RELATIONSHIPS BETWEEN FIRE FREQUENCY AND WOODY CANOPY COVER IN A SEMI-ARID AFRICAN SAVANNA

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1. INTRODUCTION

Landscape-scale fire patterns result from complex interactions among weather, ignition sources, vegetation type and the biophysical environment (Hargrove *et al*. 2000, Morgan *et al*. 2001, Keane *et al*. 2002, Hudak, Fairbanks & Brockett in press). Patch characteristics (e.g. woody canopy cover) influence fire characteristics, which in turn influence patch characteristics in a spatially and temporally autocorrelated system (Forman 1995, Morgan *et al*. 2001). In some cases fire mediates switches between alternative vegetation types resulting in positive fire-vegetation interactions (Vilà *et al*. 2001), and these interactions are in turn modified by land use practices. Turner *et al*. (1989) simulated relationships between the intensity, frequency and size of disturbance events, and suggested that disturbance characteristics (habitat, intensity, frequency, area affected) have important implications for the management of fire-prone ecosystems. Our objective was to establish relationships between fire frequency and woody canopy cover across a semi-arid savanna that varied in land use and fire management.

2. METHODS

2.1 Study Area

The 250 000 ha study area (centered at: 24° 47'S, 26° 17'E) straddles the Botswana-South Africa border just southeast of Gaborone, Botswana's capital. Climate is semi-arid (mean annual rainfall = 520 mm) with 95% of annual rainfall occurring between October and March. The savanna vegetation varies across the landscape in large part due to soil type patterns and land use. Intensive grazing occurs in Kgatleng and South East Districts of Botswana, hence few fires occur. The South African portion of the study area is divided into two areas. In one cattle ranching is the predominant land use, with occasional fires occurring. The other encompasses the Madikwe Game Reserve (MGR, established 1991), where wild herbivores have been reintroduced on former cattle farms, and a prescribed fire management program implemented since 1992. In MGR fires are ignited to maintain or enhance spatial heterogeneity, reduce woody plant encroachment, ensure fodder for large herbivores, and increase game visibility for tourists.

2.2 Image Processing

Fire occurrences and woody canopy cover were mapped from independent satellite data. Fire scars were mapped from 31 Landsat Multipectral Scanner (MSS) or Thematic Mapper (TM) images. Images were unavailable in some years (1974, 1976-1978, 1981-1985), thus any fires in these years were missed. A supervised classification was used to map burn areas after transforming the raw Landsat bands into their principal components (Richards 1984); details are given in Hudak & Brockett (in review). Topographic shadows caused some misclassifications. Two SPOT Panchromatic images were used to map woody cover in 1990 and 2001, using a textural filter (3x3 standard deviation) that was shown to be a good index of woody canopy cover in this semi-arid savanna region (Hudak & Wessman 1998).

The annual, Landsat-derived burn maps were summed for the periods 1972-1989, 1990-2000 and 1972-2000 to assess the relationship between fire frequency and woody cover, as mapped from 1990 and 2001 SPOT images. The fire zones thus defined were then labeled according to number of fires and land use zone (Fig. 1). Mean and standard deviation statistics of the texture data within each zone were then calculated from the coregistered texture images.

3. RESULTS

Fire frequencies from 1972-1989 were lower than from 1990-2000 in MGR and the surrounding South African farms, with little change in Botswana (Fig. 1). Woody canopy cover patterns were broadly consistent, with woody cover being higher in Botswana than in South Africa in both years. Woody cover was lower, and appeared to decline more, where fire frequency increased; this was especially the case in MGR (Fig. 1). Mean image texture in 2001 declined as the number of fires increased over the full 1972-2000 fire scar mapping period (Fig. 2).

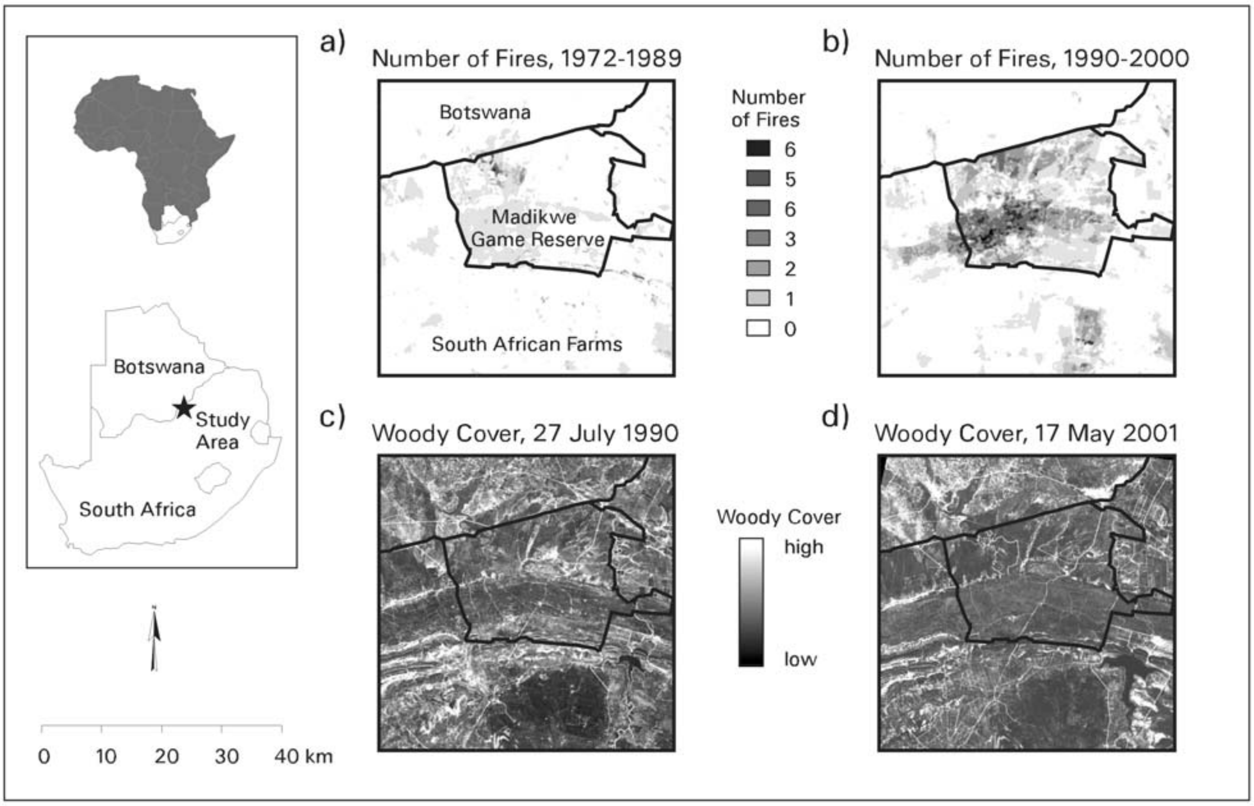

Figure 1. Map of study area location, with number of fires during periods a) 1972-1989 and b) 1990-2000 compared to subsequent woody cover (as indicated by image texture) in c) 1990 and d) 2001.

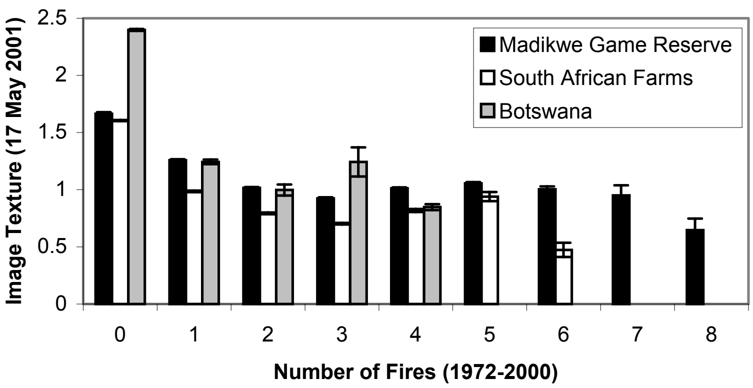

Figure 2. Mean (+SE) image texture in 2001 in relation to number of fires during the preceding 1972-2000 period.

4. DISCUSSION

It is probable that we missed some fires, especially for those years when Landsat data were unavailable. Nevertheless, we had sufficient data to indicate an inverse relationship between fire frequency and woody canopy cover in this semi-arid savanna. The similar patterning between fires and woody cover (Fig. 1) reflects known patterns in landscape composition and is supported by field observations. We did not, however, have field measurements of woody cover, so we could only map and measure relative, not absolute, woody cover and woody cover change.

In addition to relating woody canopy cover to fire frequency we could relate it to time-since-fire, which may indicate nested hierarchical relationships with fire severity. Spatial models also can be used to characterize fire regimes in relation to climate (Rupp, Chapin & Starfield 2000), topography, landscape composition and land use practice (Keane, Parsons & Hessburg 2002, Perry & Enright 2002). A goal is to use these empirical relationships to guide development of mechanistic models (e.g. cellular automata), to more fully explore fire and vegetation interactions for the mutual benefit of ecologists and managers.

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