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DETECTION, MAPPING AND ESTIMATION OF RATE OF SPREAD OF GRASS FIRES FROM SOUTHERN AFRICAN ERTS-1 IMAGERY

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Abstract:

Sequential band-6 imagery of the Zambesi Basin of southern Africa recorded substantial changes in burn patterns resulting from late dry season grass fires. One example from northern Botswana, indicates that a fire consumed approximately 70 square miles of grassland over a 24-hour period. Another example from western Zambia indicates increased fire activity over a 19-day period. Other examples clearly define the area of widespread grass fires in Angola, Botswana, Rhodesia and Zambia.

From the fire patterns visible on the sequential portions of the imagery, and the time intervals involved, the rates of spread of the fires are estimated and compared with estimates derived from experimental burning plots in Zambia and Canada. It is concluded that sequential ERTS-1 imagery, of the quality studied, clearly provides the information needed to detect and map grass fires and to monitor their rates of spread in this region during the late dry season.

INTRODUCTION

In the dry tropical regions of eastern and southern Africa, the traditional practice of grass burning during the winter dry season causes widespread destruction of vegetation and alteration of wildlife habitats. The burning of grass is an integral component of shifting cultivation and is therefore likely to persist. In these regions man makes use of fire for the removal of primary or secondary vegetation to initiate or continue the cultivation of subsistence crops. In more localized situations, grass is often burned off either to provide early green grazing or to drive wild animals during the hunt.

All these instances of burning are normally aimed at the removal of grass or other vegetation over very limited areas for individual requirements. However, due primarily to the optimum burning conditions which prevail (strong winds, high temperatures, and low humidity) particularly during the end of the dry season in September and October, these fires inevitably spread over vast areas.

The object of this paper is to demonstrate that ERTS-1, band-6 imagery obtained near the end of the dry season over these regions is capable of detecting and mapping this widespread and ecologically-important phenomenon. Moreover, it also demonstrates that this type of sequential imagery can be used to monitor the increase in area of fires and to estimate their rates of spread.

THE STUDY AREA

The 250,000-square-mile study area encompasses the watershed of the upper and middle portions of the Zambezi River and includes parts of the territories of Angola, Botswana, Rhodesia, South West Africa and Zambia in southern Africa (Fig. 1). The vegetation is comprised of tropical, dry, deciduous, partly-sclerophyll forest, xerophilic open woodland, spiny shrub and grassland. It is an area of low annual rainfall, ranging from 10 inches (northern Botswana) to 30 inches (central Zambia), which falls during a period rarely exceeding 5 months. The 7-month dry season normally extends from April to October during which no rain falls. Temperatures range from extremes in excess of 100°F during October just prior to the onset of the rains, to early morning frosts in the middle of the winter dry season, normally in June. During September and October, winds tend to increase and relative humidity drops to about 15 per cent.

MATERIALS AND METHODS

Normal, undodged, positive transparencies of ERTS-1, band-6 imagery (enlarged to 1:1,000,000), obtained from the EROS Data Centre, provided coverage (Fig. 2 and table 1) of the study area.

From the positive transparencies, contact internegatives were produced, from which paper prints were prepared.

During December 1972, soon after acquisition of the imagery at the end of November 1972, the author was able to visit areas on the ground covered by some of the imagery and to verify some of the interpreted phenomena.

All interpretation of the imagery was undertaken on the positive transparencies using a zoom stereoscope having a 7- to 30-times magnification capability. Stereo-viewing was possible on images from adjacent ERTS-1 swaths (Fig. 2 and Table 1) which provided about 17% image side-lap between the latitudes covered (approximately 13°00' S to 20°00' S). From the fire patterns apparent on some of the sequential portions of the imagery, an

Table 1 ERTS-1, band-6 coverage of study area.

Image Reference No.	General locality	Image centre point		Date 1972	Approximate local time of image acquisition (hours)
		Lat.	Long.		
1	Gago Coutinho, Angola	14°31' S	21°28' E	17 Sept.	1007
2	Senanga, Zambia	15°59' S	22°32' E	16 Sept.	1001
3	Mucussu, Angola (including part of the Caprivi Strip of South West Africa)	17°24' S	22°11' E	16 Sept.	1002
4	Okavango, Swamps, Botswana	18°51' S	23°15' E	15 Sept.	0956
5	Chobe Game Park, Botswana	18°49' S	24°42' E	14 Sept.	0951
6	Wankie Game Park, Rhodesia	18°45' S	26°08' E	13 Sept.	0945
7	Lake Kariba, Zambia/Rhodesia	17°15' S	27°58' E	30 Sept.	0939
8	Kafue River, Zambia	14°30' S	25°45' E	14 Sept.	0949
9	Kabompo/KaCana, Zambia	14°14' S	24°23' E	3 Oct.	0955

the time intervals involved, the rates of spread of the fires were estimated. These estimates were compared with rates of spread of experimental grass fires derived from burning plots in Zambia and Canada.

Some of the imagery was subsequently enhanced electronically in an attempt to accentuate the more subtle aspects of the burning patterns.

RESULTS

In general, the quality of all the imagery was excellent, and in fact all frames were ranked 8 by NASA on a 9-point scale of increasing image quality. No clouds were evident on eight of the nine images; only the Lake Kariba image (No. 7) had 10% cloud cover, and this was entirely confined to the south-west corner of the image. Some localized smoke haze resulting from active fires was evident on the Chobe Game Park image (No. 5) and the Kabompo/Kaoma image (No. 9). Portions of the area covered by image No. 9 were seen by the author from the air on 5 December, 1972, and two suspected burns were visited and confirmed on the ground on 7 December, 1972. During these visits, the entire region was experiencing an exceptionally-long dry season, as the onset of rains was then a full month overdue, and active fires were still taking place.

The most striking evidence of an active fire on the imagery was on the Chobe Game Park image (No. 5). When the image was obtained on 14 September at 0951.0 hours local time, a fire was burning and can be seen in the left centre of the image (Fig. 3, upper right). Smoke moving in a west-southwesterly direction can also be seen. On the Okavango Swamps image (No. 4), acquired from the next adjacent ERTS pass on 15 September at 0956.5 hours (exactly 24 hours, 5.5 minutes later), there can be seen a considerable areal extension in a westerly direction of patterns resulting from two lobes of the fire (Fig. 3, upper left). There was no evidence of smoke on the 15 September image, indicating that the fire had probably ceased some time during the 24-hour interval. There is portion of the westerly extension of the fire that was not imaged because at these latitudes, only about 17% image side-lap was available between adjacent ERTS-1 passes. By interpolating between the burn patterns appearing on the sequential images, it was possible to estimate the total increase in area of the two lobes (Fig. 3, lower centre). It was estimated that the northernmost fire burned approximated 29 square miles, and by making the conservative assumption that it burned during the entire period between acquisition of the two images, it is estimated that this fire spread at the rate of about 13 acres per minute¹. By similar calculations and assumptions, the southernmost fire burned approximately 45 square miles, or spread at the rate of about 20 acres per minute².

¹ 18560 acres
1445.5 minutes

² 28800 acres
1445.5 minutes

These rates of spread can be compared with those estimated from a 30-year-old experimental burning plot near Ndola, Zambia, in which each October, 11 acres burn in an average of 1 minute and 27 seconds, which is equivalent to a rate of spread of 7.6 acres per minute. Similar test-burning sites in Canada indicate that 3-to 4-foot grasses, at 4% moisture content with a 19-mile-per-hour wind, would burn along a 400-foot front at a rate of about 7 acres per minute (Pers. comm. Dr. Peter Kourtz).

The patterns resulting from many fires can be seen on much of the imagery, and in another example, the increase in area of these patterns has also been monitored. When the Kafue National Park image (No. 8) was obtained on 14 September at 0949.5 hours local time, a characteristically lobate burn pattern was clearly evident in the left centre of the image (Fig. 9, upper right). On the Kabompo/Kaoma image (No. 9) acquired from the adjacent ERTS pass on 3 October at 0955.3 hours (exactly 19 days, 5.8 minutes later) the same burn pattern had increased in size from about 7.5 square miles to about 12.5 square miles (Fig. 4, upper left). Areal increases of other burn patterns are also clearly evident in the vicinity (Fig. 4, lower centre).

DISCUSSION AND CONCLUSIONS

In the study area, the nature of the climate is such that cloud-free ERTS imagery is virtually guaranteed from late April until the end of October, and in fact, during 1972, these conditions persisted well into December. Moreover, conditions in the region are normally ideal for detecting and mapping patterns resulting from grass fires, because of the great contrast between the inherent reflectance from burned and unburned grassland and the fact that from June onwards deciduous tree species are without their impeding foliage.

With the imagery available it was unfortunately not possible to achieve complete sequential coverage of any single entire ERTS-1 frame. However, sequential coverage over a 24-hour period was obtained for some areas due to about 17% sidelap on the 13th, 14th, and 15th of September (Fig. 3), and over a 19-day period on the 14th of September and the 3rd of October (Fig. 4). However, even with the relatively small portions of the ground sequentially covered, it was possible to monitor the increase in area and direction of movement of recent and active grass fires, and to roughly estimate their rates of spread.

Given similar circumstances in terms of image quality, cloud-free conditions and sequential coverage there is no reason why ERTS-1 imagery could not be used to detect, map and monitor fires in

a variety of vegetation types in temperate latitudes. In northern Canada, for example, widespread fires occur in forest and tundra, and although the frequency of cloud-free conditions is considerably less, the greater image side-lap (57% at 60°N) would provide more opportunities for sequential coverage at 24-hour intervals.

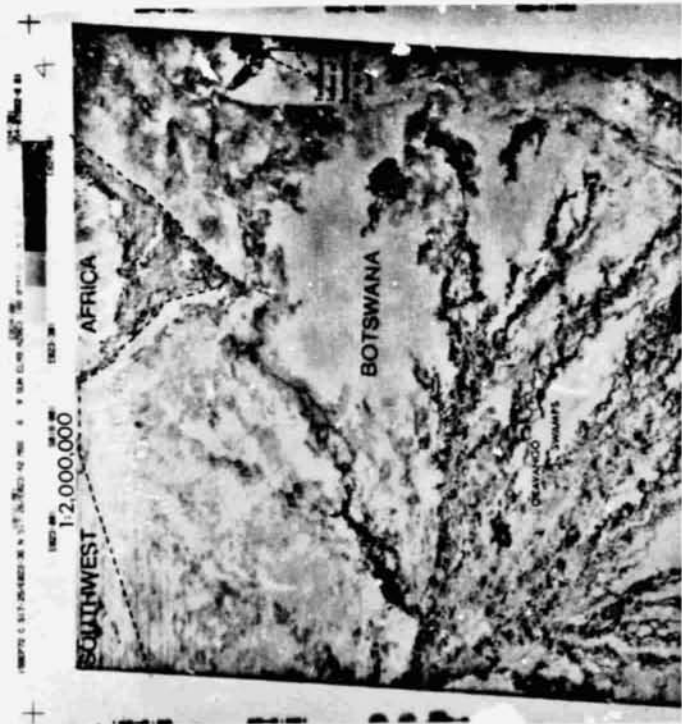
More imagery of the study area has been ordered, and it is hoped to see how fire patterns are obscured by deciduous tree foliage and cloud on imagery acquired during the rainy season. Parallel studies with imagery from northern Canada are also underway.



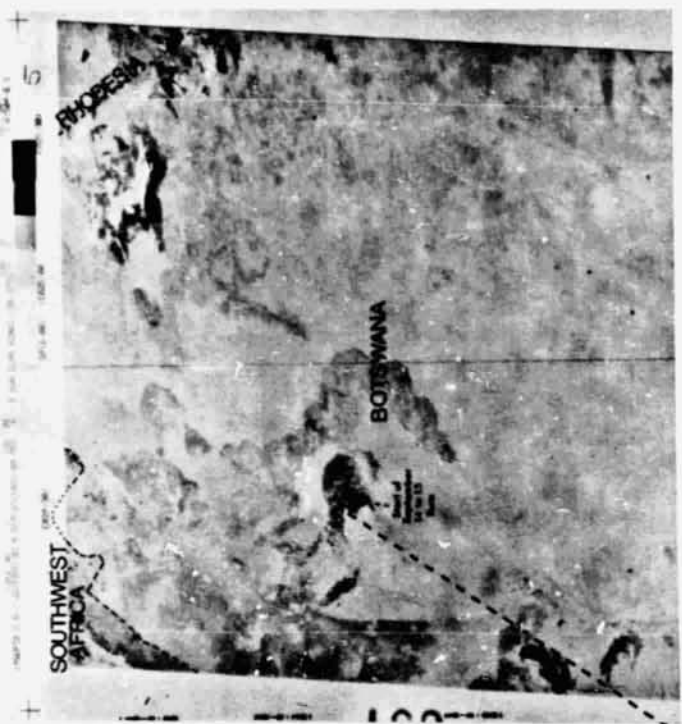
Fig. 1. Location Map of study area.



Fig. 2. ERTS-1, band-6 coverage of study area.



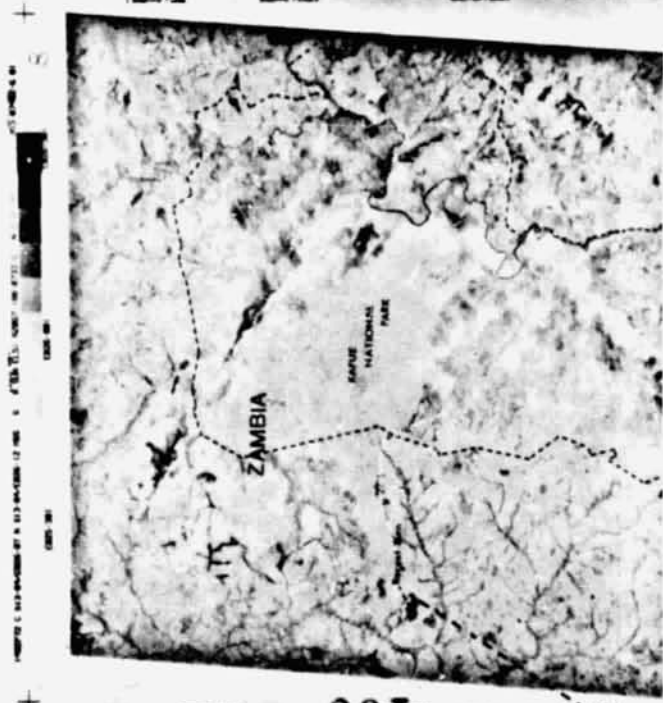
15 Sept. 1972
0956 hrs.



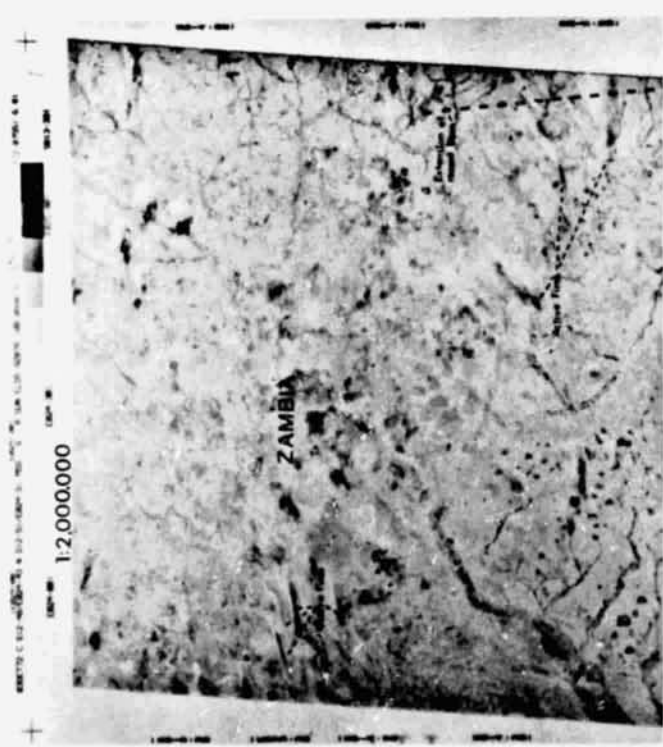
14 Sept. 1972
0950 hrs.



Fig. 3. ERTS-1, band-6 imagery of Botswana burn.



14 Sept. 1972
0949 hrs.



3 Oct. 1972
0955 hrs.



Fig. 4. ERTS-1, band-6 imagery of Zambia burn.

25°05'E