Implementation of Integrated Fire Management in Brazilian Federal Protected Areas: Results and Perspectives

Christian Niel Berlinck[1] *& Luanne Helena Agusto Lima*[1]

Recebido em 22/07/2020 – Aceito em 22/09/2020

[1] Instituto Chico Mendes de Conservação da Biodiversidade/ICMBio. Brasil. <christian.berlinck@icmbio.gov.br, luanne.lima@icmbio.gov.br>.

ABSTRACT – The implementation of the integrated fire management in Brazil transformed fire management into federal protected areas, integrating ecological and socio-cultural dimensions. The results obtained in the first years of implementation are promising with a reduction in the area affected by fire and conflicts with communities, enhancing the conservation of socio-biodiversity. This article is the result of a lecture at the 7th International Wildland Fire Conference and aims to present the Integrated Fire Management and its results in Brazil, mainly in the Cerrado and in the Amazon. We highlight three protected areas: Serra da Canastra National Park, Serra Geral do Tocantins Ecological Station and Campos Amazonicos National Park. Some protected areas in other biomes have been cited to illustrate preliminary activities. The results achieved reflect the integration between government, research and society, and served as a basis and experience for the drafting of the National Integrated Fire Management Policy.

Keywords: Brazilian protected areas; fire management; wildfire; prescribed burn.

Implementação do Manejo Integrado do Fogo em Unidades de Conservação Federais no Brasil: Resultados e Perspectivas

RESUMO – A implementação do manejo integrado do fogo no Brasil transformou a gestão do fogo em áreas protegidas federais, integrando as dimensões ecológicas e socioculturais. Os resultados obtidos nos primeiros anos de implementação são promissores com redução da área atingida por incêndio e de conflitos com comunidades, potencializando a conservação da sociobiodiversidade. Este artigo é consequência de uma palestra na 7th *International Wildland Fire Conference* e objetiva apresentar o manejo integrado do fogo e seus resultados no Brasil, principalmente no Cerrado e na Amazônia. Destacamos três áreas protegidas: Parque Nacional da Serra da Canastra, Estação Ecológica da Serra Geral do Tocantins e Parque Nacional dos Campos Amazônicos. Algumas áreas protegidas em outros biomas foram citadas para ilustrar atividades preliminares. Os resultados conquistados refletem a integração entre governo, pesquisa e sociedade, e serviram como base e experiência para a redação da minuta de Política Nacional de Manejo Integrado do Fogo.

Palavras-chave: Áreas protegidas brasileiras; manejo de fogo; incêndios; queimas prescritas.

Implementación de Manejo Integrado de Incendios en Unidades de Conservación Federales de Brasil: Resultados y Perspectivas

RESUMEN – La implementación del manejo integral del fuego en Brasil modificó la gestión del fuego en áreas protegidas federales, integrando dimensiones ecológicas y socioculturales. Los resultados obtenidos en los primeros años de implementación son prometedores con una reducción del área afectada por incendios y de conflictos con las comunidades, potenciando la conservación de la sociobiodiversidad. Este artículo es el resultado de una ponencia en la 7ma Conferencia Internacional sobre Incendios Forestales y tiene como objetivo presentar el Manejo Integral del Fuego y sus resultados en Brasil, principalmente en el Cerrado y en la Amazonía. Destacamos tres áreas protegidas: Parque Nacional Serra da Canastra, Estación Ecológica Serra Geral do Tocantins y Parque Nacional Campos Amazónicos. Se han citado algunas áreas protegidas en otros biomas para ilustrar las actividades preliminares. Los resultados alcanzados reflejan la integración entre gobierno, investigación y sociedad, y sirvieron de base y experiencia para la elaboración de la Política Nacional de Manejo Integral del Fuego.

Palabras clave: Áreas protegidas brasileñas; manejo del fuego; incendios forestales; quema prescrita.

Historical and legal context

The history of Brazilian environmental regulations for fire management begins in Colonial Brazil with the *Regimento do Pau-Brasil* (1605), the *Regimento da Relação do Rio de Janeiro* (1751) and the *Ordens para Preservação de Madeiras Navais* in 1795, aiming at preventing economic damage. During the Empire period, legislation began to show ecological concern, but the economic and social control still stands out, for examples: Land Law (Law n. 601/1850), the Decree that regulates fire extinguishing services (Decree n. 1775/1856) and the Law that defined the act of setting fire as a crime (Law n. 3311/1886) (Garda & Berlinck, 2018), influencing most of the followed legislation.

In the Republican period, Decree n. 4421/1921 created the Brazilian Forest Service emphasizing the need to defend forests from fire (Garda & Berlinck, 2018). Subsequently, Brazil went through four stages of environmental political maturation (Monosowski, 1989): management of natural resources, control of environmental pollution, territorial planning and integrated management of natural resources. The latter was characterized by the intention of integrated environmental management with the participation of government agencies, the private sector and civil society (National Environment Policy and National Environment System – Law n. 6938/81), and culminated in the Brazilian Constitution of 1988 with the Brazilian State and Society sharing responsibilities for environmental conservation.

In this perspective, the National Parks Regulation (Decree n. 84017/1979) begins to present a new approach to fire management in Brazil, despite prohibiting practices that can cause fires, it allows the use of fire as a management technique. Subsequently, the National Environment Council promulgates a Resolution authorizing the use of fire as an element of ecological management (CONAMA n. 11/1988). This vision was consolidated by the New Brazilian Forest Code (Law n. 12651/2012) with fire as a tool for the conservation management of native vegetation whose ecological characteristics are evolutionarily associated with the occurrence of fire. Thus, Brazil follows the global trend of working from the perspective of Integrated Fire Management (IFM) to prevent wildfires (Garda & Berlinck, 2018), migrating from the "fire exclusion" paradigm to fire as an ecological factor that can favor conservation socio-biodiversity.

Historically, fire exclusion and control actions have been prioritized, rather than prevention and management, with contestable efficiency and the occurrence of large fires, as in the Parque Nacional das Emas in 2010 (123,200 hectares burned, 93% of the Park), in the Chapada dos Veadeiros National Park in 2017 (85,500ha, 36% of the Park) and the Chapada dos Guimarães National Park in 2019 (7,250ha, 22% of the Park).

The exclusion of fire, even of natural origin, coupled with the departure of rural communities with reduced use of environments, added to the difficulties in authorizing the use of fire to maintain their livelihoods, has intensified conflicts, which resulted in accumulation of fuel in large continuous areas and in occurrence of fire at the end of the dry season, when fires are more intense, severe, of large proportions and difficult to control. This altered the natural fire regime causing loss of biodiversity, soil, water and climate change. This scenario can be aggravated, on a global scale, with the growth of burning season, the number of days without precipitation and burned area, which is observed in Brazil as well (Jolly *et al*., 2015).

Brazil started to manage fire in federal protected areas in the perspective of IFM from 2010 decade. These process was favored by the assessment of the paths taken by countries such as Australia, USA and South Africa, and the finding that the exclusion of fire was altering the environments and landscapes that were the objects of creation of protected areas, such as Grande Sertão Veredas National Park and Aparados da Serra National Park (corroborating with Ribeiro & Walter, 2008).

Integrated Fire Management in Federal Protected Areas

IFM considers science and society in a holistic approach to fire issues, integrating biological, environmental, social, cultural, economic and political interactions (Kaufmann *et al*., 2003). Myers (2006) considers fire management as the decisions and actions available to prevent, control and use fire, and that the management that was historically being applied would hardly solve the problem of wildfire or reestablish the ecologically appropriate fire regime in places where fire is

necessary. In order to achieve these objectives, there is an inevitable integration of socio-cultural realities and ecological needs.

With the legal difficulties overcome, we sought to discuss and understand the technical and scientific support. The federal government through the Chico Mendes Institute for Biodiversity Conservation (ICMBio) held two international seminars on IFM in protected areas, in 2013 and 2016, with specialists in fire ecology from different countries. The Brazilian Biodiversity, scientific journal of ICMBio, published two specific volumes with articles that discussed the negative and positive impacts of fire on brazilian biomes (https://www.icmbio.gov.br/revistaeletronica/index.php/BioBR/issue/view/15 e https://www.icmbio.gov.br/revistaeletronica/index.php/BioBR/issue/view/44).

It is necessary to identify the types of present environments (phytophysiognomies) and considerate the fire history of each protected area, to define which techniques and approaches are the most appropriate for the implementation of the IFM in Brazilian protected areas. Myers (2006) proposed four subdivisions for global ecosystems: fire-dependent, fire-sensitive, fire-independent and fire influenced. For Brazil, Hardesty *et al*. (2005) presents the Brazilian Biomes: Amazon Forest and the Atlantic Forest, as sensitive environments, the Caatinga as independent and, as dependent/influenced environments, the Pantanal, the Cerrado and the Pampas (Figure 1). These are macro scale, landscape, and that in each of these Biomes there are several phytophysiognomies with different sensitivities and adaptations to fire, as Figure 2 explains for the Cerrado.

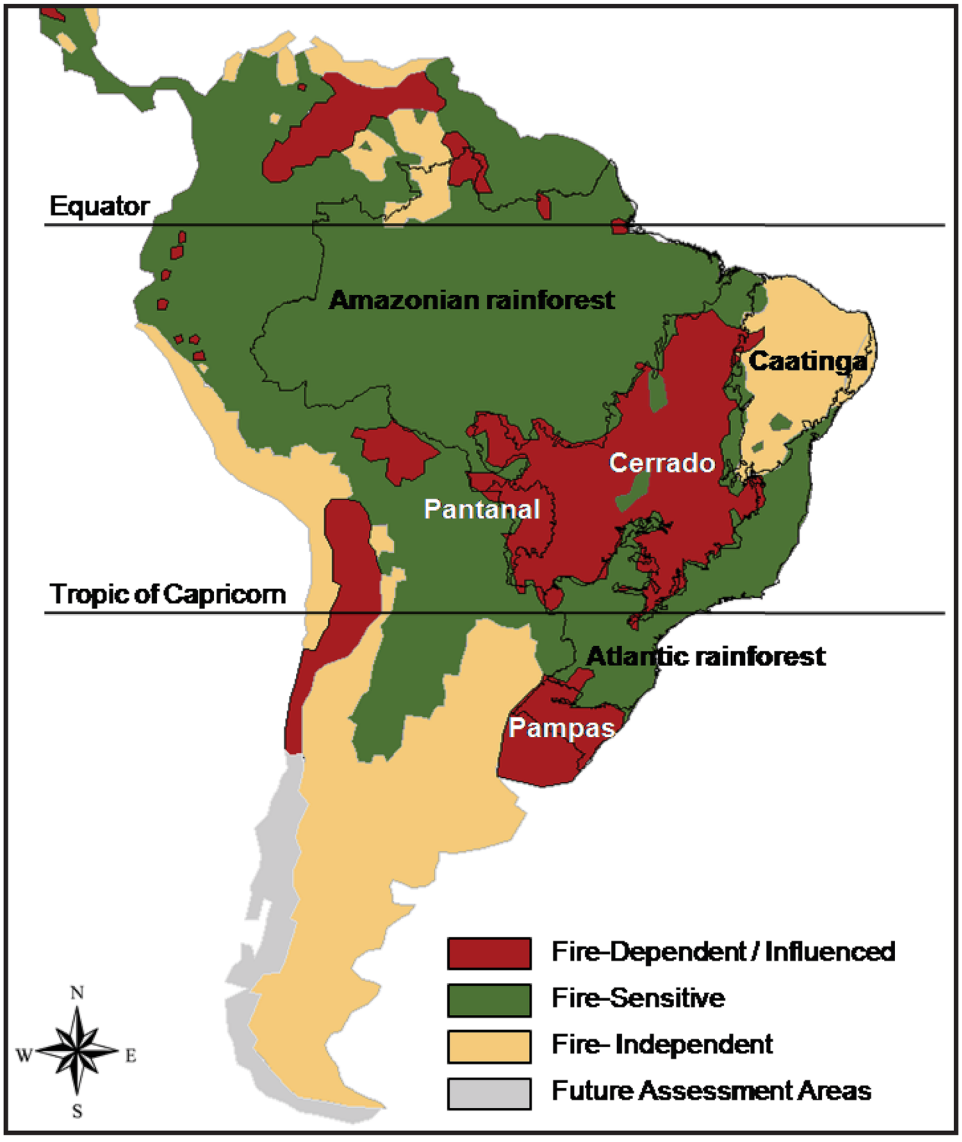

Figure 1 – Brazilian biomes and their relationship with fire (Hardesty *et al*., 2005).

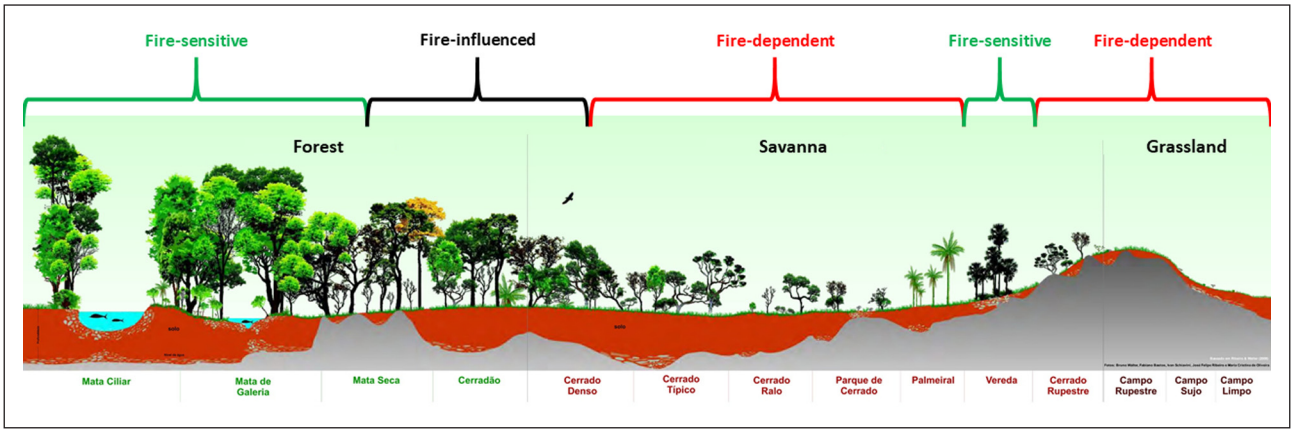

Figure 2 – Phytophysiognomies of the Cerrado biome divided into Fire-sensitive, fire-dependent and fire-influenced (adapted from Ribeiro & Walter, 2008; and Walter & Ribeiro, 2010).

It is important to define that the IFM involves prevention activities with and without fire usage for the construction of firebreaks, fuel control and protection of sensitive environments and species, as well as favoring adapted environments and species, including the involvement of communities in processes of environmental education, training, decision making, standardization and authorization of fire usage. In saying that it also important to consider the firefighting action aiming at the wildfire exclusion.

As each protected area is composed of a mosaic of environments with different ecological responses to fire, superimposed by different types of use, direct and indirect, with its own fire history, the approaches and activities are individualized requiring individual planning.

With initial objectives of: i) conservation of socio-biodiversity; ii) reduction of the area affected by fires; iii) change of the season and frequency of occurrence; iv) protection of sensitive environments and species; v) reduction of greenhouse gas emissions and vi) reduction in combat expenses, ICMBio started the implementation of the IFM in federal protected area, combining fire ecology, respecting the cultural and economic needs of fire. With this, it seeks to balance environmental and social needs, guided by monitoring, in the search for a sustainable use of fire, socially fair and environmentally balanced.

It is natural that the first steps occurred in the Cerrado Biome, Brazilian Savanna widely considered adapted to the presence of fire. The first areas are in the Jalapão region, with technical and financial support from the Cerrado Jalapão Project (http://cerradojalapao.mma.gov.br/), a bilateral Brazil-Germany cooperation. Subsequent support occurred with the Cerrado Federal Project, bilateral cooperation between Brazil and the UK; Global Environment Facility (GEF) Mar, GEF Cerrado and GEF Terrestre; in addition to USAID/USFS, bilateral Brazil – USA cooperation. This support and cooperation were essential to enhance training, national and international, and learn about successful actions in other countries and adapt them to the Brazilian reality.

Since 2010, this approach has been implemented in some protected areas of the Brazilian Cerrado with the purpose of preventing large fires, reducing greenhouse gas emissions, creating mosaics of different post-fire ages and enabling supply of conditions and resources for fauna and flora (Pivello, 2006; Pillar & Vélez, 2010; Fidelis & Pivello, 2011; Medeiros & Fiedler, 2011; Schmidt *et al*., 2011).

The ICMBio begin by understanding and accepting natural fire. Natural ignitions are quite common in the Cerrado, a flammable biome whose biodiversity, landscape structure and biogeochemical cycles have been shaped by fire for thousands of years (Beerling & Osborne, 2006; Miranda *et al*., 2009, 2010; Simon *et al*., 2009). Natural fires are caused by lightning and typically occur at the end and beginning of the rainy season. They tend to be smaller, less severe and patchier, as both the air and fuel layer are wetter, vegetation is greener and they usually are followed by rains (França *et al*., 2007; Medeiros &

Fiedler, 2004). For that reason, these fires do not cause severe damage to biodiversity. By contrast, human-started wildfires are more intense, severe, large, difficult to control and costly for fighting. Those fires occur predominantly at the end of the dry season, when most species of fauna and flora invest their energy reserves in reproduction. Offspring are expected to be more vulnerable to fire because they cannot escape the flames while plants lose reproductive structures, disrupting sexual reproduction. Large fires, in turn, can particularly affect those species with small home ranges and low displacement range (Berlinck & Batista, 2020). According to Brookman-Amissah *et al*. (1980), fire seasonality can influence the composition of plant communities so that when it occurs early in the dry season, fire tends to increase species diversity, while at the end of the dry season (late dry season fires), it reduces the species diversity in the long-term.

At the same time, prescribed burns have been performed in different periods, frequencies and areas, creating thin mosaics into the zones (Andersen *et al*., 2012; Murphy *et al*., 2015; Schmidt *et al*., 2018). Multiple postfire ages in the landscape have increased the availability of ecological niches and possibly favored biodiversity conservation (Maravalhas & Vasconcelos, 2014; Murphy *et al*., 2015). In addition, fuel control has ensured the protection of fire-sensitive physiognomies (Murphy *et al*., 2015; Schmidt *et al*., 2018) and the reduction of greenhouse gas emissions, as prescribed burns are of low intensity and severity like in the Australian savanna, other fire-prone ecosystems (Russell-Smith *et al*., 2009).

It is necessary to incorporate the socio-cultural dimension even when managing natural fire and carrying out prescribed burns. After historical mapping, we identified that many fires originated from burnings carried out by community members for the renewal of native pastures and for subsistence agriculture, in addition to illegal hunting and litigation (conflicts). Therefore, we started a process of community organization, empowerment for joint decision-making and standardization and authorization for the fire use.

As a result of IFM actions in the Cerrado, it is already possible to see signs of a reduction in the area affected by wildfires, estimated from MODIS images, in Federal protected areas (Figure 3). In general, the reduction reaches approximately 33% when compared to years of critical weather events (El Niño) such as 2010 and 2017. Particularly in 2019, the reduction reached 40%, despite political reflexes in the increase of deforestation and fire occurrence. It is also important to highlight that the observed results should still be analyzed as indicatives, once the IFM have the necessity of a long-term actions for the consolidation.

These results show us that the IFM in the Cerrado seems to be being assertive, which does not seem to be happening for the Amazon (Figure 4), which needs better understanding and complementary actions. Considering that most of the Amazon biome phytophysiognomies are fire-sensitive, management is focused on fire control and exclusion. By contrast, in some Cerrado patches (relictual vegetation) that occur in the Rondônia state in the western region of the Amazon, prescribed burns have been used to manage the

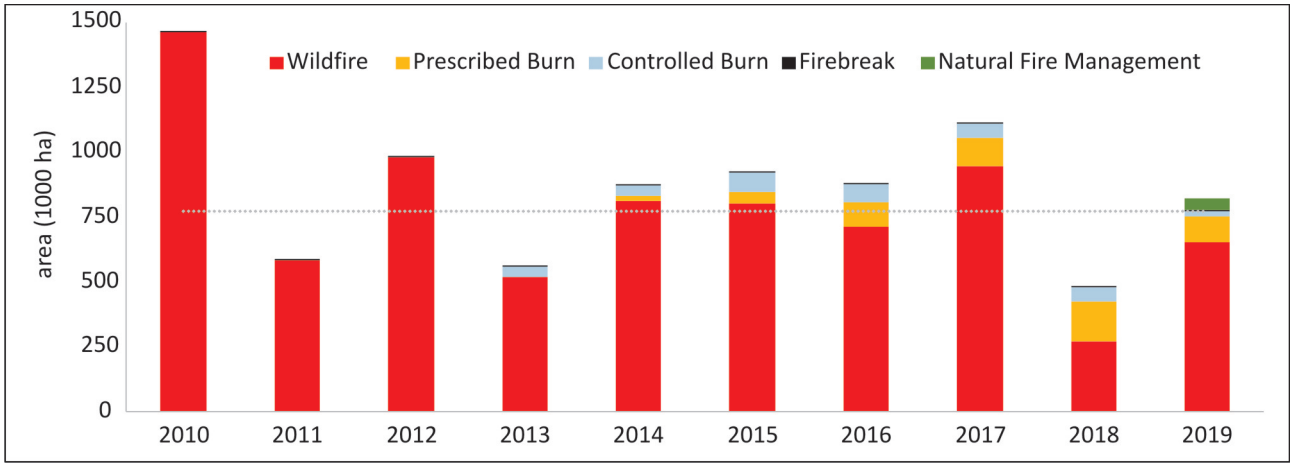

Figure 3 – Area affected by fire in the Cerrado between 2010 and 2019 divided in five categories. The line is the average of the wildfire area in the same period (Berlinck & Batista 2020).

fuel layer and protect sensitive forest vegetation in the surroundings. Another priority action is the strengthening of command and control actions to prevent deforestation, closely associated with the occurrence of fires and irregular land use (Berlinck & Batista, 2020).

For that reason, most fires in the Amazon Forest are associated with environmental crimes, irregular occupation, land grabbing, deforestation and conflicts with environmental agencies. In 2019, 75% of hotspots derived from the VIIRS satellite are concentrated in 46% of the Legal Amazon territory, in a region known as the "arc of deforestation" where private areas, land reform settlements, illegally occupied public lands and areas of unidentified dominance prevail (Berlinck & Batista, 2020). It emphasizes that deforestation and irregular agriculture in the Amazon are strongly associated with the widespread use of fire (Aragão *et al.*, 2008; Junior *et al.*, 2018). Overall, fire regimes in the Amazon region are changing from one characterized by very infrequent and probably low-intensity surface fires to one in which fires are relatively frequent and of potentially high severity (Alencar *et al.*, 2004).

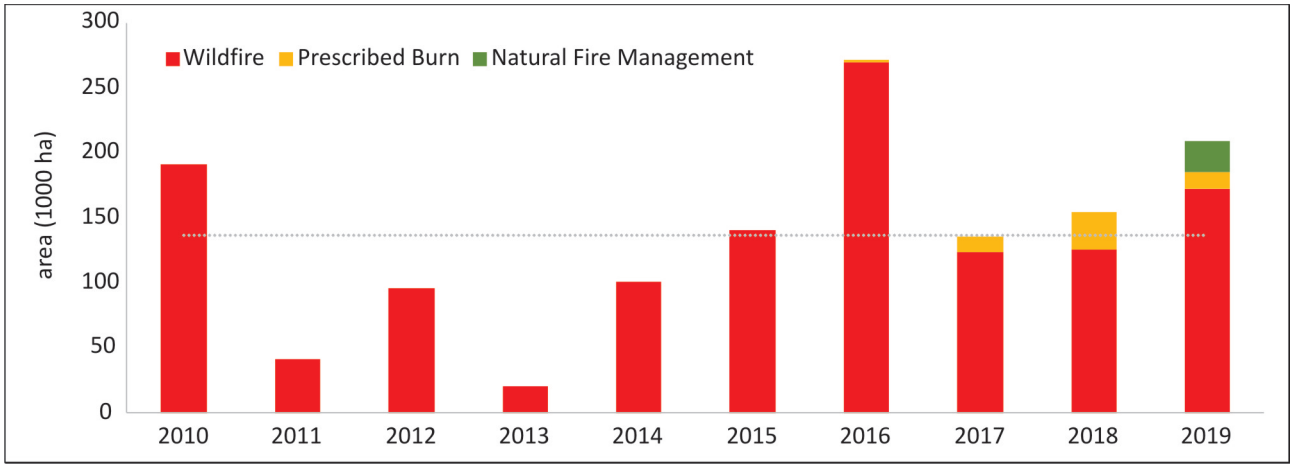

Figure 4 – Area affected by fire in the Amazon Biome between 2010 and 2019 divided in categories. The line is the average of the wildfire area in the same period (Source: ICMBio).

To illustrate the results of the actions in the Cerrado, Table 1 presents cumulative comparisons of the burned area between the following years, demonstrating the reduction of the area affected by wildfires. These five conservation units were responsible for approximately 75% of all areas affected by fires in the Brazilian federal protected areas.

Serra da Canastra National Park has authorized the use of fire by its residents since 2002. Unfortunately, few sought this authorization and used fire indiscriminately, so they did not obtain positive results in reducing fire. This National Park presents two distinct realities: in the northern portion, with the lands under the control of the Brazilian government;

Table 1 – Comparison of the area affected by wildfires, between subsequent years, in the five Brazilian protected areas with more wildfires.

Protected area	Brazilian state	2016-2017 (%)	2017-2018 (%)
Serra da Canastra National Park	Minas Gerais	-48,9	-18,0
Serra Geral do Tocantins Ecological Station	Tocantins/Bahia	-6,7	-72,5
Uruçui-Una Ecological Station	Piauí	-5,3	-32,0
Nascentes do Rio Parnaíba National Park	Tocantins/Piauí/Maranhão/Bahia	-15,8	-41,9
Araguaia National Park	Tocantins	11,5	-68,0

and in the central and southern portions, unregulated, with several resi-dents who need to use fire to renew pastures, in addition to being against the creation of a protected area of integral protection, as they should be compensated and removed from the area.

In 2016, the management team prioritized environmental education visits, evaluating and authorizing the use of fire in the south, as well as working together with the owners. While in the north, with a matrix of continuous countryside vegetation, it concentrated the preparation of firebreaks and prescribed burns. As a result, the number of residents who adhere to the authorization process increases every year, leading to a reduction in wildfires (Figure 5).

The implementation of the IFM at Serra Geral do Tocantins Ecological Station also brought significant results in reducing the area affected by fires and improving the relationship with communities. For this protected area, we highlight the reduction in the size of the largest fire event each year. The first prescribed burn to control the amount of fuel and fragment the environment occurred in 2014, before that, every fire management action was about combat. Figure 6 shows that the average area affected by wildfire between 2010 and 2013 was over 77,000 hectares, and that after 5 years of prescribed burns and integration with communities, this area plummeted to 3,000 hectares in 2018. Figure 7 demonstrates that another objective has been achieved, reducing the amount of wildfire in the

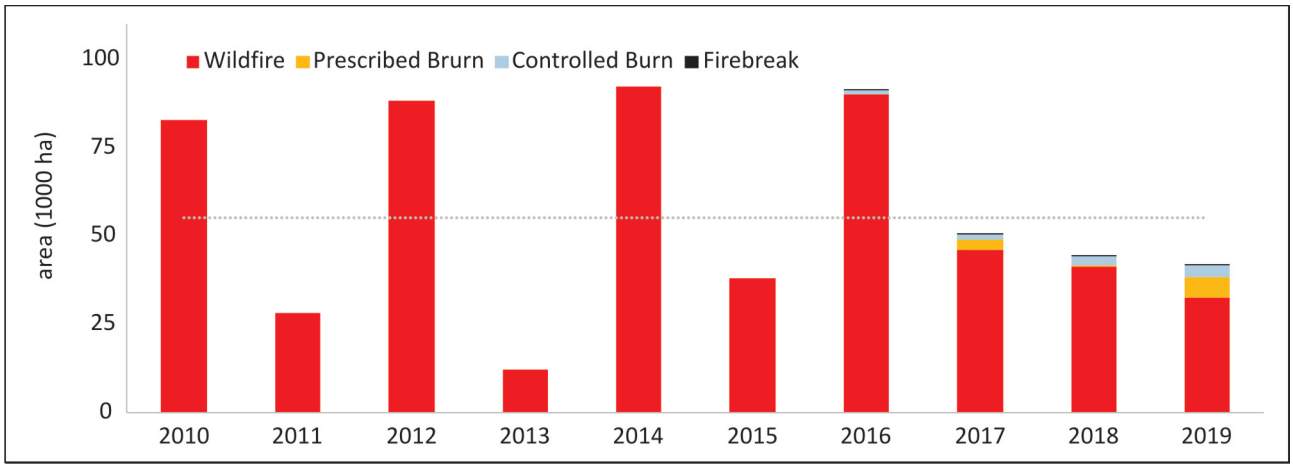

Figure 5 – Area affected by fire in the Serra da Canastra National Park between 2010 and 2019 divided in categories. The line is the average of the widfire area in the same period (Source: ICMBio).

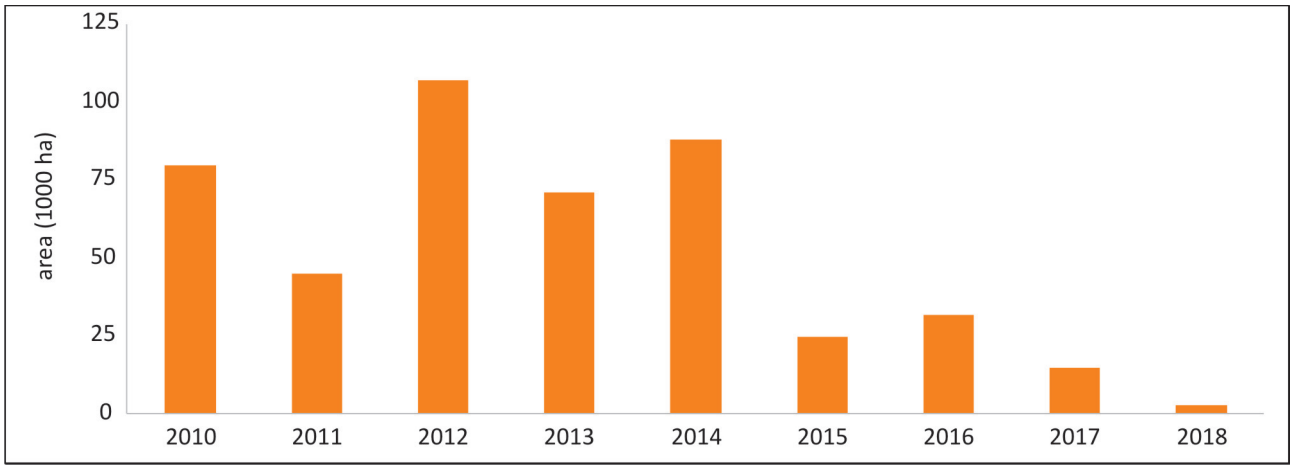

Figure 6 – Comparison of the size of the biggest wildfires in Serra Geral do Tocantins Ecological Station between 2010 and 2018 (Source: ICMBio).

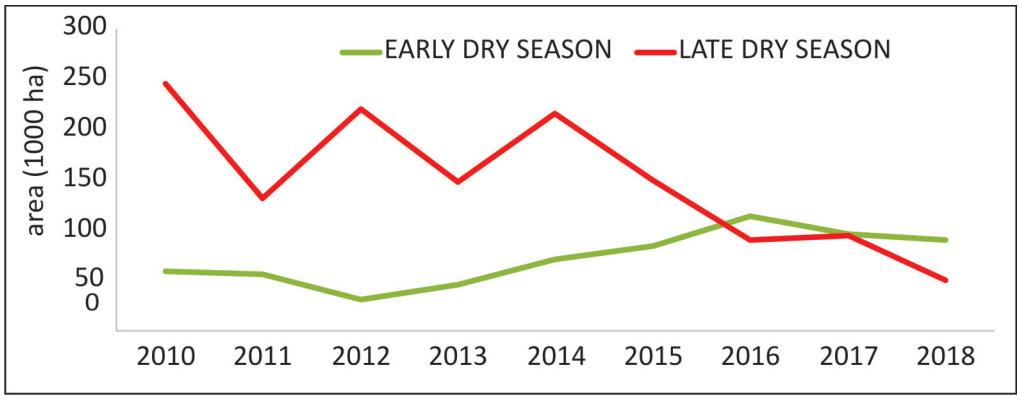

Figure 7 – Comparison of the area burned at the beginning and end of the dry season at Serra Geral do Tocantins Ecological Station (Source: ICMBio).

late dry season, with an increase in the early dry season when, according to Sato *et al*. (2010) there is less damage to vegetation because there is a probable similarity with the time of occurrence of natural fire. The late dry season is related to spring in Brazil, when most species of fauna and flora invest their energy reserves in reproduction.

In the Campos Amazônico National Park, in Amazon Forest, where most phytophysiognomies are sensitive to fire, management was focused on fire control and exclusion. Currently, in the cerrado (relictual vegetation) areas interspersed with the forest, prescribed burns have been used to manage the amount of fuel and protect the sensitive forest vegetation in the surroundings (Berlinck & Batista, 2020). In addition, they are managing lightning fires in the grasslands. The positive results were presented as of 2018 (Figure 8).

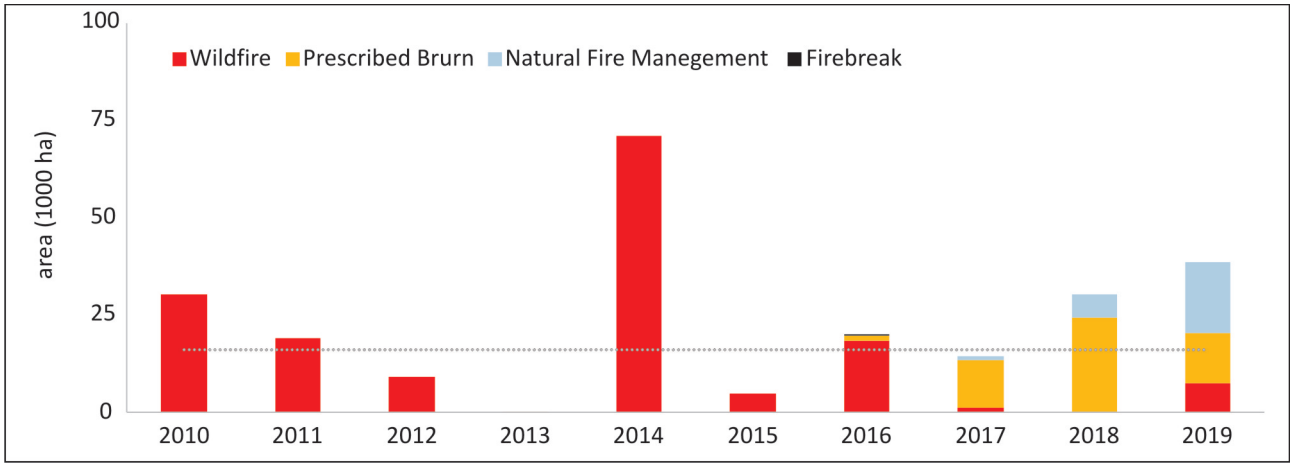

Figure 8 – Area affected by fire in the Campos Amazonicos National Park between 2010 and 2019 divided in categories. The line is the average of the wildfire area in the same period (Source: ICMBio).

We emphasize that the implementation of the IFM in the federal protected areas started in Cerrado and Amazon as they presented the biggest problems with fires, in addition to allowing replication for the other biomes. The current challenge is to better understand the relationship between Caatinga, Atlantic Forest, Pantanal and Pampas with fire.

Some experimental prescribed burns have been made in high elevation grassland at Itatiaia National Park, Atlantic Forest biome, in Rio de Janeiro State. Studies by Behling *et al*. (2020) suggest that fire occurred in these fields during the mid and late Holocene much lower frequencies than modern anthropogenic fires are occurring.

Other experimental prescribed burns have occurred in order to maintain the grasslands landscape that has been altered by successional processes after the exclusion of the management historically carried out in the region, as in Aparados da Serra National Park, in South Brazil (Behling & Pillar, 2006). As well as fires to recover degraded areas to exclude species of the genus *Pinus*, an invasive species, in the National Park of Lagoa dos Peixe, also in South Brazil, according to Almeida *et al*. (2005) and Abreu & Durigan (2013). Both with promising results.

The ICMBio work in adaptive forms of management, decisions are made as part of an ongoing process of review and evaluation of results to improve understanding of system responses to implemented practices and adjust them if necessary (Walters, 1986). Currently, research has been focused on understanding the role of fire in the ecosystems, assessing, among other important aspects, the effects of fire on vegetation structure and animals, biomass accumulation, fire behavior modeling and fire regimes description. The main goal has been to apply this understanding to develop an informed context for fire management (Berlinck & Batista, 2020).

The implementation of the IFM also considers maintaining the maximum diversity of possible environments, seeking the heterogeneity of environments to increase the amount of ecological niches, consequently species, in the perspective of the Intermediate Disturbance Hypothesis (Connell, 1978) and the Theory of Island Biogeography (Macarthur & Wilson, 1967), which are associated with the context in which Brazilian protected areas are inserted, being increasingly part of an altered anthropic matrix. In this sense, fire management seeks to create fine mosaics with different burning techniques, interspersed with less burnt or unburnt areas, also made in plots, thick mosaics. Thus, it is possible to vary the season, the weather conditions (humidity, temperature and wind), the frequency, the size of the areas, the technique and the intensity of the fire, in addition to the depth of the burning.

Another priority action, in all biomes, is the strengthening of command and control actions to prevent deforestation, closely associated with the occurrence of fires and irregular land use. Inspection and environmental recovery actions are also part of the IFM.

Conclusion and Future Perspectives

The actions and results presented, even if initial, demonstrate the integration of areas of knowledge and made it possible to manage protected areas not as integral protection, but as socio-environmental integration. There is environmental conservation only if there is social sustainability.

We realized that there is no single prevention strategy for all Brazilian Biomes and their different ecosystems. Therefore, each protected area needs to understand its fire regime and the factors that can interfere positively and negatively to achieve its conservation objectives, to define the best strategies.

The results of reducing the area affected by wildfire together with the increase in the technical capacity of Brazilian fire management specialists, associated with research projects that help to monitor and redirect actions, make it possible to advance in the knowledge of the relationship between fire and conservation biodiversity, with umbrella species as a focus for example, and using fire to promote biodiversity in suitable environments.

It is important to enact the Integrated Fire Management Federal Bill n. 11.276/2018, in this moment, under discussion in the Brazilian Chamber of Deputies. This bill was drafted with the participation of state agencies, scientists, traditional and indigenous communities (https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra?codteor=1703491&filename=Tramitacao-PL+11276/2018).

Acknowledgements

We would like to thank Camila Niel Berlinck for the support with the translation.

References

Abreu RCR & Durigan G 2013. Erradicação da invasão por árvores de Pinus no Cerrado. p. 43-46. In: Durigan G & Ramos VS. Manejo Adaptativo: primeiras experiências na Restauração de Ecossistemas. Páginas & Letras Editora e Gráfica: São Paulo.

Alencar AAC, Solórzano LA & Nepstad DC. Modeling forest understory fires in an eastern Amazonian landscape. Ecol. Appl. 14: 139-149, 2004.

Almeida FAC, Rodrigues JP, Almeida SA, Gouveia JPG & Santos NR. Efeito da temperatura sobre a germinação de três espécies de Pinus cultivadas no Brasil. Revista Árvore. 29(5): 757-765, 2005.

Andersen AN, Woinarski JCZ & Parr CL. Savanna burning for biodiversity: fire management for faunal conservation in Australian tropical savannas. Austral Ecol. 37: 658-667, 2012.

Aragão LEOC, Malhi Y, Barbier N, Lima A, Shimabukuro Y, Anderson L & Saatchi S. Interactions between rainfall, deforestation and fires during recent years in the Brazilian Amazonia. Philos. Trans. R. Soc. Biol. Sci. 363: 1779-1785, 2008.

Beerling DJ & Osborne CP. The origin of the savanna biome. Glob. Chang. Biol. 12: 2023-2031, 2006.

Behling H & Pillar VDP. Late Quaternary vegetation, biodiversity and fire dynamics on the southern Brazilian highland and their implication for conservation and management of modern Araucaria forest and grassland ecosystems. Phil. Trans. R. Soc. B. 362: 243-251, 2006.

Behling H, Jantz N & Saffordb HF. Mid- and late Holocene vegetation, climate and fire dynamics in the Serra do Itatiaia, Rio de Janeiro State, southeastern Brazil. Review of Palaeobotany and Palynology. 274: 104152, 2020.

Berlinck CN & Batista EKL. Good fire, bad fire: It depends on who burns. Flora 268: 151610, 2020.

Brookman-Amissah J, Hall JB, Swaine MD & Attakorah JY. A re-assessment of fire protection experiment in North-Eastern Ghana savanna. J. Appl. Ecol. 17: 85-99, 1980.

Connell JH. Diversity in tropical rain forests and coral reefs. Science. 199: 1302-1310, 1978.

Fidelis A & Pivello VR. Deve-se usar o fogo como instrumento de manejo no Cerrado e Campos Sulinos? Biodiversidade Brasileira 1: 12-25, 2011.

França H, Ramos-Neto MB & Setzer A 2007. O fogo no Parque Nacional das Emas. MMA, Série Biodiversidade, Brasília, pp. 27.

Garda AB & Berlinck CN 2018. Histórico do fogo no Brasil com enfoque na gestão de unidades de conservação, p. 27-53. In Lorenzon AS, Brianezi D, Valdetaro EB & Martins MC (eds). Incêndio Florestal: princípios, manejo e impactos. Ed: UFV, Viçosa.

Hardesty J, Myers R & Fulks W. Fire, ecosystems, and people: a preliminary assessment of fire as a global conservation issue. The George Wright Forum 22: 78-87, 2005.

Jolly WM, Cochrane MA, Freeborn PH, Holden ZA, Brown TJ, Williamson GJ & Bowman DMJS. Climate-induced variations in global wilfire danger from 1979 to 2013. Nat. Commun. 6: 7537, 2015.

Junior CHLS, Aragão LEOC, Fonseca MG, Almeida CT, Vedovato LB & Anderson LO. Deforestation-induced fragmentation increases forest fire occurrence in Central Brazilian Amazonia. Forests 9: 305, 2018.

Kaufmann MR, Shlisky A & Kent B. Integrating scientific knowledge into social and economic decisions for ecologically sound fire and restoration management. Proceedings 3rd International Wildland Fire Conference and Exhibition. Sydney, Australia. 2003.

Macarthur RH & Wilson EO 1967. The theory of biogeography. Princenton University Press, Princeton: New Jersey. 224p.

Maravalhas J & Vasconcelos HL. Revisiting the pyrodiversity-biodiversity hypothesis: long-term fire regimes and the structure of ant communities in a Neotropical savanna hotspot. J. Appl. Ecol. 51: 1661-1668, 2014.

Medeiros MB & Fiedler NC. Incêndios Florestais no Parque Nacional da Serra da Canastra: desafios para a conservação da biodiversidade. Ciência Florestal 14: 157-168, 2004.

Medeiros MB & Fiedler NC. Heterogeneidade de ecossistemas, modelos de desequilíbrio e distúrbio. Biodiversidade Brasileira 1: 4-11, 2011.

Miranda HS, Sato MN, Nascimento-Neto R & Aires FS 2009. Fires in the cerrado, the brazilian savanna, p. 427-450. In: Cochrane MA (Ed.), Tropical Fire Ecology: Climate Change, Land Use and Ecosystem Dynamics. Springer-Praxis, Chichester, UK.

Myers R 2006. Living with Fire – Sustaining Ecosystems & Livelihoods Throught Integrated Fire Management. The Nature Conservancy. 30p.

Monosowski E. Políticas ambientais e desenvolvimento no Brasil. Cadernos FUNDAP. Planejamento e gerenciamento ambiental, v. 16, n. 9, p.15-24. In: Resende RU. As Regras do Jogo: Legislação Florestal e Desenvolvimento Sustentável no Vale do Ribeira. São Paulo. Editora Annablume. Fapesp, 198 p., 1989.

Murphy BP, Cochrane MA & Russell-Smith J. Prescribed burning protects endangered tropical heathlands of the Arnhem Plateau, northern Australia. J. Appl. Ecol. 52: 980-991, 2015.

Pillar VD & Vélez E. Extinção dos Campos Sulinos em Unidades de Conservação: um fenômeno natural ou um problema ético? Natureza e Conservação, 8: 1-5, 2010.

Pivello VR 2006. Fire management for biological conservation in the Brazilian Cerrado, p. 129-154. In: Mistry J & Berardi A (Eds.), Savannas and Dry Forests – Linking People with Nature. Ashgate Publishing Limited, Hants.

Ribeiro JF & Walter BMT 2008. As principais fitofisionomias do bioma Cerrado, p. 151-212. In: Sano SM, Almeida SP & Ribeiro JF (Eds.). Cerrado: Ecologia e Flora. Brasília: Embrapa Cerrados/Embrapa Informação Tecnológica.

Russell-Smith J, Murphy BP, Meyer CP, Cook GD, Maier S, Edward AC, Schatz J & Brocklehurst P. Improving estimates of savanna burning emissions for greenhouse accounting in northern Australia: limitations, challenges, applications. Int. J. Wildland Fire, 18: 1-18, 2009.

Sato MN, Miranda HS & Maia JFM 2010. O fogo e o estrato arbóreo do Cerrado: efeitos imediatos e de longo prazo, p.77-91. In: Miranda HS (Org). Efeitos do regime do fogo sobre a estrutura de comunidades do Cerrado: resultados do Projeto Fogo. Brasília: Ibama.

Schmidt IB, Sampaio MB, Figueiredo IB & Ticktin T. Fogo e artesanato de Capim-Dourado no Jalapão – usos tradicionais e consequências ecológicas. Biodiversidade Brasileira 2, 69-88, 2011.

Schmidt IB, Moura LC, Ferreira MC, Eloy L, Sampaio AB, Dias PA & Berlinck CN. Fire management in the Brazilian savana: first steps and the way forward. J. Appl. Ecol. 55: 2094-2101, 2018.

Simon MF, Grether R, Queiroz LP, Skema C, Pennington RT & Hughes CE. Recent assembly of the Cerrado, a neotropical plant diversity hotspot, by in situ evolution of adaptations to fire. Proc. Natl. Acad. Sci. U.S.A. 106: 20359-20364, 2009.

Walter BMT & Ribeiro JF. 2010. Diversidade fitofisionômica e o papel do fogo no Bioma Cerrado, p. 60-76. In: Miranda HS (Org). Efeitos do Regime do Fogo sobre a estrutura de comunidades de Cerrado: Projeto Fogo. Brasília: Ibama.

Walters C 1986. Adaptive Management of Renewable Resources. Macmillan Publishing Company: New York. 374p.

Biodiversidade Brasileira – BioBrasil.
Edição Temática: 7th International Wildland Fire Conference
n. 2, 2021

http://www.icmbio.gov.br/revistaeletronica/index.php/BioBR

Biodiversidade Brasileira é uma publicação eletrônica científica do Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) que tem como objetivo fomentar a discussão e a disseminação de experiências em conservação e manejo, com foco em unidades de conservação e espécies ameaçadas.

ISSN: 2236-2886