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Research article

An evaluation of contemporary savanna fire regimes in the Canastra National Park, Brazil: Outcomes of fire suppression policies

Eugênia Kelly Luciano Batista [a, *], Jeremy Russell-Smith [b], Helena França [c], José Eugênio Côrtes Figueira [a]

[a] Department of General Biology, Federal University of Minas Gerais, Brazil
[b] Darwin Centre for Bushfire Research, Charles Darwin University, Darwin, Australia
[c] Engineering Center, Modeling and Applied Social Sciences, Federal University of ABC, Brazil

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A B S T R A C T

Fire has shaped plant evolution and biogeochemical cycles for millions of years in savanna ecosystems, but changes in natural fire regimes promoted by human land use threaten contemporary conservation efforts. In protected areas in the Brazilian savannas (Cerrado), the predominant management policy is fire suppression, reflecting a cultural heritage which considers that fire always has a negative impact on biodiversity. Here we compare resultant fire-regimes in Canastra National Park (CNP), southeast Brazil, associated with areas under and without fire suppression management, based on a 16-year Landsat imagery record. In open grasslands of the Canastra plateau (CP), firefighting is undertaken under government-sanctioned regulation, whereas in the Babilonia sector, non-sanctioned fire management is undertaken by small farmers to promote cattle grazing and cropping. Fire regimes in the Canastra sector are characterized by few, very large, late dry season wildfires recurring at intervals of two years. Fire regimes in lowlands of the Babilonia sector are characterized by many small-scale, starting at the beginning of the dry season (EDS). In Babilonia uplands fire regimes are characterized by higher frequencies of large fires. The study illustrates major challenges for managing fire-prone areas in conflict-of-interest regions. We suggest that management planning in CNP needs to effectively address: i) managing conflicts between CNP managers and local communities; and ii) fire management practices in order to achieve more ecologically sustainable fire regimes. The study has broader implications for conservation management in fire-prone savannas in South America generally.

1. Introduction

Wildfires have performed an important function in the development and expansion of savannas since the late Miocene (Beerling and Osborne, 2006; Edwards et al., 2010; Simon et al., 2009). The climate changes that have taken place from this period have created favorable conditions for the expansion of flammable C4 grasses, which are conducive for carrying fire. In a feedback process, more open landscapes have favored the higher productivity and lower decomposition rates of C4 grasses, promoting the gradual replacement of fire-sensitive woodlands by fire-prone savannas and grasslands (Cerling et al., 1997; Epstein et al., 1997; Keeley and Rundel, 2005; Pagani, 1999).

Most Cerrado plant lineages exhibit an array of syndromes associated with adaptations to fire (Gignoux et al., 1997), and started to diversify ~4 Mya, coinciding with the regional expansion of the savanna biome and dominance of C4 grasses. Despite the influence of fire shaping plant evolution and global biogeochemical cycles in savannas for millions of years, recent changes in fire regimes promoted by accelerating human land use are incurring significant deleterious impacts on some vegetation types, even in fire-prone ecosystems (Andersen et al., 2005; Murphy et al., 2010; Russell-Smith et al., 2012).

The role of human activities in changing fire regime patterns has been considered at a global scale (Bowman et al., 2011, 2009; Chuvieco and Justice, 2010). Modern humans have changed natural fire regimes by clearing forests, promoting grazing, introducing plants, suppressing fires or modifying the season and amount of ignitions. On the one hand the increase in frequency of wildfires

* Corresponding author.
E-mail addresses: biogenia.k@gmail.com (E.K.L. Batista), Jeremy.Russell-Smith@cdu.edu.au (J. Russell-Smith), helena.franca@ufabc.edu.br (H. França), cortes@icb.ufmg.br (J.E.C. Figueira).

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can stimulate the fire-grass cycle, eliminating woody or fire-sensitive species and promoting the maintenance of open ecosystems (Bond and Keeley, 2005; Bond et al., 2005; Ratajczak et al., 2014; Staver et al., 2011). On the other, the suppression of fires for long periods can result in vegetation encroachment (Sankaran et al., 2005; Smit et al., 2010; Murphy and Bowman, 2012; Scott et al., 2012), or result in high-intensity wildfires due to accumulation of large amounts of flammable biomass (D'Antonio and Vitousek, 1992; Vogl, 1979). These destructive fires, in turn, result in high greenhouse gas emissions (Edwards et al., 2015; Heckbert et al., 2012) and biodiversity losses (Andersen et al., 2005; Clarke, 2002; Hoffmann, 1999; Oliveira et al., 2015). International experience indicates that prescribed fire management in fire-prone savanna biomes can substantially reduce the risk of frequent late season fires and resultant impacts on fire-vulnerable biodiversity elements (Brockett et al., 2001; Burrows, 2008; Russell-Smith et al., 2013a; Van Wilgen et al., 2014), and reduce greenhouse emissions (Russell-Smith, 2016; Russell-Smith et al., 2015, 2013b).

The Cerrado covers an area of approximately two million km^2 of Central Brazil and parts of Bolivia and Paraguay (Cardoso Da Silva and Bates, 2002). The biodiversity is impressive and thus it has been identified as a global biodiversity hotspot with more than 10 000 plant species, 161 mammal species, 837 bird species, 120 reptile species and 150 amphibian species, all with high rates of endemism (44, 11.8, 1.4, 20, and 30%, respectively) (Cardoso Da Silva and Bates, 2002; Kier et al., 2005; Klink and Machado, 2005; Myers et al., 2000). The Cerrado is characterized by a mosaic of vegetation types ranging from grasslands, open scrublands to dense woodlands (Coutinho, 2002; Eiten, 1978, 1972), whose spatial distribution is regulated, amongst other factors, by soil type and topography, and patterning in the timing, intensity and frequency of fire (Durigan et al., 1994; Kauffman et al., 1994; Mistry, 1998; Moreira, 2000).

The contemporary Brazilian savanna has been threatened by the absence of a consistent fire policy, and most protected areas in Brazil have continued to apply total fire suppression policies (Durigan and Ratter, 2016; Schmidt et al., 2016). These policies reflect a cultural heritage which considers that fire regimes have a significant negative impact on biodiversity, and ignore the requirement that fire is essential for the dynamics and balance of savanna ecosystems (Figueira et al., 2016). The same assumption, added to the misunderstanding that the savanna biome is a product of forest degradation (Bond and Parr, 2010; Sankaran and Ratnam, 2013), has justified the total suppression of fire in other South American countries (Bilbao et al., 2010; Myers et al., 2006, 2004).

In this study we assess the effects of current Brazilian fire suppression policy on fire regimes in a major Cerrado protected area, the Canastra National Park (CNP). Specifically, we review the historical regional land use from the 18th century, measure fuel accumulation rates and describe contemporary (2000–2015) fire regime characteristics (frequency, seasonality, size distribution) for two regions of CNP with different management policies: the government-managed Canastra region, in which a total fire suppression policy is applied; and the small landholder-managed Babilonia region, where non-sanctioned fire management is undertaken to promote an array of livelihood activities (cattle grazing and cropping). The study illustrates the significant challenges associated with implementing ecologically sustainable fire management programs in Brazilian protected areas, and South America more generally.

2. Methods

2.1. Study area

The Canastra National Park (CNP) was created in April 1972 and currently comprises an area of 197 928 ha. It is located in the State of Minas Gerais, Southeast Brazil, between latitudes 20°05′20″S and 20°11′30″S and longitudes 46°55′10″W and 46°57′25″W (Fig. 1a). CNP extends over six municipalities: São João Batista do Glória, São Roque de Minas, Delfinópolis, Vargem Bonita, Capitólio e Sacramento.

Originally, CNP was restricted to the Canastra Plateau, which extends over an area of 71 503 ha. However, in 2005, when a new Management Plan was released, the CNP was enlarged to cover an additional area of 126 425 ha called the Babilonia region (Fig. 1a). Because of ongoing land use conflicts in the region, and to allow the extraction of mineral resources, recently it has been proposed to restrict the park extent to the Canastra region solely. In January 2017, the grazing of cattle has been permitted in unconsolidated Park lands, and which has revived conflicts with the Chico Mendes Institute for Biodiversity Conservation (ICMBio), the Government Agency responsible for the management of CNP.

The climate is markedly seasonal with high rainfall in the wet season (~1500 mm), from October to April, and a dry season from May through September (~10% of annual precipitation). Temperatures throughout the year vary across the Park, ranging between 16° to 20 °C in the Canastra region, and from 18° to 23 °C in the Babilonia region. According to the Köppen classification, the climate in the Canastra National Park is Cwa, with dry winters and hot summers (Alvares et al., 2013).

The road infrastructure in CNP differs between regions. On the Canastra Plateau the roads are larger but smaller in number, and used as firebreaks by the park managers. The Babilonia region is heavily dissected by small rural, poorly maintained roads connecting farms.

CNP is located in the Cerrado phytogeographical domain, characterized as an area of grassy-woody savanna (IBGE, 2012, 2004; Veloso et al., 1991). There are three main land types in CNP: (1) valleys, predominantly occupied by pastures and agricultural activities (PA, 28% of CNP); (2) natural woody vegetation, comprising wooded savannas (WS, 1% of CNP) on flat to gently undulating terrain, and riparian and mesophilic forests (FO, 9% of CNP) associated with watercourses; and (3) natural grasslands (GR, 41% of CNP) which predominate on flat surfaces of the Canastra Plateau, and rupestrian grasslands (RG, 17% of CNP) on more stony soils.

2.2. Land use and vegetation map

A land cover map of CNP was created by using OLI/Landsat-8 scenes acquired in the late dry season of 2015, and joined to create an image covering the whole protected area. Late dry season imagery was used to avoid the high cloud density typical of rainy seasons. Mapping was performed using Geographic Object-Based Image Analysis (GEOBIA) with the software eCognition Developer 8.7, applying standard techniques (Flanders et al., 2003). Mapping surfaces included standard vegetation indices: Plant Senescence Reflectance Index (PSRI), Normalized Difference Vegetation Index (NDVI), Visible Atmospherically Resistant Index (VARI), Visible Green Index (VIg), Triangular Vegetation Index (TVI), Modified Triangular Vegetation Index (MTVI), Char Soil Index (CSI), Normalized Burn Ratio (NBR), Mid-Infrared Burn Index (MIRBI), Soil Adjusted Vegetation Index (SAVI), Enhanced Vegetation Index (EVI), and elevation and slope surfaces derived from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) imagery.

For this study, we divided the whole area of CNP into three fire management zones (Fig. 1b): (1) Canastra plateau (CP - 71 503ha), a large natural and continuous grassland interspersed with small highly disconnected forest fragments, low density of roads, and government-regulated ‘zero-fire’ policy; (2) the Babilonia plateau