IDENTIFYING INDIVIDUAL FIRES FROM SATELLITE-DERIVED BURNED AREA DATA

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ABSTRACT

An algorithm for identifying individual fires from the Modis burned area data product is introduced for southern Africa. This algorithm gives the date of burning, size of fire, and location of the centroid for all fires identified over 8 years in Africa south of the equator. The results are compared with other available spatial information on fires, and tested to see whether they give reasonable results in a range of different fire systems in the region. Initial results indicate that humans can have massive impacts on fire size distributions and on the area burned by large fires. This information on fire number and fire size can be used to ask important questions on the effect of increasing human ignitions, and the barriers to fire spread in savanna systems.

Index Terms— fires, algorithms, environmental factors,human factors,image processing

1. INTRODUCTION

One of the many ways in which moderate-resolution satellite imagery has expanded our view of the earth system is the information that it has been able to provide on fire. Mapping fire over large regions is complicated because the occurrence of fire at a single point in space and time is a stochastic process which depends upon many interacting factors. In Africa until daily remotely sensed information became available information on regional fire regimes was limited to anecdotal accounts supported by some localised field records [1, 2, 3].

In the last few years, however, satellite information has been used successfully to explore the spatial and temporal patterns of burning on the continent [4, 5, 6, 7, 8, 9]. However, one key piece of information still missing is information on ignition frequency, fire size and fire number. Active fires provide data on the temporal patterns of fire, fire intensity and fuel loads. Burn scar data record area burnt and fire return period. However, it has not been possible to identify individual fires, so it has not been possible to ask questions about human effects on ignition frequency, and about the barriers to fire spread.

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Here we introduce a method for identifying individual fires from the MODIS burnt area (MODB45) product, and describe some ways that it can be used to describe the different fire regimes in the southern African region and to test hypotheses about ignition frequency and fire spread. These data help us to understand the patterns of fire in southern Africa - and in particular the effect that human activity has on fires.

2. METHODS

An evaluation version of the MODIS MOD45B burnt area product [10] is available from 2000 to 2008. This product gives the location and approximate day of burning of burn scars at 500m resolution. It is accompanied by quality flag information on the confidence of the detection as well as a monthly data product indicating which pixels were ”invalid” i.e. unable to be classified as either burned or unburned.

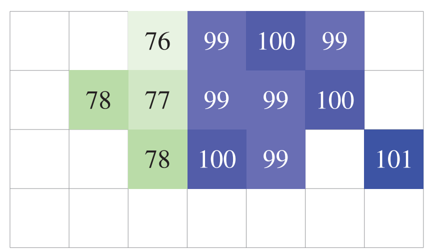

Fig. 1: Demonstrating the algorithm for identifying individual fires. Pixel shade and pixel number indicate the day of burning. Neighbouring pixels which burned within 8 days of each other are classified as the same fire. Diagonal pixels are included as neighbours. In this instance two separate fires were identified - one with mean burn date on day 77 and one on day 99.

These data were used to identify individual fires using a modified flood-fill algorithm (Figure 1). All burnt pixels start off as unclassified, and are then allocated individual fireID’s based on the following rules: the first burnt pixel is given a fireID of 1. All burnt pixels neighbouring this pixel, including diagonals (8 possible neighbours), are then identified. If any of these pixels is recorded as burned within 8 days of the centre pixel, it is given the same fireID. The neighbours of

Table 1: Sensitivity analysis on the effect of using diagonals and changing the time period on the fire size statistics. Total number of fires as well as the percentage of fires in each of 6 size classes are reported for one fire year (2003). Including diagonals and using an 8-day cut-off results a smaller proportion of very small fires.

	# fires	<1 km	1-5 km	5-10 km	10-50 km	50-100 km	100-500 km	>500 km
8-day with diagonal	261×10^3	51	34	8	6	0.62	0.39	0.07
8-day no diagonal	343×10^3	57	31	6	5	0.46	0.27	0.04
4-day with diagonal	525×10^3	66	26	4	3	0.27	0.16	0.02
4-day no diagonal	703×10^3	73	22	3	2	0.18	0.11	0.01

these pixels are then identified, and tested to see whether they had burned within 8 days of their centre pixel, in which case they are given the same fireID.

This process continues until no more neighbouring pixels can be found that have burned within 8 days. The next unclassified burnt pixel is then identified and given a fireID of 2. The same flood-fill process is repeated until all pixels have been allocated an individual fireID.

Eight days was used as a cut-off because that is the temporal accuracy of the original MODIS data [10]. Sensitivity analyses were run to investigate the effect of different cut-off times and of including or excluding diagonal neighbours on the fire size statistics.

The individual fires identified were then compared with annual fire maps created by the Kruger National Park. These fire maps are produced with information from the field rangers on the date and location of individual fires and corroborated using satellite data (Figure 2). The total number of fires identified by each method each year was compared over a range of size classes (from 2000-2006). The estimated area burned by fires of different size classes was also compared.

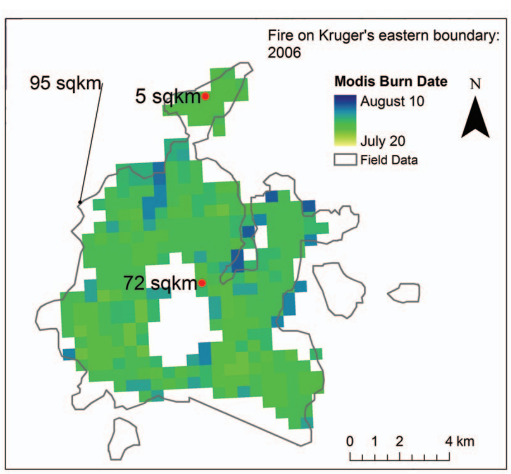

Fig. 2: Comparing fires identified by field data and from the Modis burn scar data. Colours represent day of burning (ranging from July 20 to August 10). Where the field data identified one fire of 95 km^2, the Modis algorithm identifies two fires of 72 and 5 km^2 each.

The Modis fire size data were then used to look at fire size distributions in different savanna systems in southern Africa. Information on rainfall, tree cover, human population density and burnt area were collated at 1-degree resolution over southern Africa (see [9] for information on data collection). Three representative grid squares were selected in each of four different regions, representing a range of rainfall, population densities, and tree covers. The Kalahari has low rainfall, tree cover and people, Northern Angola has high rainfall and tree cover, but relatively few people. Zambia represents median rainfall, tree cover and human densities, and Malawi has similar rainfall and tree cover to Zambia, but very high human population densities. Fire size class distributions were computed for each 1-degree grid and compared across these regions. Because large fires are known to contribute disproportionately to the total area burned [11], the percentage area burned by each size class was also calculated for each pixel.

3. RESULTS

3.1. Sensitivity Analysis

As would be expected, including diagonal pixels in the fire algorithm resulted in fewer fires being identified overall, and a smaller proportion of them being small fires ($< 1km^2$, Table 1). On the other hand, if 4-days instead of 8-days was used as the cut-off (i.e. neighbouring pixels had to have burned within 4 days of each other to be identified as the same fire) then more fires were identified, and more of these fires were small fires.

3.2. Comparison with field data

The fire size distributions from the two different data products were similar over the 6 year comparison period (Figure 4a). The Modis method identified more small fires than the field data (paired t.test, p = 0.002, n = 6), but the number of fires larger than 1km that were identified by both methods were similar (paired t.test p = 0.62, n = 6). The difference in small fires is unlikely to be important as the area burnt by these very small fires is negligible ($\approx 1\%$: Figure 4b).

Figure 3 shows how the area burnt accumulates over the

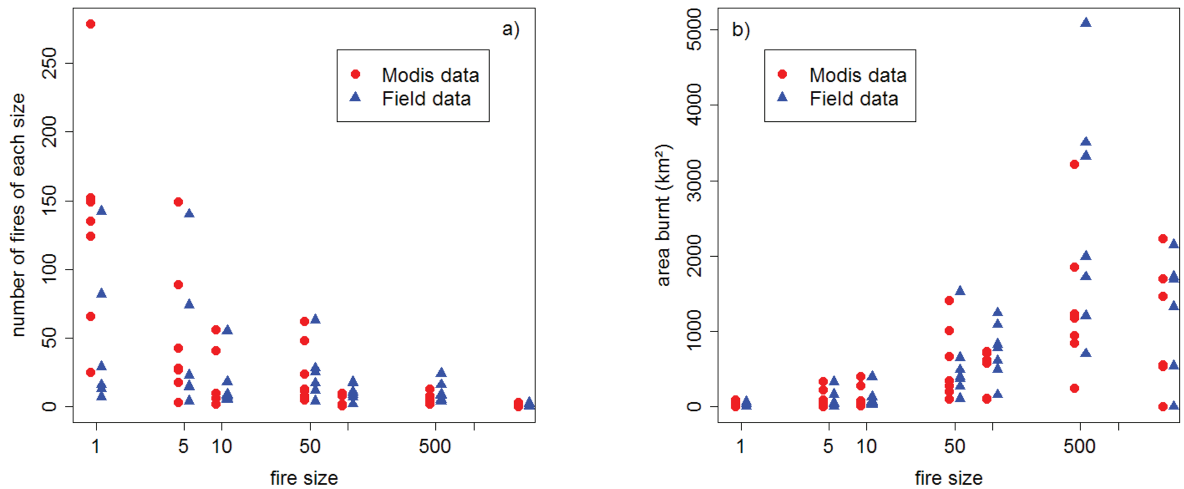

Fig. 4: Comparing a) the fire size distributions and b) area burnt by fires of different sizes identified by two different methods over a six year period in the Kruger National Park, South Africa

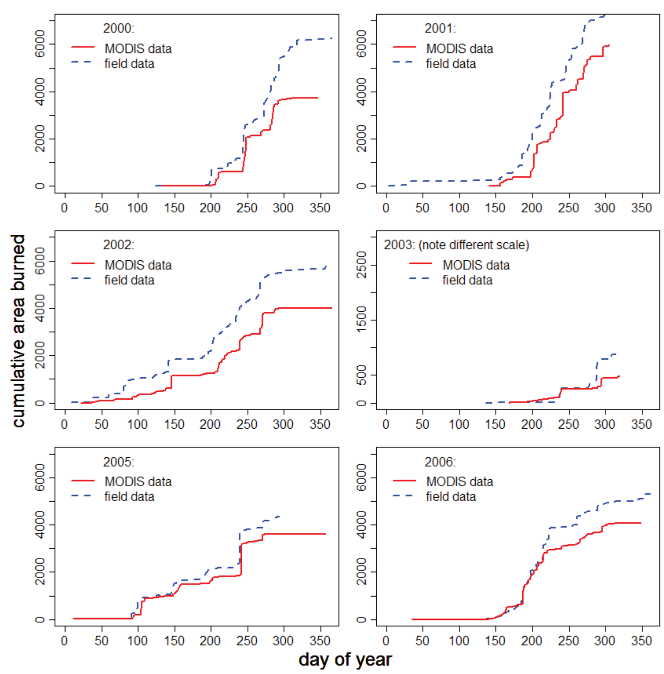

Fig. 3: Cumulative area burnt by individual fires identified by two different methods in the Kruger National Park, South Africa. Fire areas were accumulated over the year after being sorted by start date. Six different fire years are shown.

year for the six years. The occurrence of large fires is represented by steps in the curve. Both data sources identified the same fires, but because fire size estimated from the field data is usually higher than that estimated from Modis data the total area burnt each year is higher. The true accumulation curve is likely to be somewhere between these two lines: Modis data does not pick up all the burn scars, but field data does not pick up the patchiness of many of the fires (Figure 2).

3.3. Fire size distributions in different parts of southern Africa

There are substantial differences in fire size distributions in the four different regions. In the Kalahari and Angola 13% and 9% of the fires were larger than 10 km^2, compared with 4% and 1% in Zambia and Malawi respectively. This translates to massive differences in the area burned by large fires (Figure 5): in Malawi most of the area is burned by fires 1-10 km^2 in area, in Zambia, most of the area is burned by fires of 10-100 km^2, whereas in Angola and the Kalahari over 40% of the area is burned by fires > 500 km^2.

A full investigation of the drivers of these patterns is beyond the scope of this paper, but the pattern does not appear to be related to rainfall or the total area that burns. The strongest relationship found was with human population density: areas with more people have fire-size distributions skewed towards the lower fire sizes.

4. CONCLUSIONS

The flood-fill algorithm developed here identifies individual fires and calculates the area burnt, the date of burning, and the centroid of each fire. Many of the fires identified by the algorithm are very small: 1-4 pixels (0.25-1 km^2). Despite this, these data can successfully differentiate between systems with many small fires, and systems with a few large fires. The differences in fire size distributions shown between areas with

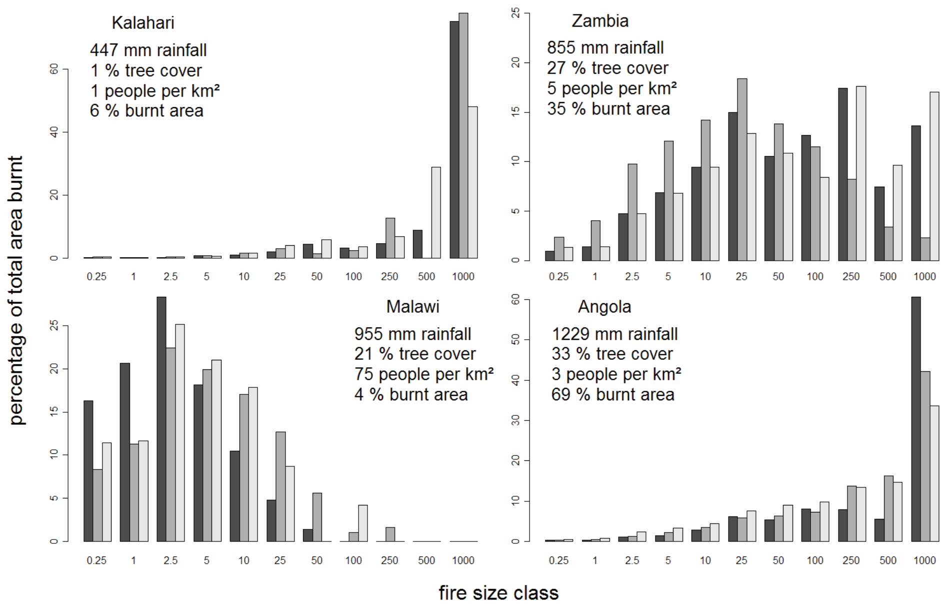

Fig. 5: The percentage of the total area burned by fires of different sizes in four different parts of southern Africa. Data from three representative 1-degree grid squares are reported for each region. The mean (average of the three grid squares) environmental characteristics for each region are also shown. Areas with fewer people have a higher proportion of large fires, and substantially more of the landscape is burned in large fires. This pattern seems to hold across the rainfall gradient

low and high human population density are striking, and point to some intriguing relationships between human ignitions and fire spread.

One of the biggest questions remaining in African savannas concerns the effect that humans have had on fire regimes since they first began to manipulate fire several hundred thousand years ago. Information on fire size and fire number can be used to test hypotheses on the current human impact on ignition frequency, timing, and fire spread.

These data and the spatial fire data recorded by the Kruger National Park give comparable results. The field data have their own potential sources of error so any differences between the two data sets can not be attributed to error in either method. The flood-fill method is very sensitive to changes in the cut-off date for neighbouring pixels to be considered one fire, and to the use of diagonals as neighbours. The parameters chosen here are considered the most appropriate for the spatial resolution and temporal accuracy of the MODB45 data (500 m and 8-days respectively).

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