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Fire regime in the Brazilian Savanna: Recent changes, policy and management

Isabel Belloni Schmidt[a,b], Ludivine Eloy[c,d,*]

[a] Departamento de Ecologia/ Instituto de Ciências Biológicas
[b] Universidade de Brasília, Campus Universitário Darcy Ribeiro, Brasília, DF CEP 70.910-900
[c] CNRS UMR Art-Dev 5281, Université Montpellier 3, Site Saint-Charles - Rue Henri Serre, 34090 Montpellier, France
[d] Centro de Desenvolvimento Sustentável, Universidade de Brasília, Campus Universitário Darcy

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ABSTRACT

In 2019 Brazil recorded the highest wildland fire occurrence South America has seen for the last 15 years. Added to the Amazon, the Brazilian savanna (Cerrado) faces changes in fire regimes. Climatic changes and the recent weakening of environmental law enforcement are factors, but historic and large-scale trends and drivers of fire regimes must be analyzed. We discuss ecological and policy drivers of recent changes in fire regimes in the Cerrado, in order to highlight management strategies. The Cerrado has evolved with natural fires and anthropogenic fires are also common for millennia. In the past 50 years, wildfires tend to be concentrated in the late dry season and to occur every two / three years, causing serious damage in fire-sensitive vegetation. Apart from climatic variations, the drivers of wildfires are deforestation and fire suppression policies. Nearly half of the original vegetation of the Cerrado biome has disappeared largely due to agribusiness expansion. Fire is associated with deforestation in two ways: vegetation conversion to monocultures, and lack of fire management in the remaining native vegetation. Indeed, the attempts to exclude fires from this fire-prone ecosystem disrupted traditional fire management. Fire suppression policies lead to increased wildfire risks due to fuel load and the multiplication of sources of ignition (conflicts, roads). The recent advances in Integrated Fire Management in protected areas in the Cerrado are evident. However, the recent budget cuts by the Brazilian government in environmental management and research undermine the chances of decreasing occurrences of wildfires in this biodiversity hotspot.

1. Introduction

Brazil had the highest wildland fire occurrence in South America during the last 15 years (White, 2019), with the highest records in 2019 (+46 % of active fire detected in comparison to 2018[1]). While the world's attention turned to the unprecedented wildfires in the planet's largest rainforest, the Amazon, other South American ecoregions were also submitted to dramatic changes in their fire regime. Climatic variations help explain why wildfires are more numerous and hit larger areas in certain years. This is especially true in fire-prone ecosystems, such as savannas, where longer dry seasons lead to longer fire seasons (Alvarado et al., 2017; Archibald et al., 2013). Although such climatic fluctuations are periodic (e.g. El Niño events during the years of 2004, 2015 and 2016), they tend to become more frequent and extreme due to climate change, clearly pointing to the necessity of better policy and management actions that can help prevent environmental, human health and economic damage caused by wildfires (Jolly et al., 2015).

The 2019 wildfire events in Brazil were also influenced by political changes that decreased the investments in the protection of natural ecosystems, weakening environmental law enforcement, and political rhetoric that promoted deforestation as the only possible way to economic development. These political changes cause direct increases in deforestation, many times associated with wildfires, violence against local communities and environmentalists as well as the certainty of impunity associated with such crimes, in particular in the Amazon[2] .

The Brazilian savanna, known as the Cerrado, is a biodiversity hotspot with the highest rates of deforestation in Brazil, as well as the highest number of wildfires and area burnt (Strassburg et al., 2017) (Fig. 1). Apart from being the most biodiverse savanna in the world, the Cerrado plays an important role in the water production of Amazonian rivers. Numerous watersheds of the Amazonian Basin originate in the Cerrado region, emphasizing the need to consider the continental scale

* Corresponding author.
E-mail address: ludivine.eloy@univ-montp3.fr (L. Eloy).
[1] http://queimadas.dgi.inpe.br/queimadas/portal-static/situacao-atual/.
[2] https://www.bbc.com/news/world-latin-america-49415973

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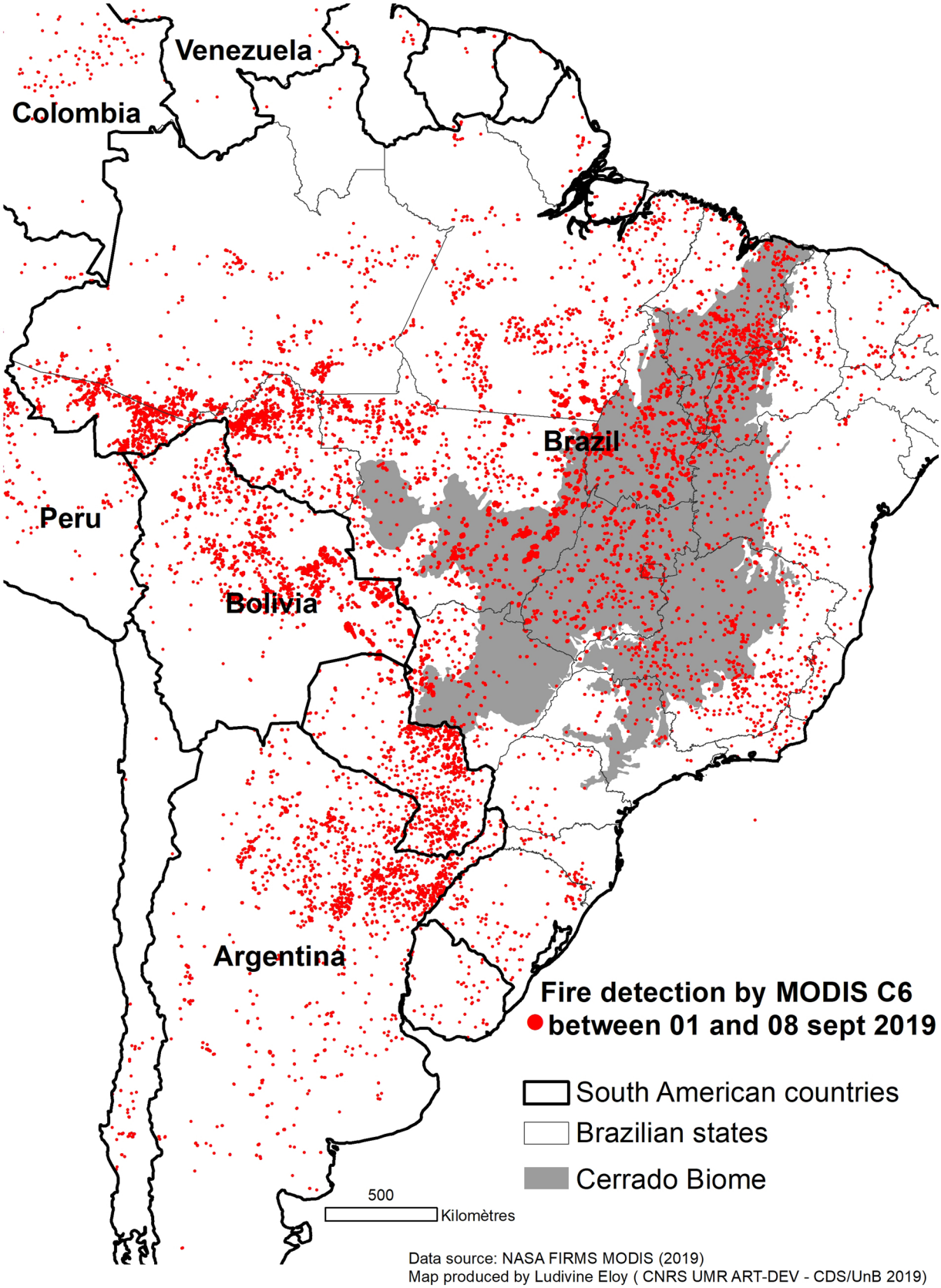

Fig. 1. South America fire detection map between September 1st and 8th, 2019. Data Source: NASA FIRMS (MODIS C6).

when discussing and implementing environment policies (Davidson et al., 2012). The fact that the smoke from Amazonian wildfires has reached the largest South American city, São Paulo, over 2700 km south in August 2019 has helped the general public's understanding of the interdependency among South American bioregions[3] . But only recently the importance of fire management policies for the Cerrado has been recognized (Durigan and Ratter, 2016).

In this paper, we discuss ecological and policy drivers of the recent changes in fire regimes in the Cerrado, highlighting important management strategies, already in process, to reduce the negative impacts of large wildfires.

2. Data and analysis

This paper is based on our first-hand experiences, field notes, published papers and technical reports produced since 2013 through fire management projects in the Cerrado. To better understand fire regime variations within this region, we compiled fire occurrence patterns from 2002 to 2018 considering remote sensing data provided by INPE (Brazilian Institute for Spatial Research[4]). We also compiled data on natural vegetation conversion to agriculture and pasture land since 1995 (data provided by MapBiomas, https://mapbiomas.org/en). To verify the association between wildfires and land use change, we considered wildfire occurrence in the Cerrado region as a whole and compared it to the wildfire occurrence in the largest agricultural frontier of the region - MATOPIBA. MATOPIBA is located in the northeastern part of the Cerrado, comprising parts of four states (Maranhão, Tocantins, Piauí and Bahia), and represents the largest remnant area of conserved Cerrado. However, recently it also has been targeted as the largest agricultural frontier in the world in the past years (Araújo et al., 2019).

3. Fire ecology in Cerrado

The Cerrado has evolved with natural fires for the past 4 million years (Simon et al., 2009), and anthropogenic fires date from at least 4000 years (Pivello, 2011). The effects of fire in Cerrado grasslands and savannas vary according to fire season and frequency. The original vegetation of the Cerrado can be described as a matrix of fire-resistant old-growth grasslands and savannas, with fire-sensitive riparian forest and dry forests imbed within this mosaic of vegetation types (Walter and Ribeiro, 2010). The continuous grass layer that characterizes grasslands and savannas easily promotes fire spread through these vegetation types during the dry season and in the transition between dry and rainy seasons, when natural (lightning) fires mostly occur (Ramos-Neto and Pivello, 2000). As in other savannas (Russell-Smith et al., 2013; van Wilgen et al., 2007), experimental fires indicate that late-dry season fires cause higher tree mortality than early dry-season fires (Miranda, 2010). The mortality of topkill (loss of the aerial plant portion) of adult, sapling and seedling from tree species is related to high fire intensity and flame height as well as tree species phenology, since they mostly flower and fruit during late dry season (Oliveira and Gibbs, 2000). As a result, frequent late-dry season fires favor gramineous over woody species leading to more open vegetation types (Moreira, 2000).

On the other hand, large scale natural fires are rather rare in fire-sensitive forest vegetation, where there is no continuous grass layer (Hoffmann et al., 2009). Therefore, these plants did not evolve with fire and present high mortality when hit by increasingly frequent anthropogenic wildfires (Franco et al., 2014). During the past 50–60 years, the fire regimes in the region have been particularly intensified: fires have become more frequent and more concentrated in the late dry season (August to October). Moreover, large wildfires spread through both fire-resistant and fire-sensitive vegetation and cause high negative ecological effects (Durigan and Ratter, 2016; Fidelis et al., 2018; Schmidt et al., 2018). Such huge wildfires tend to occur every two to three years, for example in 2004, 2007, 2010, 2012, 2015, and 2017 (Fig. 2).

4. Drivers of changes in fire regime

Apart from climatic variations on annual precipitation patterns, two main drivers may help explain the change in fire regimes in the Cerrado: deforestation and fire suppression policies. The first driver is the conversion of natural vegetation. Although occupied by a great diversity of rural populations, the Cerrado was always considered as a "desert" space, ready for agricultural colonization. From the 1960s, a policy of conquest and transformation of this territory was implemented through public investments and support for the migration of farmers from southern regions of Brazil to the western and northern parts of the country. This enabled the development of large-scale agriculture based on sugar cane, eucalyptus, soybean, cotton and maize, propelling the country as a global giant in the export of agricultural products (Eloy et al., 2016). Nearly half of the original vegetation of the Cerrado has already disappeared largely due to the advancing agricultural frontier (Fig. 2). The annual deforestation rate has been more than two times higher in the Cerrado than in the Amazon (Strassburg et al., 2017). Moreover, while 50.8 % of the Amazon was covered by protected areas in 2018, these areas represent barely 13.1 % of the Cerrado.[5]

In private areas in the Cerrado - as in the Amazon - wildfires are commonly associated with deforestation. Our data analysis shows that MATOPIBA (30 % of the Cerrado surface), the most active frontier, represents 40 % of deforestation of the Cerrado biome (MapBioma data) and an average of 57 % of fire detection points between 2000 and 2018 (INPE data). Fire in the Cerrado is associated with deforestation in two ways: opening new areas for monocultures (February–May), and lack of fire management in the remaining native vegetation, causing wildfires during late dry season (August–October) in the natural areas in the vicinity of plantations (Fig. 3).

The second driver of the intensification of fire regimes, especially causing late-dry season large wildfires, was the attempt to implement a zero-fire policy (Durigan and Ratter, 2016). Indeed, the attempts to exclude fires from this fire-prone ecosystem disrupted traditional fire management. Fire suppression policies lead to increased wildfire risks due to large fuel loads (Pereira et al., 2014) and the multiplication of sources of ignition (conflicts, roads, agriculture and pasture management) (Eloy et al., 2018a; Moura et al., 2019). Late-dry season fires tend to reach larger areas, commonly becoming megafires ($>50{,}000$ ha). Such megafires occur due to large amounts of cured fuel load continuously distributed over the landscapes of grasslands and savannas from which fire has been excluded (Fidelis et al., 2018). Under late-dry season climatic conditions of high temperatures (commonly above 30 °C), fast winds and low air humidity (<30 %), these large fires commonly hit and damage also fire-sensitive forest (Schmidt et al., 2018; Durigan and Ratter, 2016), causing very high adult tree mortality (Franco et al., 2014).

Anti-fire discourses also are adopted by powerful agribusiness landowners interested in denigrating fire as part of a political narrative contesting local communities and Indigenous rights to land, which hinders fire management policies (Eloy et al., 2019). Although frequently disconsidered by large landowners and policy makers, seasonal burning patterns of traditional fire management systems in the Cerrado can create a mosaic of areas with different fire histories, preventing the rapid spread of large wildfires through the landscape (Eloy et al., 2018b; Welch et al., 2013), as described in other fire-prone ecosystems

[3] https://www.euronews.com/2019/08/21/amazon-burning-sao-paulo-s-smoke-filled-skies-make-it-dark-at-2-p-m.

[4] http://queimadas.dgi.inpe.br/queimadas/bdqueimadas.

[5] https://www.mma.gov.br/areas-protegidas/cadastro-nacional-de-ucs.

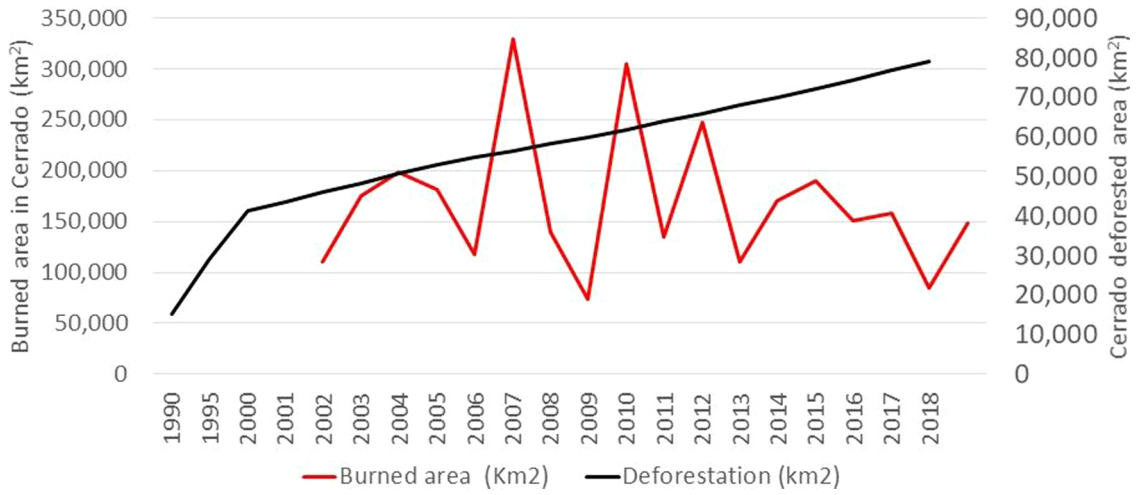

Fig. 2. Evolution of burned area and deforestation in the Cerrado region. Data source: INPE queimadas and MapBiomas.

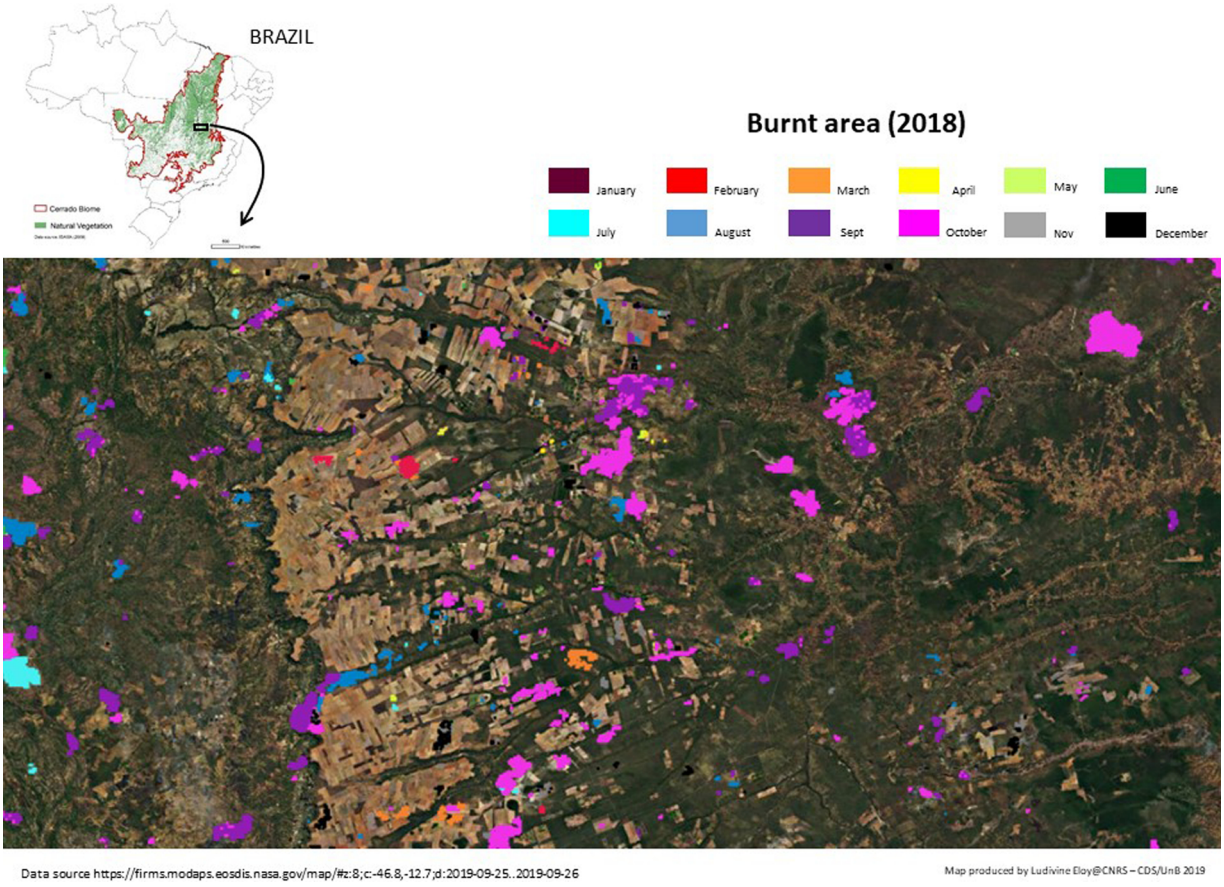

Fig. 3. Fire distribution in an agriculture frontier in the Cerrado region (Bahia and Goiás State).

(Bird et al., 2008; Laris, 2002; Métailié, 2006). However, zero-fire policies criminalize such practices, causing their abandonment and the loss of traditional ecological knowledge related to fire management practices.

5. Innovative experiences

Considering the social environmental consequences of zero-fire policies, the Brazilian government started an Integrated Fire Management (IFM) program in federal Protected Areas (PA) and Indigenous Territories (IT) in 2014. The principles of this IFM program are to consider the use of fire by local communities, to promote controlled early-dry season fires with both productive and conservationist goals in fire-resistant vegetation, creating a mosaic with different fire histories, and to protect fire-sensitive vegetation types from fires. It has recently been implemented in the majority of Cerrado PA and IT. Although incipient, it has changed fire regimes in some of these areas, reducing late-dry season wildfires and helping to protect fire-sensitive vegetation from wildfires (Schmidt et al., 2018). The IFM program is based on hiring and training local community dwellers as fire management agents to perform controlled fires and, especially in the IT, incorporating local ecological knowledge and practices into fire management (Falleiro et al., 2016; Mistry et al., 2018). The main goals of this program, including the recognition of fire-fighters and managers as

a profession in Brazil, are included in a Law proposition under analysis in the federal parliament (PL 11276/2018).

These recent advances in fire management policy and practice in PA and IT in the Cerrado are evident in terms of reduction of wildfires and conflicts in IFM areas. However, this is still an initial program[6] that clearly indicates the need for improvement and acquisition of information and experience (Schmidt et al., 2018). An important point is that most of the Cerrado land is privately owned. For IFM practices to achieve these areas, large investments are necessary to actively involve state governments – since they are responsible by most environmental law regulation and enforcement in private lands – as well as land owners.

Integrated fire management is innovative and important in the Brazilian context as local knowledge is included in fire management, thus providing better results and also raising awareness for conservation and management issues in local populations. The fact that most of Cerrado is private land should result in the development of programs that include private property holders, and ways to expand the current program should be sought.

However, the present weakening of Brazilian environmental policies and research, through budget cuts and political speeches, is a major issue, since the context requires investment in management policies to extend successful experiences to areas under state and private jurisdiction. The complexity of drivers for wildfire in the Cerrado, from natural heterogeneity of climatic features and fuel loads, to climate change and political issues influencing human behavior, make Integrated Fire Management a complex issue, and should need more interaction between science and conservation policy.

CRediT authorship contribution statement

Isabel Belloni Schmidt: Conceptualization, Methodology, Writing the manuscript. **Ludivine Eloy:** Conceptualization, Formal analysis, Methodology, Writing the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Alvarado, S.T., Fornazari, T., Cóstola, A., Morellato, L.P.C., Silva, T.S.F., 2017. Drivers of fire occurrence in a mountainous Brazilian cerrado savanna: tracking long-term fire regimes using remote sensing. Ecol. Indic. 78, 270–281.

Araújo, M.L.Sd., Sano, E.E., Bolfe, É.L., Santos, J.R.N., dos Santos, J.S., Silva, F.B., 2019. Spatiotemporal dynamics of soybean crop in the Matopiba region, Brazil (1990–2015). Land Use Policy 80, 57–67.

Archibald, S., Lehmann, C.E.R., Gómez-Dans, J.L., Bradstock, R.A., 2013. Defining pyromes and global syndromes of fire regimes. Proc. Natl. Acad. Sci. 110, 6442–6447.

Bird, R.B., Bird, D.W., Codding, B.F., Parker, C.H., Jones, J.H., 2008. The "fire stick farming" hypothesis: australian Aboriginal foraging strategies, biodiversity, and anthropogenic fire mosaics. Proc. Natl. Acad. Sci. 105, 14796–14801.

Davidson, E.A., de Araújo, A.C., Artaxo, P., Balch, J.K., Brown, I.F., Bustamante, M.M., Coe, M.T., DeFries, R.S., Keller, M., Longo, M., Munger, J.W., Schroeder, W., Soares-Filho, B.S., Souza, C.M., Wofsy, S.C., 2012. The Amazon basin in transition. Nature 481, 321–328.

Durigan, G., Ratter, J.A., 2016. The need for a consistent fire policy for Cerrado conservation. J. Appl. Ecol. 53, 11–15.

Eloy, L., Aubertin, C., Toni, F., Lúcio, S.L.B., Bosgiraud, M., 2016. On the margins of soy farms: traditional populations and selective environmental policies in the Brazilian Cerrado. J. Peasant Stud. 43, 494–516.

Eloy, L., Bilbao, B., Mistry, J., Schmidt, I.B., 2018a. From fire suppression to fire management: advances and resistances to changes in fire policy in the savannas of Brazil and Venezuela. Geogr. J. 185, 10–22.

Eloy, L., Schmidt, I., Borges, S.L., Ferreira, M.C., Dos Santos, T., 2018b. Seasonal fire management by traditional cattle ranchers prevents the spread of wildfire in the Brazilian Cerrado. Ambio 48, 890–899.

Eloy, L., Hecht, S.B., Steward, A., Mistry, J., 2019. Firing up: policy, Politics and Polemics under new and old burning regimes. Geogr. J. 185, 2–9.

Falleiro, Rd.M., Santana, M.T., Berni, C.R., 2016. As contribuições do manejo integrado do fogo para o controle dos incêndios florestais nas Terras Indígenas do Brasil. Biodiversidade Brasileira 6, 88–105.

Fidelis, A., Alvarado, S.T., Barradas, A.C.S., Pivello, V.R., 2018. The year 2017: megafires and management in the Cerrado. Fire 1, 49.

Franco, A.C., Rossatto, D.R., de Carvalho Ramos Silva, L., da Silva Ferreira, C., 2014. Cerrado vegetation and global change: the role of functional types, resource availability and disturbance in regulating plant community responses to rising CO_2 levels and climate warming. Theor. Exp. Plant Physiol. 26, 19–38.

Hoffmann, W.A., Adasme, R., Haridasan, M., de Carvalho, M.T., Geiger, E.L., Pereira, M.A., Gotsch, S.G., Franco, A.C., 2009. Tree topkill, not mortality, governs the dynamics of savanna–forest boundaries under frequent fire in central Brazil. Ecology 90, 1326–1337.

Jolly, W.M., Cochrane, M.A., Freeborn, P.H., Holden, Z.A., Brown, T.J., Williamson, G.J., Bowman, D.M.J.S., 2015. Climate-induced variations in global wildfire danger from 1979 to 2013. Nat. Commun. 6, 7537.

Laris, P., 2002. Burning the seasonal mosaic: preventive burning strategies in the wooded savanna of southern Mali. Hum. Ecol. 30, 155–186.

Métailié, J.-P., 2006. Mountain landscape, pastoral management and traditional practices in the Northern pyrenees (France). In: Agnoletti, M. (Ed.), The Conservation of Cultural Landscapes. CABI, Florence, Italy, pp. 108–124.

Miranda, H.S., 2010. Efeitos Do Regime De Fogo Sobre a Estrutura De Comunidades De Cerrado: Projeto Fogo. Ibama, Brasília.

Mistry, J., Schmidt, I.B., Eloy, L., Bilbao, B., 2018. New perspectives in fire management in South American savannas: the importance of intercultural governance. Ambio 48, 172–179.

Moreira, A.G., 2000. Effects of fire protection on savanna structure in Central Brazil. J. Biogeogr. 27, 1021–1029.

Moura, L.C., Scariot, A.O., Schmidt, I.B., Beatty, R., Russell-Smith, J., 2019. The legacy of colonial fire management policies on traditional livelihoods and ecological sustainability in savannas: impacts, consequences, new directions. J. Environ. Manage. 232, 600–606.

Oliveira, P.E., Gibbs, P.E., 2000. Reproductive biology of woody plants in a cerrado community of Central Brazil. Flora 195, 311–329.

Pereira Júnior, A., Oliveira, S., Pereira, J., Turkman, M., 2014. Modelling fire frequency in a Cerrado savanna protected area. PLoS One 9, e102380.

Pivello, V.R., 2011. The use of fire in the Cerrado and Amazonian rainforests of Brazil: past and present. The Journal of the Association for Fire Ecology 7, 24–39.

Ramos-Neto, M.B., Pivello, V.R., 2000. Lightning fires in a Brazilian savanna National Park: rethinking management strategies. Environ. Manage. 26, 675–684.

Russell-Smith, J., Cook, G.D., Cooke, P.M., Edwards, A.C., Lendrum, M., Meyer, C., Whitehead, P.J., 2013. Managing fire regimes in north Australian savannas: applying Aboriginal approaches to contemporary global problems. Front. Ecol. Environ. 11, e55–e63.

Schmidt, I.B., Moura, L.C., Ferreira, M.C., Eloy, L., Sampaio, A.B., Dias, P.A., Berlinck, C.N., 2018. Fire management in the Brazilian Savanna: first steps and the way forward. J. Appl. Ecol. 55, 2094–2101.

Simon, M.F., Grether, R., de Queiroz, L.P., Skema, C., Pennington, R.T., Hughes, C.E., 2009. Recent assembly of the Cerrado, a neotropical plant diversity hotspot, by in situ evolution of adaptations to fire. Proc. Natl. Acad. Sci. 106, 20359–20364.

Strassburg, B.B., Brooks, T., Feltran-Barbieri, R., Iribarrem, A., Crouzeilles, R., Loyola, R., Latawiec, A.E., Oliveira Filho, F.J., Scaramuzza, Cd.M., Scarano, F.R., 2017. Moment of truth for the Cerrado hotspot. Nat. Ecol. Evol. 1, 0099.

van Wilgen, B.W., Govender, N., Biggs, H.C., 2007. The contribution of fire research to fire management: a critical review of a long-term experiment in the Kruger National Park, South Africa. Int. J. Wildland Fire 16, 519–530.

Walter, B.M.T., Ribeiro, J.F., 2010. Diversidade fitofisionômica e o papel do fogo no bioma cerrado. In: Miranda, H.S. (Ed.), Efeitos do regime de fogo sobre a estrutura de comunidades de Cerrado: Projeto Fogo. IBAMA, Brasília, Brazil, pp. 59–76.

Welch, J.R., Brondizio, E., Hetrick, S.S., Coimbra Jr, C.E.A., 2013. Indigenous burning as conservation practice: neotropical savanna recovery amid agribusiness deforestation in Central Brazil. PLoS One 8, e81226.

White, B.L.A., 2019. Satellite detection of wildland fires in South Amercia. Floresta 49, 8.

[6] Until 2018, IFM were implemented in 21 Protected Areas and Indigenous Territories in Brazil (Eloy et al., 2018a).