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POLICY DIRECTION

The need for a consistent fire policy for Cerrado conservation

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Summary

1. The Cerrado is a fire-dependent savanna requiring a clear and urgent fire management policy. The extensive misuse of fire for deforestation or pasture management in Brazil has created an overall perception that its use is always deleterious. This view, reinforced by threats of global warming and climatic change, has lead to current policies of fire suppression.

2. Cerrado ecosystems depend on the historical fire regime to maintain their structure, biodiversity and functioning. The suppression of fire has transformed savanna vegetation into forests, causing biodiversity losses and drastic changes in ecological processes.

3. *Policy implications*. The National Fire Policy required by law must be urgently implemented in Brazil, including use of fire for Cerrado conservation in public and private lands on the basis of existing knowledge of indigenous people and scientists. Objective regulations on prescribed burning, land manager training, incentives for fire research and experimentation and a broad campaign to disseminate the benefits of fire for Cerrado conservation should be the cornerstones of the policy. If implemented, the policy can give the biodiversity of the Cerrado a future that has previously been severely threatened by fire suppression.

Key-words: Brazil, conservation, environmental legislation, fire management, fire policy, fire suppression, prescribed burning, savanna

Introduction

Besides rapid land-use conversion, remnants of the most biodiverse savanna in the world – the Cerrado (i.e. the Brazilian savanna biome) – have been severely threatened in the absence of a consistent fire policy. We suggest in this article that the future of the Cerrado depends on clear fire management strategies based on the experience and science-based knowledge. While many nations with fire-dependent ecosystems already prescribe use of fires for conservation, Brazil still does not. Although the new environmental law (the misnamed 'Forest' Code, Law number 12651, in effect since May 2012) has lead to considerable advancements, by legalizing fire management for Cerrado Conservation (Article 38) in protected areas, burning native vegetation outside reserves is illegal. In addition, the National Fire Policy (required by Article 40) – which includes use of fire for conservation – still needs to be elaborated and implemented. At present, controlled fires can be legally applied only to a few protected areas whose management plans include prescribed burning. All remaining Cerrado areas in private properties are prohibited from using fire and are therefore subjected to the consequences of vegetation encroachment (Coutinho 1990; Durigan & Ratter 2006; Scott *et al*. 2012) or of uncontrolled and high-intensity wildfires (Keeley, Fotheringham & Morais 1999; Silveira *et al*. 1999).

The current policies of fire suppression arose as a response to the extensive misuse of fire for deforestation or pasture management in Brazil, particularly over the 20th century. From that period onwards, an overall perception that fire is always deleterious was disseminated, including the misunderstanding that Cerrado is a product of forest degradation (Dean 1997). This idea, in addition to concerns over global warming and climate change, supported current policies of fire suppression (Dias 2006), disregarding the ecological importance of fire in maintaining the diversity of the rich flora and fauna of the Cerrado. Here, we review some basic principles of Cerrado ecology to demonstrate that fire management should be an essential part of a broader strategy to conserve this

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biome. Thenceforth, we point out the most relevant issues to be addressed by a consistent fire policy aimed at Cerrado conservation.

Cerrado ecology and its relationship with fire

The Brazilian Cerrado (savanna) biome is the dominant vegetation of central Brazil, originally covering *c.* 2 million km^2, representing about 25% of the country. It comprises a mosaic of vegetation types forming a structural gradient from grasslands through savanna woodland to forests. Like savannas in other regions of the world, the Cerrado is highly inflammable during the dry season and therefore typically subject to fire. Despite variation in environmental factors such as availability of soil nutrients and water influencing Cerrado vegetation structure, fire has been the most important factor maintaining the biomass gradient of Cerrado types (Coutinho 1990; Mistry 1998), as it is for other savannas in the world (Bond, Woodward & Midgley 2005; Staver, Archibald & Levin 2011). Changes in the historical fire regime, however, can have a negative effect through homogenization of the mosaic. Fire at too high frequencies, intensified by feedback between fire and invasive grasses (Setterfield *et al.* 2010), create grass-dominated landscapes. Conversely, fire suppression results in biome shift and biodiversity losses, with forest vegetation replacing savannas and grasslands (Coutinho 1990; Andersen, Hertog & Woinarski 2006; Bond & Parr 2010; Scott *et al.* 2012).

The effects of fire have long been studied in the Cerrado from various aspects (e.g. reviews in Coutinho 1990; and Mistry 1998). Besides the influences on plant populations and community structure (Hoffmann 1996; Munhoz & Amaral 2010; Sato, Miranda & Maia 2010), these studies have demonstrated the fire factor controlling ecological processes such as gas emissions (Pinto & Bustamante 2010), mineral cycling (Oliveras *et al.* 2013) and plant reproduction (Araújo *et al.* 2013). The effects of fire on distinct faunal groups have also been studied, including large (Prada 2001) and small (Briani *et al.* 2004) mammals, ants (Frizzo, Campos & Vasconcelos 2012; Maravalhas & Vasconcelos 2014), avifauna (Cavalcanti & Alves 1997) and herpetofauna (Costa *et al.* 2013), among others. In general, animal species in savannas are resilient to fire, except under extreme fire regimes (Andersen, Woinarski & Parr 2012). Fire is, therefore, a crucial factor for the maintenance of the structure, biodiversity and functioning of Cerrado ecosystems.

The consequences of fire suppression

Dense uniform tall vegetation (cerradão or forest) has replaced open Cerrado in many sites in the absence of fire (Cardoso *et al.* 2009; Pinheiro & Durigan 2009; Pinheiro, Azevedo & Monteiro 2010). Estimating the proportion of the biome where forest vegetation could never establish even after fire suppression due to shortage or excess of soil water (e.g. high water-table) or nutritional limitations is difficult. On the basis of climate alone, Bond, Woodward & Midgley (2005) predicted that the whole Cerrado biome would be replaced by forest vegetation. Indeed, rapid increase in density and basal area after suppression of fires have been demonstrated by studies of community dynamics over various regions of Brazil: in the Central Plateau (Moreira 2000; Henriques & Hay 2002), in the Cerrado – Amazonian forest transition (Mews, Marimon & Maracahipes 2011), in the transition to the Atlantic Forest in the south-east (Oliveira *et al.* 2014), or even close to the dry Caatinga in the north-east (Roitman, Felfili & Rezende 2008). In addition to structural changes, some of those studies also observed changes in the composition of tree communities, with fire-sensitive species increasing in abundance and some new species arriving, including trees from neighbouring forests. Unfortunately, none of those studies has analyzed the probably more radical changes in the structure and species composition of the ground layer, mentioned by Coutinho (1990). Hundreds of light-demanding herbaceous or shrubby species are lost by shading when cerradão or forest succeeds more open Cerrado after suppression of fire (Fig. 1). Neither changes in Cerrado fauna as a result of such habitat change nor the consequences on ecological processes, such as the decrease in ground water recharge as woody biomass increases (Jackson *et al.* 2005), have been monitored – but their consequences are probably very great.

In addition to biodiversity losses due to vegetation encroachment (Coutinho 1990 for plants; Andersen, Hertog & Woinarski 2006 for ants in Australian savannas), suppression of fires for long periods has been reported to cause high-intensity wildfires due to accumulation of large amounts of inflammable material (Keeley, Fotheringham & Morais 1999), causing high greenhouse gas emissions (Russell-Smith *et al.* 2009) and biodiversity losses (Silveira *et al.* 1999). The consequences of wildfires can be particularly negative in fragmented landscapes, where the habitat as a whole can be simultaneously burned, hindering the escape of animals to unburned sites and temporarily eliminating all sources of food for primary consumers.

Technical, ethical and political obstacles to fire management

In spite of general recognition by ecologists that total suppression of fire – a policy maintained in Brazil for decades – threatens savanna ecosystems, there is still a lack of clear guidelines on how to rectify the situation. Even in other continents, where fire experiments have been carried out and monitored for decades, as in the Kruger Park, South Africa, with fire management since 1954 (van Wilgen, Govender & Biggs 2007), and the Kakadu National Park, Australia, started in 1989 (Andersen, Cook & Williams 2003), among others, there is no single recommendation on how to apply a prescribed fire programme to the savannas. Some fire ecologists argue

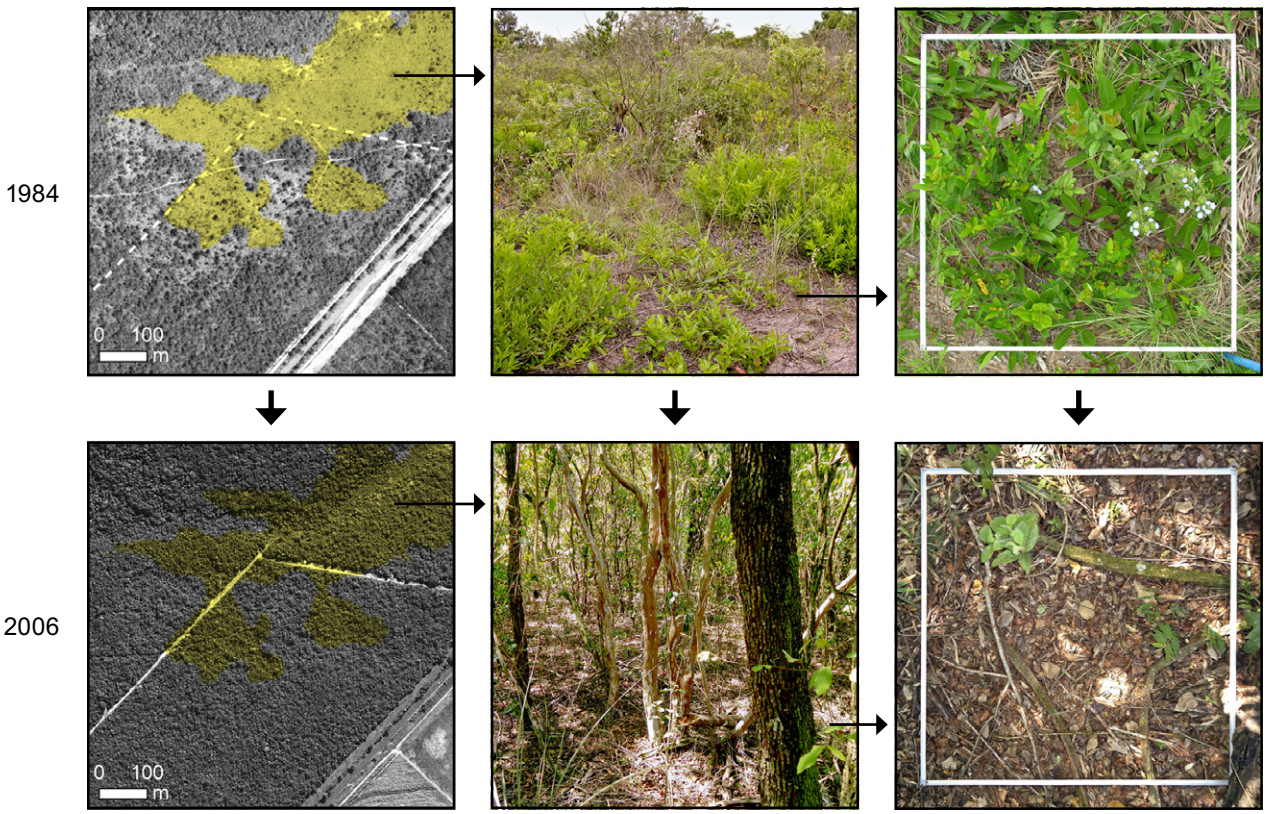

Fig. 1. *Top panels*: a patch (delimited with a yellow colour) of Cerrado grassland from aerial photos in 1984 (left), a view of this vegetation on the ground (centre) and a detail of 1 m^2 of its highly diverse ground layer (right). *Bottom panels*: the same patch protected from fire, 22 years later (left), covered by a dense woody vegetation (centre) and the ground layer restricted to sparse tree seedlings (right). *Vertical arrows*: changes in time. *Horizontal arrows*: changes in scale. The two figures on the left were adapted from Pinheiro & Durigan (2009), who described and quantified these changes at Assis Ecological Station (SP, Brazil).

that fire-prone landscapes depend on a wide range of fire regimes to maintain biodiversity (Martin & Sapsis 1992), so that a single fire regime would not be enough for conservation of the whole species pool in a landscape. This hypothesis, however, has not been confirmed by recent studies, at least for faunal groups (Parr & Andersen 2006; Davies *et al*. 2012; Farnsworth *et al*. 2014; Maravalhas & Vasconcelos 2014), for which maintaining a mosaic of burned and unburned patches seems to be enough.

While the debate on how to manage fire in other savannas of the world flourishes, some decision makers in Brazil still deny that fires in Cerrado are natural, and do not accept that replacement of tropical grassy biomes by forest occurs in the absence of fire. Evidence of natural fires coming from palaeological studies, or records of them started by lightning (e.g. as recorded in the National Parks of Brasília, by Ramos 1995; and Emas, by Ramos-Neto & Pivello 2000), have been disregarded, as well as studies showing that the evolution of plant species in savanna biomes has been influenced by fire and that savannas are not results of forest degradation (Simon *et al*. 2009).

Advocating the deliberate burning of biomass in times of global warming is generally perceived as something reprehensible, almost criminal. The media invariably show burning native vegetation as a disaster and there is no explanation for the public about the positive aspects of controlled fires on fire-adapted ecosystems. Historically, fire-related policies have been condemned on the grounds that fire is destructive. Managers of protected areas are reluctant to prescribe fire in fear of formal punishment or social condemnation.

It is surprising and positive that the new Brazilian environmental law includes the controlled burning of natural ecosystems in protected areas among the exceptions when prohibiting the use of fire, and states that fire management for conservation must be considered in the National Fire Policy (Art. 40). However, time-lag from law enactment to full application may take so long that, if and when it happens, Cerrado encroachment may have crossed the threshold after which ecological losses are irreversible. The risks are particularly high inside protected areas, where fire prevention has been more effective. Since it has been effective but not infallible, uncontrolled wildfires can occur, with negative consequences. In addition, as previously mentioned, the law does not apply to Cerrado remnants in private properties.

Directions for management, science and policymaking

It is certain that fire is essential for maintaining the mosaic of vegetation types in the Cerrado. Studies have

shown that both extremes – fire too often or too seldom – are adverse for conservation of savanna ecosystems and biodiversity, and the goal is to find the right balance. That is not enough, however, to establish an ideal fire regime on a broad scale. Bridging the gap between knowledge and application is the big challenge to be overcome and that depends on addressing very important policy issues and surpassing social barriers.

The challenge for management relies on setting objective criteria for decisions on the use of planned prescribed fires at each individual site. We advocate that these criteria and the ecological metrics to support management decisions should consider the practice of traditional dwellers of savannas, such as the Australian Aboriginals, African tribes and American Indians, who inhabited and burned the vegetation for thousands of years without destroying ecosystems. These people discovered by experience when, how and where to burn, so that the ecosystems never lost their ecological properties – the target outcome of good fire management. Indigenous people, at present, burn the Cerrado for many reasons, such as cultivation of crops, hunting, protection or enhancement of resources, livestock grazing or simply 'cleaning' the vegetation, since they 'feel' that the Cerrado has to be 'renewed' (Mistry *et al.* 2005; Dias 2006; Pivello 2011). Purpose, seasonality and periodicity of fires vary among ethnic groups. On the basis of both indigenous knowledge and ecological studies, Pivello (2011) recommends use of controlled cool fires in a mosaic arrangement, every 4 to 6 years, to reduce the amount of fuel and avoid wildfires in Cerrado. Preserving fire-free forest patches is also important for providing refuges during fire and to maintain biodiversity. Burning at the beginning of the dry season when fuel moisture content is higher is one of the ways to reduce greenhouse gas emissions (Russell-Smith *et al.* 2009). We agree with Pivello (2011) that the existing knowledge from indigenous people or based on experimentation, even if imperfect or incomplete, is enough to base a National Fire Policy to be implemented on an emergency basis, at least inside protected areas.

The challenge for science relies on providing answers for basic questions on how to improve fire management, such as (i) What is the best ecological indicator of the stage at which the ecosystem needs fire? (ii) Is there an ideal season to burn? (iii) Is there an ideal size of fire to minimize possible negative effects on populations of plants and animals? (iv) How to avoid the positive feedback between fire and invasive grasses that increases both and reinforces the deleterious effects of fire? Besides those questions whose answers will inform fire management and policies, scientists should investigate fire impact in the face of climatic changes and habitat fragmentation. Comparative studies between burned and unburned sites are also necessary to provide evidence on the benefits of fire for the biodiversity, ecological processes and ecosystem services in the Cerrado. Besides carrying out those studies, fire ecologists must be pro-active in sharing their knowledge with decision makers and spreading the positive aspects of fire to society as a whole, never neglecting the risk of being considered as pyromaniacs, or of seeing their arguments being misused for those interested in the destructive use of fire.

The decision-making process in all environmental instances in Brazil should address the urgent need for a clear fire management policy and strategies aiming at Cerrado conservation. Objective regulations on prescribed burning based on the existing knowledge, mandatory inclusion of fire in the management plans of protected areas, extensive training for those planning and applying fire in Cerrado vegetation, governmental incentives for research and experimentation on fire, including demonstration sites, and a broad campaign to spread the benefits of fire for Cerrado conservation should be the cornerstones of the National Fire Policy, required by law.

The Cerrado comprises a large portion of the savanna biome, certainly the most severely threatened by land conversion in the last few decades (Beuchle *et al.* 2015). Cerrado remnants are also jeopardized by changes in the historical fire regime that cause biodiversity losses, changes in ecological processes and impairment of ecosystem services at a continental scale. The current policies restricting fire management to protected areas under complex regulations do not help in re-establishing an adequate fire regime for maintaining this diverse mosaic of vegetation types and associated fauna, putting at risk a huge proportion of global biodiversity.

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Data accessibility

Data have not been archived because this article does not contain data.

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