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► **To cite this version:**

Isabel Belloni Schmidt, Ludivine Eloy. Fire regime in the Brazilian Savanna: Recent changes, policy and management. *Flora*, 2020, 268, pp.151613. 10.1016/j.flora.2020.151613 . hal-02626944

HAL Id: hal-02626944

<https://hal.science/hal-02626944>

Submitted on 22 Aug 2022

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1 **Fire regime in the Brazilian Savanna: recent changes, policy and management**

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10 **Highlights**

- 11 • The Brazilian savanna (Cerrado) faces changes in fire regimes;
- 12 • Wildfires in late dry season cause serious damages in fire-sensitive vegetation;
- 13 • Climatic changes, deforestation and fire suppression policies influence fire regimes;
- 14 • Recent advances in Integrated Fire Management are threatened by the current political context

15

16 **Abstract**

17 Wildfires in South America have reached alarming numbers during the last decade. Added to the
18 Amazon, the Brazilian savanna (Cerrado) faces dramatic changes in fire regimes. Climatic changes
19 and the recent weakening of environmental law enforcement are factors, but historic and large-
20 scale trends and drivers of fire regimes must be analyzed. We discuss ecological and policy drivers
21 of recent changes in fire regimes in the Cerrado, in order to highlight management strategies. The
22 Cerrado has evolved with natural fires and anthropogenic fires are also common for millennia. In
23 the past 50 years, wildfires tend to be concentrated in the late dry season and to occur every
24 two/three years, causing serious damage in fire-sensitive vegetation. Apart from climatic
25 variations, the drivers of wildfires are deforestation and fire suppression policies. Nearly half of the
26 original vegetation of the Cerrado biome has disappeared largely due to agribusiness expansion.
27 Fire is associated with deforestation in two ways: vegetation conversion to monocultures, and lack
28 of fire management in the remaining native vegetation. Indeed, the attempts to exclude fires from
29 this fire-prone ecosystem disrupted traditional fire management. Fire suppression policies lead to
30 increased wildfire risks due to fuel load and the multiplication of sources of ignition (conflicts,
31 roads). The recent advances in Integrated Fire Management in protected areas in the Cerrado are
32 evident. However, the recent budget cuts by the Brazilian government in environmental

33 management and research undermine the chances of decreasing occurrences of wildfires in this
34 biodiversity hotspot.

35

36 Keywords: Cerrado; Deforestation; Fire suppression; Integrated Fire Management; Wildfires;
37 Zero-fire policy;

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40 **Introduction**

41 Brazil had the highest wildland fire occurrence in South America during the last 15
42 years (White, 2019), and especially in 2019 (+46% of active fire detected in comparison to
43 2018¹). While the world's attention turned into the unprecedented wildfires in the planet's
44 largest rainforest, the Amazon, other South American ecoregions were also submitted to
45 dramatic changes in their fire regime. Climatic variations help explain why wildfires are more
46 numerous and hit larger areas in certain years. This is especially true in fire-prone
47 ecosystems, such as savannas, where longer dry seasons lead to longer fire seasons (Alvarado
48 et al., 2017; Archibald et al., 2013). Although such climatic fluctuations may be historic, they
49 tend to become more frequent and extreme due to climate change, clearly pointing to the
50 necessity of better policy and management actions that can help prevent environmental,
51 human health and economic damage caused by wildfires (Jolly et al., 2015).

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

58 The Brazilian savanna, known as the Cerrado, is a biodiversity hotspot with the highest
59 rates of deforestation in Brazil, as well as the highest number of wildfires and area burnt
60 (Strassburg et al., 2017) (Figure 1). Apart from being the most biodiverse savanna in the world, the
61 Cerrado plays an important role in the water production of Amazonian rivers. Numerous

¹ <http://queimadas.dgi.inpe.br/queimadas/portal-static/situacao-atual/>

² <https://www.bbc.com/news/world-latin-america-49415973>

62 watersheds of the Amazonian Basin come from the Cerrado region, emphasizing the need to
 63 consider the continental scale when discussing and implementing environment policies (Davidson
 64 et al., 2012). The fact that the smoke from Amazonian wildfires has reached the largest South
 65 American city, São Paulo, over 2,700 km south in August 2019 has helped the general public's
 66 understanding of the interdependency among South American bioregions³. But only recently the
 67 importance of fire management policies for the Cerrado has been recognized (Durigan and Ratter,
 68 2016).

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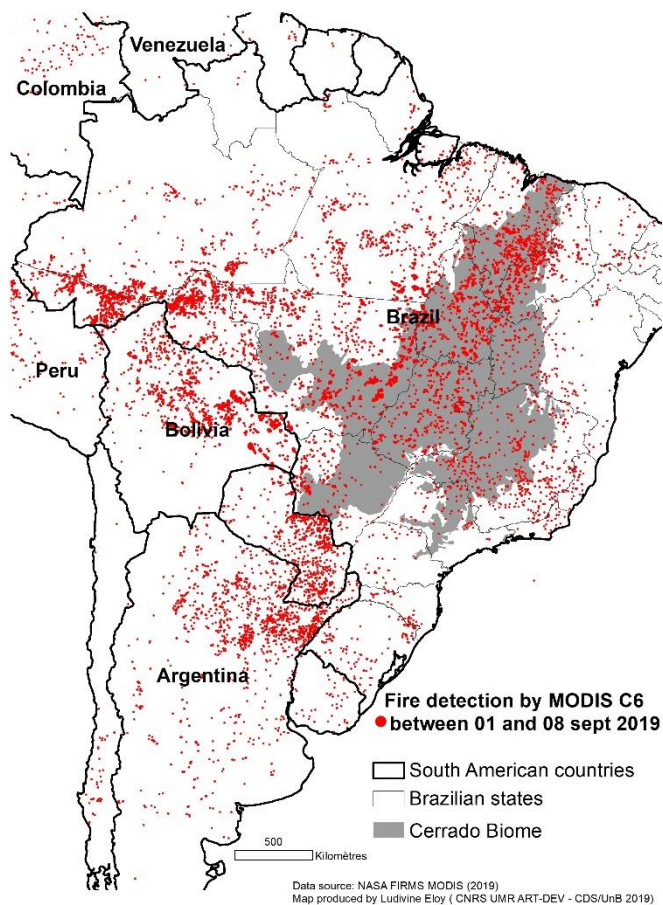
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Fig. 1. South America fire detection map between September 1st and 8th, 2019. Data Source: NASA FIRMS (MODIS C6).

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

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

93

94 **Data and analysis**

95 This paper is based on our first-hand experiences, field notes, published papers and
96 technical reports produced since 2013 through a fire management projects in the Cerrado. To better
97 understand fire regime variations within this region, we compiled fire occurrence patterns from
98 2002 to 2018 considering remote sensing data provided by INPE (Brazilian Institute for Spatial
99 Research⁴). We also compiled data on natural vegetation conversion to agriculture and pastureland
100 since 1995 (data provided by MapBiomas, <https://mapbiomas.org/en>). To verify the association
101 between wildfires and land use change, we considered wildfire occurrence in the Cerrado region as
102 a whole and compared it to the wildfire occurrence in the largest agricultural frontier of the region
103 - MATOPIBA. MATOPIBA is located in the northeastern part of the Cerrado, comprising parts
104 of four states (Maranhão, Tocantins, Piauí and Bahia), and represents the largest remnant area of
105 conserved Cerrado. However, recently it also has been targeted as the largest agricultural frontier
106 in the world in the past years (Araújo et al., 2019).

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108 **Fire Ecology in Cerrado**

109 The Cerrado has evolved with natural fires for the past 4 million years (Simon et al., 2009),
110 and anthropogenic fires date from at least 4,000 years (Pivello, 2011). The effects of fire in
111 Cerrado grasslands and savannas vary according to fire season and frequency. The original
112 vegetation of the Cerrado can be described as a matrix of fire-resistant old-growth grasslands and
113 savannas, with fire-sensitive riparian forest and dry forests imbed within this mosaic of vegetation
114 types (Walter and Ribeiro, 2010). The continuous grass layer that characterizes grasslands and
115 savannas easily promotes fire spread through these vegetation types during the dry season and in
116 the transition between dry and rainy seasons, when natural (lightning) fires mostly occur (Ramos-
117 Neto and Pivello, 2000). As in other savannas (Russell-Smith et al., 2013; van Wilgen et al., 2007),
118 experimental fires indicate that late-dry season fires cause higher tree mortality than early dry-

⁴ <http://queimadas.dgi.inpe.br/queimadas/bdqueimadas>

119 season fires (Miranda, 2010). The mortality of topkill (lost of the aerial plant portion) of adult,
 120 sapling and seedling from tree species are related to high fire intensity and flame height as well as
 121 tree species phenology, since they mostly flower and fruit during late dry season (Oliveira and
 122 Gibbs, 2000). As a result, frequent late-dry season fires favor gramineous over woody species
 123 leading to more open vegetation types (Moreira, 2000).

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

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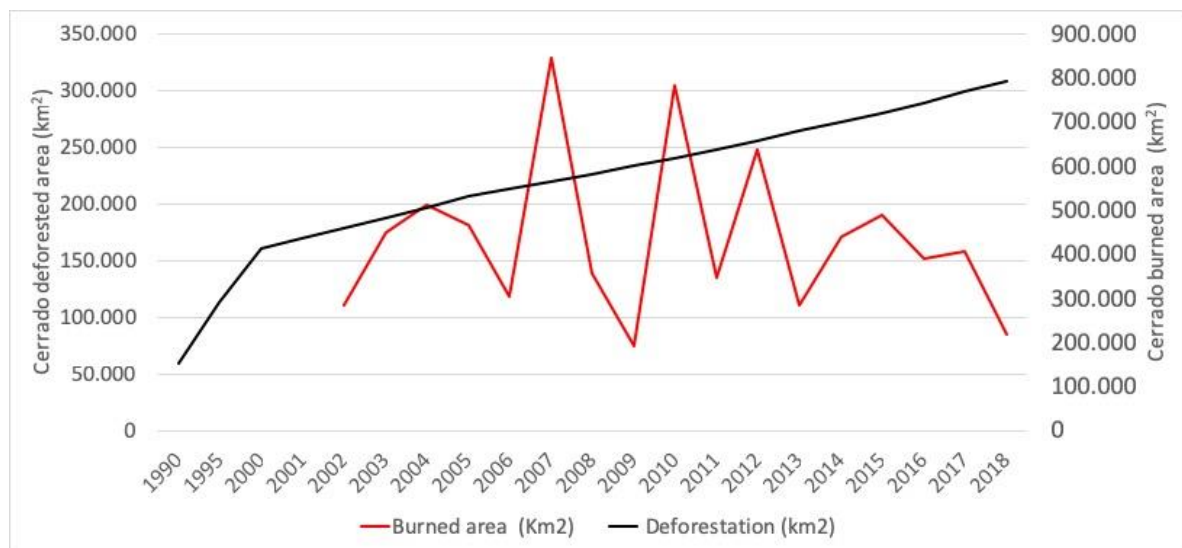
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Fig. 2. Evolution of burned area and deforestation in the Cerrado region. Data source: INPE queimadas and MapBiomias

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151 Drivers of changes in fire regime

152 Apart from climatic variations on annual precipitation patterns, two main drivers may help
153 explain the change in fire regimes in the Cerrado: deforestation and fire suppression policies. The
154 first driver is the conversion of natural vegetation. Although occupied by a great diversity of rural
155 populations, the Cerrado was always considered as a desert space, ready for agricultural
156 colonization. From the 1960s, a policy of conquest and development of this territory was
157 implemented through public investments and support for the migration of farmers from southern
158 regions of Brazil to the western and northern parts of the country. This enabled the development of
159 large-scale agriculture based on sugar cane, eucalyptus, soybean, cotton and maize, propelling the
160 country as a global giant in the export of agricultural products (Eloy et al., 2016). Nearly half of
161 the original vegetation of the Cerrado has already disappeared largely due to the advancing
162 agricultural frontier (Figure 2). The annual deforestation rate has been more than two times higher
163 in the Cerrado than in the Amazon (Strassburg et al. 2017). Moreover, while 50.8% of the Amazon
164 was covered by protected areas in 2018, these areas represent barely 13.1% of the Cerrado⁵.

165 In private areas in the Cerrado - as in the Amazon - wildfires are commonly associated with
166 deforestation . Our data analysis shows that MATOPIBA (30% of the Cerrado surface), the most
167 active frontier, represents 40% of deforestation of the Cerrado biome (MapBioma data) and an
168 average of 57% of fire detection points during (INPE data) between 2000 and 2018. Fire in the
169 Cerrado is associated with deforestation in two ways: opening new areas for monocultures
170 (February–May), and lack of fire management in the remaining native vegetation, causing wildfires
171 during late dry season (August–October) in the natural areas in the vicinity of plantations (Figure
172 3).

173 The second driver of the intensification of fire regimes, especially causing late-dry season
174 large wildfires, was the attempt to implement a zero-fire policy (Durigan and Ratter, 2016). Indeed,
175 the attempts to exclude fires from this fire-prone ecosystem disrupted traditional fire management.
176 Fire suppression policies lead to increased wildfire risks due to large fuel load (Pereira Júnior et al.,
177 2014) and the multiplication of sources of ignition (conflicts, roads, agriculture and pasture
178 management) (Eloy et al., 2018a; Moura et al., 2019). Late dry season fires tend to reach larger
179 areas, commonly becoming megafires (>50,000 hectares). Such megafires occur due to large

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

180 amounts of cured fuel load continuously distributed over the landscapes of grasslands and savannas
 181 from which fire has been excluded (Fidelis et al., 2018). Under late-dry season climatic conditions
 182 of high temperatures (commonly above 30 °C), fast winds and low air humidity (<30%), these
 183 large fires commonly hit and damage also fire-sensitive forest (Schmidt et al., 2018; Durigan and
 184 Ratter, 2016), causing very high adult tree mortality (Franco et al., 2014).

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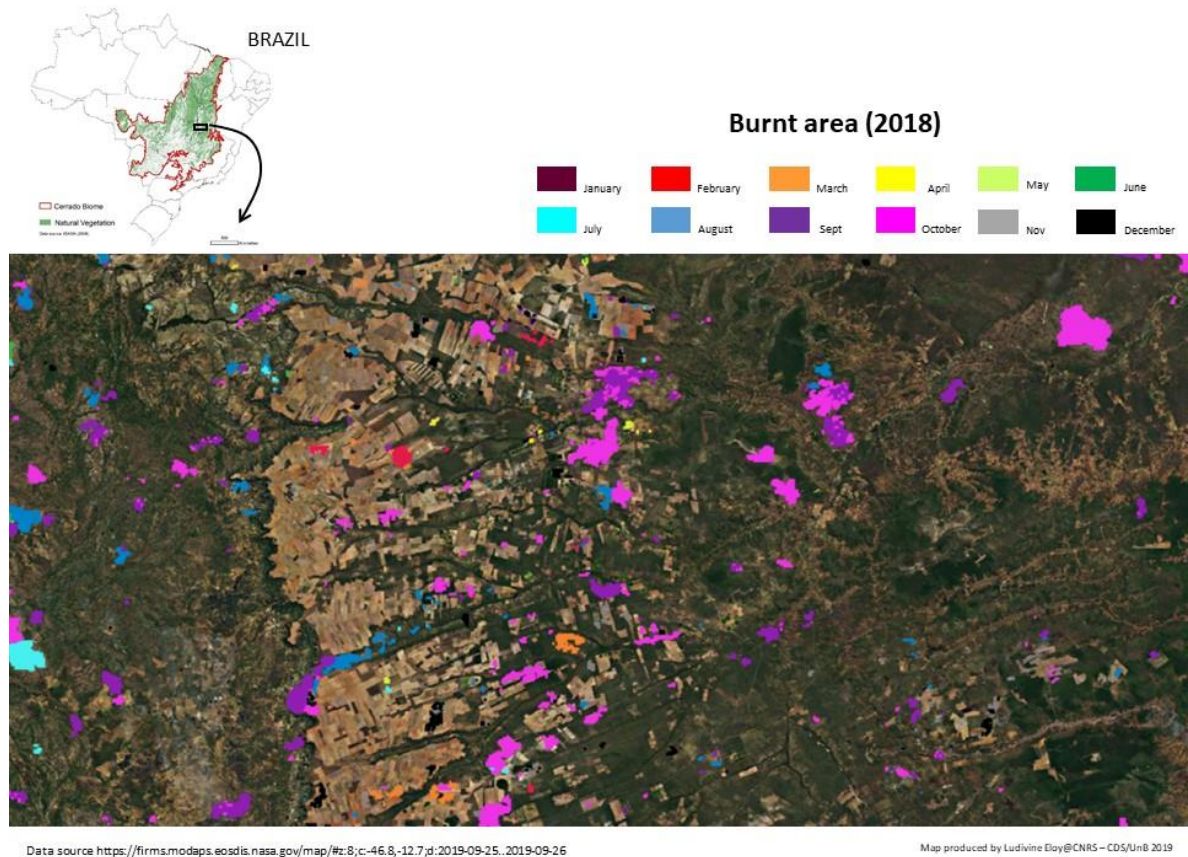
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202 Figure 3: Fire distribution in an agriculture frontier in the Cerrado region (Bahia and Goiás State)

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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 wildfire through the landscape (Eloy et al., 2018b; Welch et al., 2013), as described in other fire-prone ecosystems (Bird et al., 2008; Laris, 2002; Métaillé,

211 2006). However, zero-fire policies criminalize such practices, causing their abandonment and the
212 loss of traditional ecological knowledge related to fire management practices.

213

214 **Innovative experiences**

215 Considering the social environmental consequences of zero-fire policies, the Brazilian
216 government started an Integrated Fire Management (IFM) program in federal Protected Areas (PA)
217 and Indigenous Territories (IT) in 2014. The principles of this IFM program are to consider the use
218 of fire by local communities, to promote controlled early-dry season fires with both productive and
219 conservationist goals in fire-resistant vegetation, creating a mosaic with different fire histories, and
220 to protect fire-sensitive vegetation types from fires. It has recently been implemented in the
221 majority of Cerrado PA and IT. Although incipient, it has changed fire regimes in some of these
222 areas, reducing late-dry season wildfires and helping to protect fire-sensitive vegetation from
223 wildfires (Schmidt et al., 2018). The IFM program is based on hiring and training local community
224 dwellers as fire management agents to perform controlled fires and, especially in the IT,
225 incorporating local ecological knowledge and practices into fire management (Falleiro et al., 2016;
226 Mistry et al., 2018). The main goals of this program, including the recognition of fire-fighters and
227 managers as a profession in Brazil, are included in a Law proposition under analysis in the federal
228 parliament (PL 11276/2018).

229 These recent advances in fire management policy and practice in PA and IT in the Cerrado
230 are evident (reduction of wildfires and conflicts in IFM areas), however, this is still an initial
231 program⁶ that clearly indicates the need for improvement and acquisition of information and
232 experience (Schmidt et al., 2018). An important point is that most of the Cerrado land is privately
233 owned. For IFM practices to achieve these areas, large investments are necessary to actively
234 involve state governments – since they are responsible by most environmental law regulation and
235 enforcement in private lands – as well as land owners.

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

⁶ In 2018, IFM were implemented in 21 Protected areas in Brazil (Eloy et al. 2018a).

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

248

249 **Acknowledgements**

250 This work has benefited from funds from GIZ (83198593), FAP/DF (0193001481/2017),
251 FAPESP (JP 2015/06743-0), Cnpq (441951/2018-0), International Mobility Grant from
252 CNRS/INSHS (France), CAPES (Ciências Sem Fronteiras), and supported by ICMBio,
253 Naturatins and Prevfogo/Ibama and Institute of Research for Development (IRD, France).
254 We also thank Prof. James Taylor for his thorough English language editing.

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346

347 Figure captions

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

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

352 Figure 3: Fire distribution in an agriculture frontier in the Cerrado region (Bahia and Goiás State)

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