, distinguishing GPS coordinates within the burnt area or the ignition source, and the cause of fire. This information was sent through via e-mail and no fire report was required from the ranger.

**Mapping system**

Established methods of mapping fires were augmented by satellite data. Early attempts to incorporate advances in e-mail availability and electronic data capture for fire reporting were largely unsuccessful primarily due to internet unavailability and the unreliability of electronic communication in many parts of the park. It was during this period that satellite imagery was incorporated into the fire mapping system. On-screen digitising from MODIS images was done at Scientific Services in Skukuza. The NASA Goddard Space Flight Centre (GSFC), in collaboration with the University of Maryland (http://rapidfire.sci.gsfc.nasa.gov), provided real-time image subsets of MODIS, spatial resolution 250 m, bands 7-2-1 (false colour) from the Terra and Aqua satellites for the KNP. In this composite, MODIS bands 7, 2, and 1 are assigned to the red, green and blue portions of the digital image. This combination is most useful for identifying burn scars. Visual observations of burnt areas were made on the three-band composites. To aid visual interpretation, vectors of prominent boundaries such as rivers and roads were overlaid on the MODIS image to provide geographic context. Although this was a great improvement from the traditional fire mapping procedure, the on-screen digitising proved to be tedious and subject to human bias and error.

In 2006, to improve the mapping techniques and remove the error due to human bias, an automated digital classification and processing of remote sensing images was developed. The procedure is based on digital image classification of MODIS images that were already radiometrically and geometrically corrected using the NASA Standard. Digital image classification commenced at the onset of the fire season (June) in 2006. The process is repeated every month until November in order to capture the temporal changes in burnt areas during the fire season (Figure 6). Using fire detection points from the MODIS Rapid Response

Figure 5: An example of the burnt area mapping between 2001 and 2003 in the Skukuza section (blocks S059A and S060A) in KNP. The burnt area could be digitised electronically or the map was printed and the ranger drew the boundary of the burnt area on the printed map.
System that coincide with the coordinates obtained from rangers’ ignition points, the images were trained for classification. This technique proved to adequately map burnt areas in the KNP in a more accurate manner than was previously the case.

2007–2011 Reporting system
As per the National Veld and Forest Fire Act, 1998 (Act No. 101 of 1998) and the registration of the Kruger National Park Fire Protection Association (KNPFPA) in March 2006, it was once again instituted that a written fire report be sent to the KNP Fire Protection Officer in Skukuza. Details provided on the fire incident report include the start and end date of fire, the location of the fire (section or burn block name and GPS coordinates within the burnt area), cause of fire and suppression costs incurred to contain the fire. This information is captured on an electronic database.

Mapping system
No changes have been made to the previous era of fire mapping.

Fire behaviour data set (1954–2011)
In 1954 a series of experimental burning plots were established in four of the major savanna vegetation types in the KNP (van der Schijff 1958). The experiment covered fire frequency treatments at annual winter (August only), biennial and triennial intervals in the following seasons, late summer (February), autumn (April), winter (August), after first spring rains (October) and early summer (December). After 1974, quadrennial and sexennial burns in October were added to the experiment. Treatments were replicated four times in each of four major landscapes in the park with each plot covering approximately 7 ha. The experiment is described in detail by Biggs et al. (2003).

At the onset of the experiment from 1959 until 1971, the data that was collected for each application of the treatments included weather conditions at the fire (only air temperature, wind speed and wind direction), a description of the pre-fire condition of the grass, trees and shrubs and a qualitative description of the post-fire effects on the grass, forbs, trees and shrubs. Thereafter from 1972 until 1981, the data collected at each treatment improved to include a brief fire history of the plot (recorded if an accidental fire took place), on-site weather conditions (air temperature, wind speed and direction, and relative humidity) and a description of pre- and post-fire vegetation (grass, forbs, trees and shrubs) condition. In 1982 Professor WSW Trollope introduced a system of collecting key fire behaviour data that included weather conditions at the time of fire (air temperature, wind speed and direction, and relative humidity), the start and end times of the head and back fires, fuel biomass measurements (using a disc pasture meter; Trollope and Potgieter 1986), fuel moisture measurements, rates of spread of the back and head fires, fire line intensity and an estimated percentage of the plot that burnt. This protocol to collect fire behaviour data at all research and experimental fires continues to date and has been used in several publications to model, understand and interpret fire behaviour and fire intensity characteristics (Govender et al. 2006, Higgins et al. 2007).

Discussion
The value of keeping long-term fire records can be summarised into four important contributions towards ecosystem management. Firstly, long-term fire records...
provide ecosystem managers with surrogate measures of biodiversity outcomes, in the absence of actual measures of biodiversity outcomes. The current fire strategy within KNP seeks to create a mosaic of fire patches representative of a range of fire histories (intensity and frequency), so as to generate heterogeneity across space and time (Parr and Brockett 1999). A key assumption associated with the KNP current fire policy is that fire patterns (number of patches, mosaics and variations in the frequency, intensity and patch size of fires) act as surrogates for biodiversity (Parr and Andersen 2006). Within ecosystems that show a high degree of resilience in their response to fire effects, it is important to understand the ecological significance of fire patterns. Access to long-term fire records provides an opportunity to determine fire trends and patterns over time and space, thereby identifying the ‘pyrodiversity that begets biodiversity’ (Parr and Andersen 2006).

Secondly, access to long-term fire records allow managers to identify when management interventions are required. The KNP has adopted a strategic adaptive management policy towards ecosystem conservation. Thresholds of potential concern (TPCs) are monitoring endpoints that alert managers when interventions, actions or policies are ineffective (Biggs and Rogers 2003). TPCs are defined as ‘those upper and lower levels along a continuum of change in a selected environmental indicator, which when reached, prompts an assessment of the causes, and results in (1) management action to moderate the cause, or (2) recalibration of the threshold to a more realistic level’ (South African National Parks 1997). The long history of fire reporting and monitoring in Kruger provides a basis that allows scientists to address the fire TPCs set (van Wilgen et al. in Kruger provides a basis that allows scientists to address the fire TPCs set (van Wilgen et al. 2008) and to assess the effectiveness of current fire policy in achieving their stated objectives. Analysis of historical fire patterns and trends, obtained from long-term fire records, supports managers in making decisions regarding whether to implement a prescribed fire or not in order to maintain the status quo of current vegetation communities or to change vegetation structure (Higgins et al. 2007, Smit et al. 2010).

Thirdly, fire records are valuable as a research tool, which allows researchers to understand and interpret observed biodiversity outcomes in terms of a known fire history. The KNP long-term fire database has been used extensively as a research tool in improving our understanding of fire behaviour, dynamics and various fire interactions in the landscape, e.g. fire–vegetation interactions studies (van Wilgen et al. 2000, 2004, Higgins et al. 2007, Smit et al. 2010), fire–nutrient interactions (Coetsee et al. 2010, 2011) and fire behaviour (Govender et al. 2006), thereby allowing ecologists and managers to examine the nature of the fire regimes and their effects in the park.

Finally, extensive fire records have been invaluable in supporting, improving and validating new technological developments in fire monitoring and mapping techniques. The current efforts made to improve on and supplement field mapping techniques with the use of remotely sensed satellite data (Hetherington 1997, Landmann 1999, Roy et al. 2005a) have made the capturing of burnt areas more rapid and efficient. In the late 1990s when the hand-drawn fire maps from rangers were first electronically digitised, Hetherington (1997) compared the ranger’s fire mapping techniques of ‘eye-balling’ the extent of the fire to fire-scar mapping based on Landsat TM and NOAA. Using Landsat TM with a high spatial resolution as a reference, he determined that the rangers were overestimating the extent of the burnt area by 25% and the ranger’s technique of mapping was comparable to the spatial scale of the NOAA Dekad images. The reason for the overestimation was that the two methods (ranger mapping and NOAA Dekad) prohibited the fine-scale mapping of internal patchiness within the burnt area (burnt and unburnt areas) and only mapped the overall boundary of the total burnt area, thereby ignoring the inherent patchiness of the burnt area.

Currently, using MODIS 250 m resolution images to map the burnt areas in Kruger has allowed managers to address the above shortcomings of not capturing the internal patchiness (burnt and unburnt areas) within fire scars at finer scales. This prevents the overestimation of the total area burnt as well as clearly mapping the heterogeneity of the burnt area. Other advantages of using the MODIS images include free access to the data, full spatial coverage of the area and the high temporal resolution. The application of the mapping techniques has been extended from the scientific and academic arena (Roy et al. 2005a) to an operational and on-the-ground management domain for ongoing everyday use in Kruger.

However there are disadvantages to using MODIS imagery for fire mapping and these include the identification of ‘false positive’ areas. For example, pans and borrow pits are identified as burnt areas. Possible methods to correct for this include changing the algorithm, using a fuzzy classifier, obtaining validation points of fires from rangers for ground truthing of the imagery or just account for these permanent structures and live with it. Frequent days with persistent cloud cover are also not conducive to obtaining images for use. However, the high temporal resolution, hence the acquisition of images twice daily, every day, negates this problem. The coarse resolution of MODIS also does not allow detailed fire scar mapping, thus small fire scars of less than 250 m are not captured. The reported accuracy of MODIS based on validation with field observations is around 75% (Roy 2009). Finally, using remote sensing to map fires is an extremely specialised task and in order to effectively use the system there is a need to train personnel in the use, application and functions of the system. There is also a need to increase the awareness and to educate the numerous users of the end products and their potential use, advantages and disadvantages associated with mapping fires with remote sensing satellite images (Roy et al. 2005b).

Acknowledging these limitations, satellite imagery is being used as a management tool that has improved fire detection and mapping fires over large and often remote areas where direct observations and previous techniques attempted by resource mangers have proved less useful or feasible (Roy et al. 2005b). It is envisioned that satellite-derived fire data will be used in conjunction with other data sets in the park to help achieve its biodiversity mandate.

Conclusion

Savanna ecosystems are complex and dynamic systems, which require decision-making to be based on reliable,
relevant and current information. Embedded within the park's culture and based on a history of science-based management, basic research and monitoring is necessary to make good decisions about how to manage ecosystems. This has led to the ongoing support of research and monitoring of key drivers that influence the system in KNP (Freitag 1998). The fire data sets (reporting, mapping and research) in KNP comprise one of the longest-running programs in the park and represent arguably the best data set available for exploring long-term spatio-temporal patterns over landscape scales in a fire-prone semi-arid African savanna (van Wilgen et al. 2004, Archibald et al. 2010, Smit et al. 2010, Roy and Boschetti 2009). This data set has evolved and improved over time in the detail and level of accuracy required to assist both managers and researchers in improving our understanding and knowledge of fire in shaping our landscape. As such we are afforded an opportunity to study the effects of various fire regimes on savanna ecosystems. This unique data set covers several climatic cycles, six different fire management policies and extends over a sufficiently diverse and large area so that the effects of a rainfall gradient, contrasting geologies and variable landscape positions on fire regimes can be studied. Therefore maintenance of this data set by park managers and researchers will continue.

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References


Hetherington DS. 1997. GIS and satellite RS as tools to assist fire management protocols in the national parks of southern Africa. MSc thesis, University of Greenwich, UK.


Rogers KH. 2003 Adopting a heterogeneity paradigm: implications for management of protected savannas. In: du Toit JT, Rogers KH,


