

Integrated Fire Management: Serra Geral do Tocantins Ecological Station's Journey (2001 to 2020)

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ABSTRACT – Fire drives evolutionary and ecological process in tropical savannas. Nevertheless, fire as a tool for managing biodiversity in wildlands is still controversial and encounters strong resistances. For decades, fire in savanna's protected areas was perceived as 'an evil' requiring strong efforts for its suppression. Anti-fire policy had led to large and recurrent wildfire due to fuel load accumulation and vegetation continuity, also impacting traditional livelihood in savannas. Circumstantially, fire use and management has been accepted as a 'necessary evil' in order to avoid wildfires. An emerging fire management policy has been recognizing fire as 'a necessity' for savannas' biodiversity and people, dealing with intercultural governances. Such a participatory fire management approach is in the context of Integrated Fire Management (IFM). In Brazil, a paradigm shift in fire policies is underway, and the telling of such institutional change must consider the experience of Serra Geral do Tocantins Ecological Station. This is a strict protected area (PA) of 7000km², created in 2001 by a federal act. After a decade of anti-fire management policy, the PA was annually dealing with large and destructive wildfire, with strong impact also on traditional burning systems. The negotiation of a fire management agreement with local traditional people, who recognize themselves as *quilombolas*, involved discussions, meetings and training, led to a progressive paradigm change – first accepting the controlled use of fire and currently integrating multiple perspectives on burning, aiming to create a patch mosaic burning for biodiversity conservation. Besides reduction of large wildfires occurrences, there is a healthy environment of collective learning and reduced conflict. Such management changes are fully incorporated into management instruments, representing positive impacts at the institutional level through debates and conceptual developments, and the learning are being shared with other PAs and at national and international levels.

Keywords: Adaptive management; effective management; knowledge dialogue; participatory management; fire policies.

Manejo Integrado do Fogo: Trajetória da Estação Ecológica Serra Geral do Tocantins (2001 a 2020)

RESUMO – O fogo tem sido considerado um fator-chave para a biodiversidade das savanas tropicais, em termos evolutivos e ecológicos, e por isso precisa ser melhor compreendido e melhor utilizado no manejo das áreas protegidas. Entretanto, por muitas décadas, prevaleceu a busca pela exclusão do fogo das áreas naturais mobilizando elevados investimentos em equipes e equipamentos. Repetidas vezes tal decisão de manejo resultou em grandes incêndios nas savanas, devido ao acúmulo e continuidade de material combustível, junto a elevados impactos sociais, especialmente para os povos e comunidades tradicionais. A constatação da inevitabilidade do fogo em tal contexto levou à aceitação de seu uso como um 'mal necessário' em algumas circunstâncias, quase que exclusivamente para controle de combustível e redução de incêndios. Uma terceira abordagem de gestão, emergente, entende o fogo como um fator 'necessário' tanto para a biodiversidade como para as pessoas que vivem em ecossistemas que evoluíram com o fogo, sendo que a definição de objetivos e estratégias de manejo deve ser alcançada em ambientes e processos multiatores. Vem sendo chamada de manejo integrado do fogo (MIF) esta abordagem que lida com diferentes expectativas e necessidades, respeitando especificidades locais. No Brasil, a mudança de paradigma da exclusão do fogo à adoção do MIF não deveria ser contada sem a experiência da Estação Ecológica Serra Geral de Tocantins, uma unidade

de conservação (UC) de proteção integral criada em 2001 parcialmente sobre território quilombola. Uma década de manejo visando a exclusão do fogo nos mais de 700 mil ha de Cerrado protegidos pela UC levou a área ao topo do ranking de UC mais incendiadas no país, e as comunidades locais se viram ameaçadas em suas formas de vida, tanto pela recorrência de grandes incêndios como pela coibição de suas práticas tradicionais. A negociação de termos de compromisso com a comunidade quilombola envolveu estudos, oficinas, intercâmbios, capacitações e vivências que impulsionaram a transição entre paradigmas de gestão do fogo. Primeiro houve a aceitação do fogo como ferramenta, para confecção de aceiros, e desde 2014 o fogo é manejado sob múltiplas perspectivas, tanto pela equipe da UC como pelos quilombolas, considerando um horizonte comum e dialogado de criação de mosaico de regime de queimas. A premissa, sob investigação científica, é de que nos ambientes evoluídos com o fogo a pirodiversidade é correlacionada à biodiversidade. Grandes incêndios já não mais ocorrem, e percebe-se um ambiente muito mais saudável de diálogo, aprendizagem coletiva e de redução de conflitos. Essas mudanças de manejo foram incorporadas nos instrumentos oficiais de gestão, exigindo debates e aprendizagem em toda a hierarquia institucional. As experiências estão sendo compartilhadas com equipes de outras áreas protegidas em nível nacional e internacional.

Palavras-chave: Diálogo de saberes; efetividade de manejo; gestão participativa; manejo adaptativo; políticas de gestão do fogo.

Manejo Integral del Fuego: Trayectoria de la Estación Ecológica Serra Geral do Tocantins (2001 a 2020)

RESUMEN—La idea de que el fuego actúa como un factor clave en términos ecológicos y evolucionarios en sabanas tropicales y que por esto necesita ser mejor comprendido y utilizado en el manejo de áreas protegidas es bien aceptada actualmente. Entretanto, muchas son las barreras para su adecuada incorporación en las prácticas cotidianas. Por muchas décadas, ha prevalecido la promoción de la exclusión del fuego de las áreas naturales – el fuego como un mal – movilizándolo elevadas inversiones en personal y equipamientos. Repetidas veces, este manejo resultó en incendios severos, debido a la acumulación de combustible. Adicionalmente, crecían las denuncias acerca de importantes impactos sociales, especialmente sobre los pueblos tradicionales. La inevitabilidad de los incendios en este contexto llevó a una aceptación del uso del fuego en algunos casos, casi exclusivamente para evitar incendios catastróficos – el fuego como un ‘mal necesario’. Un tercer entendimiento, ganando más espacio cada año, es del fuego como necesario tanto para la biodiversidad como para la gente que vive en ecosistemas que han evolucionado con el fuego. En tal contexto socio-ambiental, siempre complejo, la definición de metas y de estrategias de manejo deben alcanzarse en ambientes y procesos multi-actores. El enfoque de este desafío a menudo se denomina comúnmente Manejo Integrado del Fuego (MIF), y debe haber adaptación para cada realidad. En Brasil, el cambio de paradigma desde la exclusión del fuego hasta el MIF no debería ser narrada sin la experiencia de la Estación Ecológica Serra Geral de Tocantins. Esta es una reserva de 700.000 hectáreas, en el corazón de la sabana brasileña, el Cerrado, e hay sido creada en 2001 como un área de protección estricta. Una década de manejo con políticas anti-fuego produjo el mayor nivel histórico de áreas incendiadas en la Reserva. Similarmente, las poblaciones locales se vieron amenazadas en sus formas de vida, tanto por la represión de las prácticas tradicionales, como por la alta incidencia de incendios. La negociación de un acuerdo de la gestión de la reserva con las comunidades tradicionales afectadas (conocidas como ‘quilombolas’) han contado con estudios, talleres, intercambios y capacitaciones, lo que ha facilitado la transición hacia un nuevo paradigma. Primero, con la aceptación del fuego como herramienta de protección. Desde 2014, el fuego es utilizado por el equipo de la reserva y por los quilombolas para una variedad de razones, pero con el horizonte común y dialogado de crear un mosaico de regímenes de quema a cada año. Los grandes incendios ya no ocurren, y se observa un ambiente mucho más saludable, con diálogo, aprendizaje colectivo, y reducción de conflictos con las comunidades locales. Estos cambios de manejo han sido incorporados en los instrumentos de gestión, exigiendo debate y aprendizaje por toda la jerarquía institucional, y las experiencias están siendo compartidas con otros equipos, a nivel nacional e internacional.

Palabras clave: Diálogo de conocimiento; gestión participativa; manejo adaptativo; manejo efectivo; políticas de fuego.

Fire policies in tropical savannas

Increasingly studies support the understanding that fire plays a fundamental role in the composition and distribution of global terrestrial biota (Bond *et al.*, 2005; Bond & Keeley, 2005; Bond & Parr, 2010; Lehmann *et al.*, 2014; Parr *et al.*, 2014), driving ecological and evolutionary processes in fire-prone ecosystems, including savannas (Pyne, 1997; Bond & Keeley, 2005; Myers, 2006; Pausas & Keeley, 2009; Archibald 2016; Bowman *et al.*, 2011; Pausas & Parr, 2018).

Although fire is considered a natural ecological factor in tropical savannas, human activities are strongly influencing its regimes mainly by enforcing fire suppression or allowing fire management (Laris & Wardell, 2006; van Wagtenonk, 2007; Bowman *et al.*, 2011). Such fire policies have been modifying landscapes in savanna protected areas and surroundings by changing the fuel load amount and fuel load connectivity and thus altering the size of burned area, intensity and return interval of fire (Archibald, 2016; Alvarado *et al.*, 2018).

Fire policies may consider an ensemble of scientific, cultural, social, ecological and political contexts, but we cannot disregard the human and personal dimensions, related to the perceptions involving the use and impact of fire, that are also shaping fire management paradigms in savannas protected areas (Barradas *et al.*, 2020). Laris & Wardell (2006) pointed out that the political decision about the use or exclusion of fire in West African savannas relates to different perceptions about fire, either as “evil”, “necessary evil” or “necessity”. When fire is seen as an evil, it often involves colonialist perceptions that the traditional use of fire is generally a careless and archaic practice, which alters the landscape and the soils negatively, damaging mainly the tree cover, usually better valued in comparison to natural grasslands or savannas, bias also noted by Overbeck *et al.* (2015) in Brazil. The vision of fire as a *necessary evil* implies that its use may be accepted, but only under specific or controlled circumstances, usually at the early dry season and regulated by permits, whereas late dry season fires are discouraged or prohibited. Finally, the perception of fire as *necessity* recognizes fire not only as a tool to avoid wildfires, but also as an ecological and cultural component for savanna maintenance.

Myers (2006) also identified three distinct approaches to fire policies: “fire exclusion”, “fire management” and “integrated fire management”. The *fire exclusion* policy usually considers fire as a threat to the biota and natural resources, attempting to eliminate it, often with sophisticated firefighting systems and large investments in equipment and human resources. The *fire management* policy mainly refers to technologies and tools associated with the triad ‘prevention’, ‘suppression’ and ‘(technical) use of fire’. Finally, the *integrated fire management* policy comprehends knowledge diversity, expectations, needs (biological, social/cultural and economic) and different scales (time and space) related to fire in the ecosystems, emphasizing the importance of participatory governance systems involving dialogue in multiple hierarchical levels, to uphold decisions about the use or not of fire in certain territories.

In addition, Bilbao *et al.* (2019) present the possibility of an *intercultural fire management* policy, suggesting that, in order to understand the role of fire in a territory, it is mandatory to share multiple perspectives on burning traditions to find more just and sustainable ways to effectively integrate traditional fire practices into national fire management policy.

Fire policies in Cerrado

In the Brazilian tropical savanna, the Cerrado, there is evidence that fire occurred long before the arrival of humans in South America (Salgado-Labouriau & Ferraz-Vicentini, 1994), as illustrated by the evolutionary adaptation of plants to fire with the ecological dominance of flammable C4 grasses, on a scale of millions of years (Simon *et al.*, 2009; Simon & Pennigton, 2012).

Leopoldo Coutinho and Vânia Pivello are ecologists who have devoted themselves to defending the use of fire for Cerrado management (Durigan, 2020) and, since the final quarter of the 20th century, their research already showed the ecological need of fire in the biome, such as for its physiognomies maintenance and environmental dynamic and also for regrowth, flowering, nutrient cycling, seed germination, among other ecological processes (Coutinho, 1978, 1980, 1990; Pivello & Coutinho, 1992; Pivello & Coutinho, 1996). Both scientists confronted the historical and generalized attempts of suppressing fire in all wildlands during Brazilian environmental legislation construction,

helping to promote the term *manejo do fogo* [fire management] to name a desirable fire policy for Cerrado management in the 1980s.

However, although Brazilian environmental legislation has envisaged the use of fire for managing fire-prone ecosystems for quite some time (e.g. CONAMA Resolution 11/1988, Decree 2.661/1998 and Law of Native Vegetation Protection 12.651/2012), in practice, for the past forty years, few protected areas in the Cerrado have actually dared to break the predominant fire suppression paradigm.

One of the first institutional *fire management* initiatives in Brazil was undertaken in Emas National Park (ENP), a Cerrado protected area located in the state of Goiás. Fire occurrences in this park are often associated with the high incidence of lightning (Ramos-Neto & Pivello, 2000). After its land tenure regularization in the 1980s, a network of (burned) firebreaks and (mechanical) fuelbreaks was created in order to fragment the landscape and limit fire spread, aiming to prevent wildfires and to attract wildlife for tourism (França *et al.*, 2007). The maintenance of firebreaks in ENP is still ongoing, with enormous commitment of its teams, associating different practices over time, such as tolerance to some lightning-ignited wildfires, although all other fires continue to be suppressed. Unfortunately, this case of intensive management, rare among Brazilian protected areas, has not been monitored by a sufficiently articulated research effort to understand the ecological dynamics associated with fire management decisions and responses.

Yet in the 1980s, firebreaks were implemented in the Brasília National Park, bordering the perimeter of the protected area in an attempt to isolate built up fuel loads by avoiding the spread of wildfires ignited from the surroundings. Other national parks (NP) in the Cerrado, such as Guimarães NP and Serra do Cipó NP, also incorporated the use of fire in their management plans in 2006 and 2009, respectively. Fire management objectives in Guimarães NP focused on protecting its infrastructure and in Serra do Cipó NP the main objective was to protect the fire-sensitive vegetation, such as '*capões de mata*' (forest patches). However, concrete actions in both parks have only taken place in recent years, as a reluctant response to recurrent wildfires.

Between 1980 and 2015, there were some cases of fire management in other Cerrado protected areas related to burning permits or decisions in not fighting certain types of fire occurrences, but such tolerance to fire was limited to local managers' discretion, with almost no official records in planning documents or reports. Such informal fire management initiatives may be related to the fear of official penalties or social condemnation, since the use of fire for management has primarily remained as an institutional taboo (Durigan & Ratter, 2016).

Despite the background of fire management carried out in some protected areas in Brazil since the 1980's, the idea of *integrated* fire management (IFM) was boosted very recently (Falleiro *et al.*, 2016; Schmidt *et al.*, 2018; Franke *et al.*, 2018; Fidelis *et al.*, 2018; Barradas *et al.*, 2020; see also the Special Issue in *Flora*, v. 268, 2020).

Currently, to talk about IFM in Brazil it is central to present the case of the Serra Geral do Tocantins Ecological Station, a Cerrado protected area that has been changing the course of fire management policies in the country, evidencing, in practice, that an intercultural approach related to environmental management decisions can effectively protect the biodiversity.

Fire policies in Serra Geral do Tocantins Ecological Station

Serra Geral do Tocantins Ecological Station (SGTES) is a large protected area (~7.000km²) located in the Jalapão region (Tocantins and Bahia states, Brazil), where open Cerrado physiognomies – such as *campos limpos* (pure grassland), *campos sujos* (grassland with sparse presence of shrubs) and *cerrado ralo* (grass/shrub-dominated vegetation with scattered trees) – predominate (Franke *et al.*, 2018). Its flat and grass-dominated landscape becomes highly flammable during the dry season and the fire return interval can be very short (two to three years) (Pereira *et al.*, 2014; Barradas, 2017). Not surprisingly, the Ecological Station is often one of the most burned protected areas in the country, representing up to 35% of the total area burned per year in federal strict protected areas (Garda *et al.*, 2014).

The history of wildland management in the SGTES has been well documented in planning tools, technical reports and scientific papers. Based

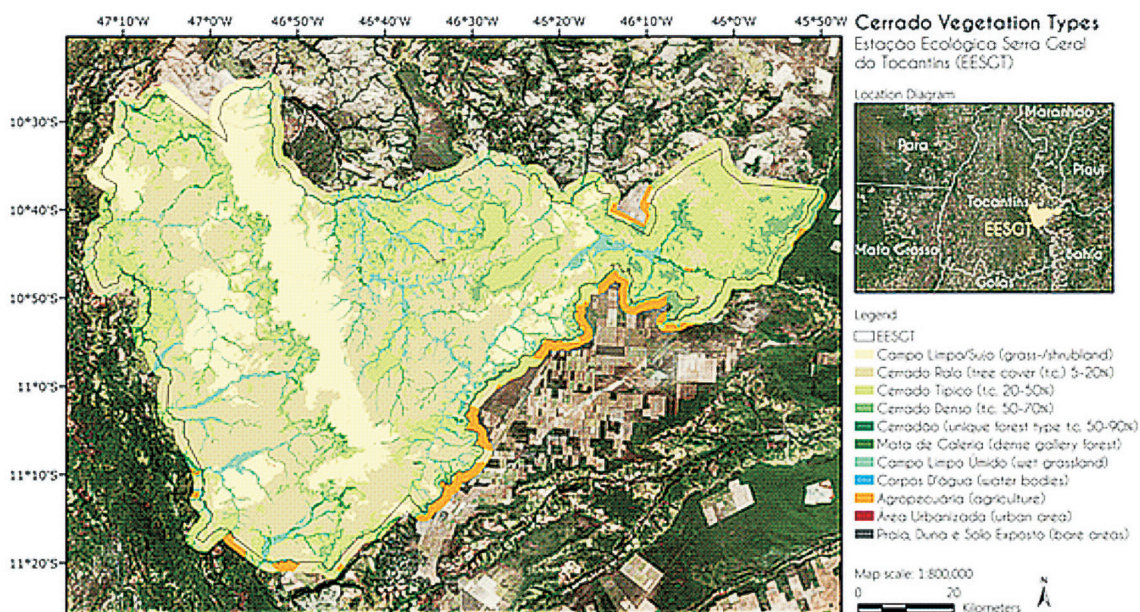


Figure 1 – Serra Geral do Tocantins Ecological Station: location and Cerrado vegetation types. Source: Franke *et al.* (2018).

on them and on the personal experience of the first author, as part of the management team of the protected area, we suggest three remarkable management periods associated to different fire policies from its creation (2001) until the present (2020), following the gradation: *fire suppression period, paradigm shift period and integrated fire management period* (Figure 2).

Fire suppression period

In the Brazilian National System of Conservation Units (SNUC), ecological stations are strict preservation areas where there should be no human occupation and the human uses are expected to be restricted to research and education, closely related to the American concept of wilderness. However, before SGTES' creation, it was already the homeland of traditional communities, including *quilombolas* (maroon communities) who have been living with fire for centuries in *quilombos* (settlements historically founded by enslaved Africans) spread across the Jalapão region (Fagundes, 2019b; Silva, 2019).

Indigenous lands and *quilombolas* territories are considered protected areas in Brazil, but they are ruled by different legislation from the ones grouped in 'conservation units', which in federal

level are under responsibility of Chico Mendes Institute for Biodiversity Conservation (ICMBio). Often, traditional people do not have the land tenure of their own land. When conservation units' creation overlaps traditional territories without consulting the local people about the creation of strict preservation areas, socio-environmental conflicts arise, as happened in Jalapão region: "We lived for years with the State absence and when it arrived, it came with the power to prohibit the use of fire. It didn't matter the arguments that the Jalapoeiro people had about how they dealt with fire as an indispensable tool for life existence for centuries. We feel trapped, because fire is an instrument that produces life, we use it not only to harvest capim dourado [*Syngonanthus nitens*], but, mainly, for food production, such as the swidden agriculture, animal breeding and hunting" (free translation; Silva, 2019).

For more than a decade, fire in SGTES was perceived as the major threat to biodiversity conservation – as an evil that should be pragmatically fought. Governmental managers also believed that wildfires were mainly caused by *quilombolas* 'misuse' of fire – sometimes considered arsonists – or by cattle ranchers, who use fire for cattle foraging during the dry season. Thus, fire suppression policy in SGTES focused on supervising the use of fire and also understanding

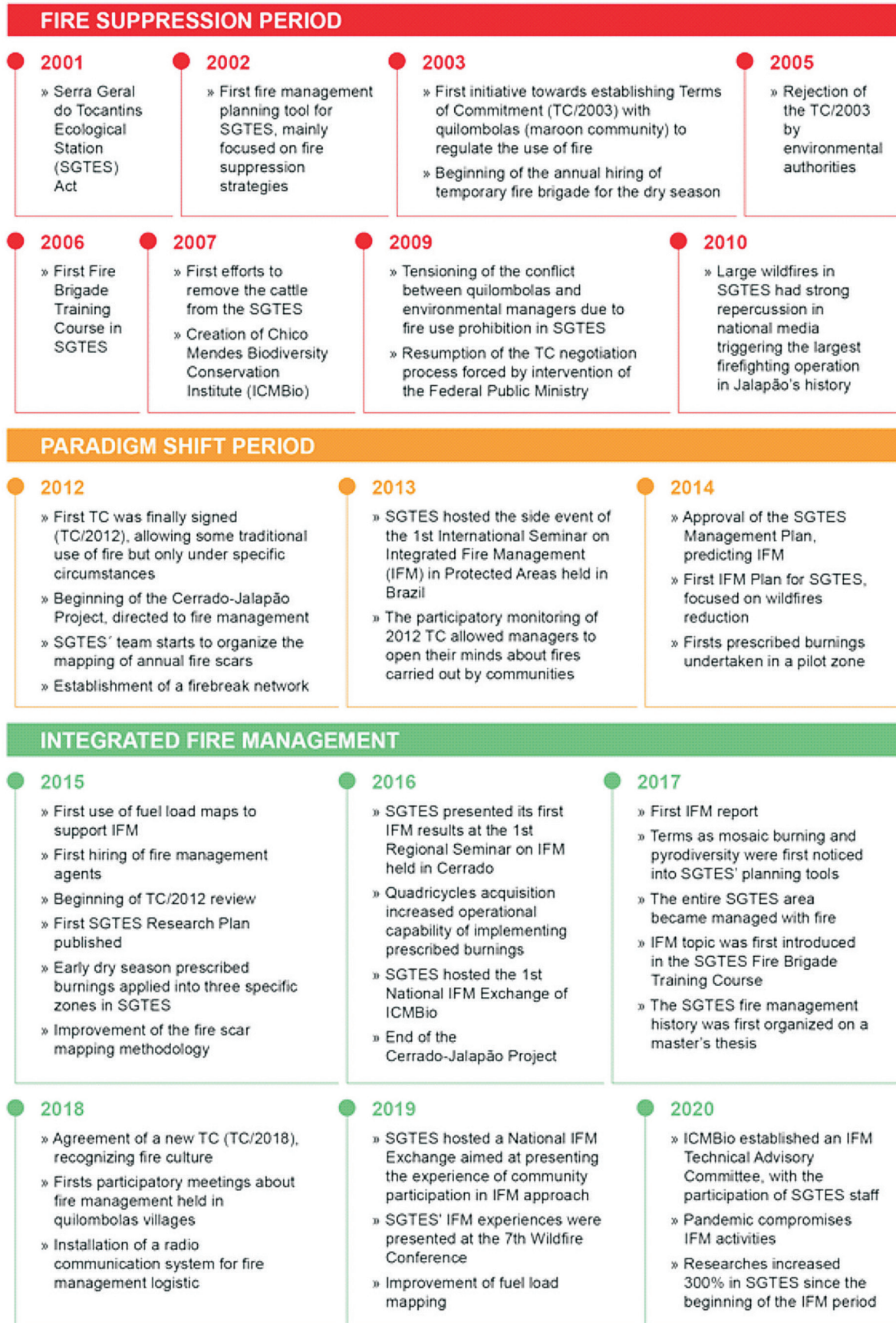


Figure 2 – Milestones in fire management across the last two decades in Serra Geral do Tocantins Ecological Station (2001-2020).

that fire users needed to be 'educated' in order to control the 'indiscriminate use of fire', disregarding ancestral knowledge, commonly related to traditional fire management practices.

A complex and historical socio-environmental conflict involving ideological divergences about fire was triggered: on one hand, environmental agents dealing with fire mostly as a problem; on the other hand, *quilombolas* proclaiming that fire plays an indispensable role in their livelihoods (Lindoso, 2014; Silva, 2019). This conflict emerged together with the ecological station's creation, guiding the graduation of fire management decisions in SGTES for the past twenty years.

Termos de compromisso [terms of commitment], or TC, are a planning tool predicted in the Brazilian environmental legislation used for allowing land management or uses by traditional communities living in strict protected areas, where human occupations are not supposed to be allowed. Although TC were designed to contribute to the management of socio-environmental conflicts in the sense of benefiting people and nature, the participatory process may not effectively involve traditional people in final decisions. Perhaps, TC rules devotes more attention to preservation principles than social needs, as observed in the first attempt to conciliate a TC between *quilombolas* and SGTES in 2003. Despite the command and control expectations for wildland management, this version of the term (TC/2003) was refused by governmental authorities under the argument that it could set precedents for undesirable land uses in strict preservation areas (Talbot, 2016).

Quilombolas kept questioning the wildland management restrictions imposed by environmental governmental agencies and claimed for their rights to maintain their own culture – including the fire culture – in a collective land tenure (Lindoso, 2014; Talbot, 2016). In 2009, the TC process was resumed under strong pressure from the Federal Public Ministry, which enforced the conciliation between environmental and social legal rights, both linked to the Brazilian Constitution. For the following three years, governmental managers and *quilombolas* negotiated the rules of this agreement, although there were disparate perceptions and engagements regarding the use of fire.

The Fire Suppression Period in SGTES was also marked by recurrent large wildfires (Barradas,

2017). Local communities usually associate these wildfires to the creation and implementation of strict protected areas in the Jalapão region (Lindoso, 2014). The removal of a significant part of the cattle (the main biomass consumer), the hiring of *brigadistas* (fire brigade members) specially trained on firefighting techniques and the prohibition of traditional fire use are some examples of decisions that contributed to changes in fuel load dynamic, enhancing the risks of wildfires in SGTES.

Several mega-wildfires (e.g. events > 500km²) were registered during the SGTES fire suppression period, demanding effortful logistics, very high costs and high negative ecological and social impacts. The year of 2010 was specially marked by the largest firefighting operation in the Jalapão region, with wide media repercussions. Despite extensive efforts to control the fire spread, 44% of the Ecological Station area (~3200km²) was burned in the peak of that dry season (ICMBio, 2010; see Table 1), resulting in an undesirable landscape strongly impacted by the intense and severe wildfires that also burned large areas of fire-sensitive vegetation. It was a traumatic firefighting season for environmental managers, but also an opportunity to rethink fire management strategies.

Changing fire management paradigms

Firefighting experiences highlighted the challenge of extinguishing extreme wildfire events in the end of the dry season, even with robust support. In that context, the use of fire for managing fuel load became a possibility in order to avoid late dry season wildfires and its negative ecological impacts (Mascarenhas & Cortes, 2012).

In 2012, for the first time, an extensive firebreak network replaced the usual mechanical fuelbreaks (opened by tractors, adding strong erosion risks to the prevailing sandy and friable soils). Firebreaks were considered a faster and less environmentally damaging method, being strategically planned based on wildfire risks inferred from the overlapping of annual burning scars and average fire return interval in the area (Borges, 2012; Mascarenhas & Cortes, 2012). Thus, the firebreak network could be adjusted every year, according to the wildfire risk changes.

Despite advances, the effectiveness of the firebreak network was questioned because in the hottest, windiest and driest period of the year (September/October), even the firebreaks with more than 200m width could not be enough to control the spread of fire (Beatty, 2013).

In the same year, the TC negotiation process, which started in 2009, was finally concluded, resulting in a ruled agreement that allowed the use of fire for some traditional practices such as agriculture, grazing and harvest of *capim dourado* (*Syngonanthus nitens*, Eriocaulaceae) – the golden grass, but only upon formal authorization. This agreement (TC/2012) was the first one in ICMBio to allow fire use by *quilombola* communities in a strict protected area (Fagundes, 2019b). Nevertheless, the TC/2012 also imposed some restrictions: late dry season fires were forbidden; the minimum fire return interval was stipulated as three years, and the use of fire in wildlands along the *Novo* river was also forbidden, because it is the *habitat* of *pato-mergulhão* (*Mergus octoetaceus*) – an endangered brazilian merganser.

Although the TC/2012 can be considered a milestone in the process of de-marginalizing traditional fire use in Cerrado protected areas, it had serious limitations because the social and cultural needs of using fire were denied and ancestral fire practices, such as patch-mosaic burning, remained condemned. Fortunately, the participatory monitoring of the TC/2012 approximated ICMBio staff and *quilombolas*, changing perceptions about *how* people use fire.

The incipient, but bold, SGTES fire management experiences – related to firebreaks and the legalization of some traditional burnings – drew national attention to fire use in strict protected areas. In 2013, SGTES was selected to host the side event of the 1st International Seminar on Integrated Fire Management held in the country, organized by the Cerrado-Jalapão Project (a Brazil-Germany partnership). This seminar was probably the first time most Brazilian environmental stakeholders working in protected areas heard about the IFM.

Since then, SGTES managers were involved in a learning trail about IFM that included a technical visit to the Northern Territory in Australia, where their experiences on the use of fire for management reasons were presented in two protected areas (Warddeken Indigenous Protected

Area and Kakadu National Park). International exchanges of experiences were also provided by the Ecological Corridor Project (Japanese technical cooperation) in 2011 and 2012, when SGTES managers had the opportunity to visit protected areas in Japan and learn with advanced initiatives of social participation in biodiversity conservation. Such exchange was an important educational experience for Brazilian governmental managers to broaden the understanding about plural governance in general and related to fire management, raising courage on those involved to assume uncertainties and risks in benefit of better management techniques.

Soon after the visit to Australia, in 2014, SGTES published its Management Plan (ICMBio, 2014) and its IFM Plan (Barradas *et al.*, 2014), presenting for the first time in Brazil the IFM approach officially as a conservation strategy for a protected area. These plans are important milestones for IFM institutionalization in environmental management at federal level, since fire use has previously only been accepted for fire ecology research, at small scales. The main IFM goal in this initial management trajectory was to reduce late dry season wildfires by using prescribed burnings along the early dry season.

Yet in 2014, some prescribed burnings were carried out in the early dry season, in a particular management zone in the south of SGTES. These ignitions were conducted without a burning block perspective, but in a patch burning setting for wildlands areas. All burnings were monitored by Robin Beatty, a consultant and specialist in fire management in tropical savannas, who stimulated and improved the interaction between ICMBio staff, *brigadistas* and the local community.

Integrated fire management period

A more consistent implementation of the IFM approach in SGTES was especially evident in 2015, when the triad fire management, fire culture and fire ecology gained scale and connection.

In the constant process of learning from experience, fire management aimed at firefighting and prescribed burnings activities have been improving. Prescribed burnings gradually expanded to the entire area of the Ecological Station inspired by patch mosaic burnings, an ancient practice carried by traditional communities

that results in heterogeneity in savannas landscape (Martin & Sapsis, 1992; Russell-Smith *et al.*, 1997; Laris & Wardell, 2006; Bilbao *et al.*, 2010; Pivello, 2011; Mistry *et al.*, 2016).

Combined with ancient technologies, fuel load maps, derived from geo-information on fuel conditions, have been used to support planning and assessing all fire management strategies in SGTES. The methodology used for fuel load mapping involves spectral responses from the vegetation phenological state (green or dry) and bare soil, as described by Franke *et al.* (2018). Besides fuel load maps, geo-information datasets related to the Cerrado vegetation type and burned

areas (scars mapping) are also fundamental for planning, monitoring and assessing integrated fire management in the SGTES until nowadays. Geo-technologies for fuel load and scar mapping have been improved over time considering semi-automatic procedures.

From the Fire Suppression Period to the current IFM moment, changes in fire regime – referring to fire seasonality, extension, intensity and frequency – have been varying across the landscape in time and space due to fire management policies decisions within SGTES history, as shown in Figure 3 and Table 1.

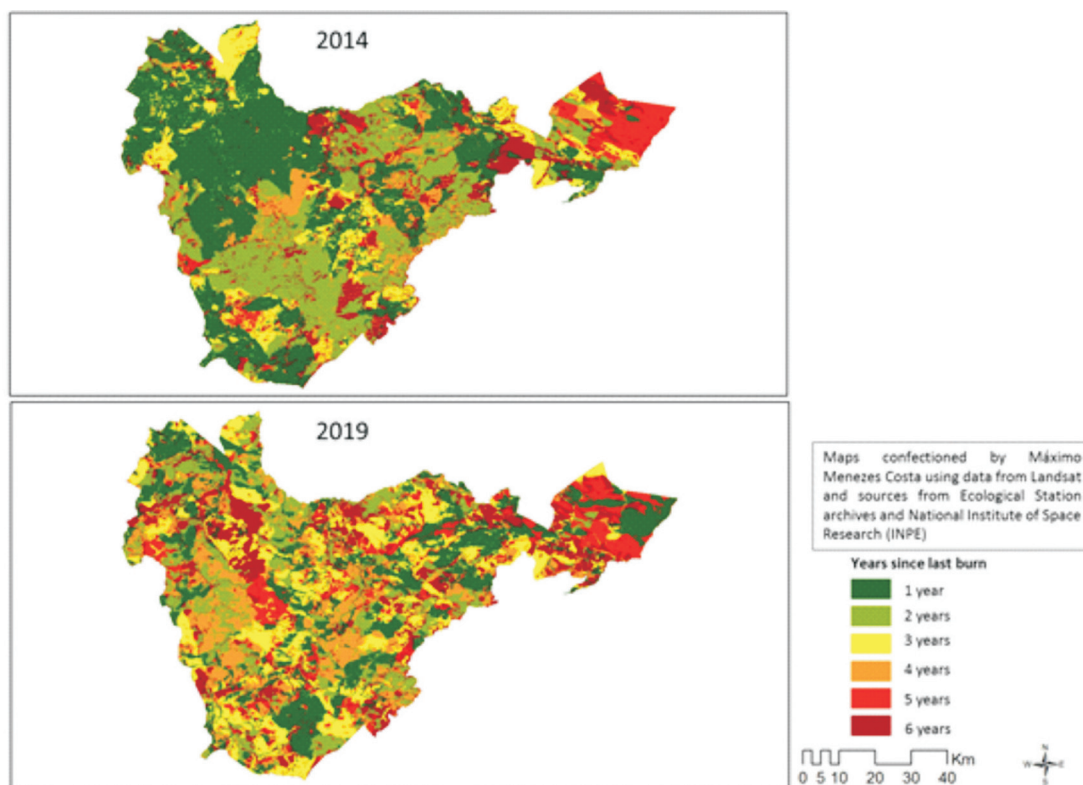


Figure 3 – Changes in burning patterns in the Serra Geral do Tocantins Ecological Station: comparison between fire scars landscapes in 2014 (fire suppression period) and 2019 (integrated fire management period).

In 2014, SGTES' landscape was extremely homogenized because of recurrent mega-wildfires, but in 2019 we observe a heterogeneous landscape related to pyrodiversity. As suggested by Martin & Sapsis (1992), we have assumed that in this region biodiversity needs pyrodiversity and, in this context, current studies are investigating this hypothesis for SGTES' reality, looking for better prescribed burnings settings.

In addition to the ecological and social benefits, patch mosaic burning has also brought economic benefits to the public administration, since no more mega-wildfires have been registered in SGTES since 2015 (see Table 1), which means that major efforts to fight extreme wildfires events are no more necessary.

Table 1 – Largest annual wildfire event and total area burned per year in the past ten years in Serra Geral do Tocantins Ecological Station, according to technical reports (Barradas *et al.*, 2020b; Fidelis *et al.*, 2019).

	2010*	2011	2012*	2013*	2014*	2015	2016	2017	2018	2019
Size of the largest wildfire (km ²)	800	450	1070	710	880	250	320	150	30	110
Total area burned in the year (km ²)	3200	2180	2850	2090	3030	2240	2150	1890	1400	1630

* Years of mega-wildfires (events > 500 km²)

Since 2017, the main objective of IFM in the Ecological Station is related to conservation and maintenance of socio-biodiversity and ecological processes, including appreciation of the culture of fire, not only as a social right and cultural heritage but also as an important knowledge for conservation purposes.

Participatory workshops during the TC/2012 review consisted on important occasions for sharing multiple perspectives about the social and ecological benefits of fire uses and practices. We believe that the presence of social scientists, always observant of the asymmetrical weaknesses in processes and of impositions, during negotiations, helped to achieve a better equalization of ‘voices’

between mainly environmental managers and *quilombolas*. A special contribution came from the anthropologist Guilherme Fagundes, who is involved in studies about culture and rights of *quilombolas* (see Fagundes, 2019b) and helped to build bridges between stakeholders, sometimes bringing up their shared ancient history related to African diaspora.

In 2018 a new TC was finally signed (TC/2018), now considering the social and cultural dimensions of fire culture in the *quilombolas* community, enlightening democratic horizons for an intercultural approach aimed at the co-management of fire in SGTES.

Table 2 – Main changes of the current Term of Commitment (TC/2018) in relation to the former one (TC/2012).

TC/2012	TC/2018
Fire management controlled by environmental agency	Participatory fire management approach
Fire use depended on burning permits	Fire use is agreed upon burning calendars
Late dry season burnings were forbidden Three-years was the minimum burnings interval Fire use along the banks of Novo river was forbidden	Pyrodiversity and patch mosaic burnings are recommended
Fire use was accepted only to productive activities (e.g. cattle raising and swidden agriculture)	Traditional practices related to the culture of fire are allowed

The pioneering in intercultural fire management in SGTES has been attracting a number of researchers from all over Brazil and other countries willing to address this theme, despite the obstacles to foster a bold research agenda to meet the challenges in the Ecological Station management (SGTES is geographically isolated in relation to urban centers and airports and

infrastructure to receive researchers is precarious, therefore, field expeditions are logistically complex and expensive). However, more efforts to bring researchers from varied areas of knowledge, encompassing the social, cultural, political and economic aspects of fire in a territory, is clearly necessary.

The first Research Plan for SGTES (Nogueira, 2015) analyzed all studies carried out in the protected area between 2001 and 2014 (fire suppression period), totaling 28 publications in 14 years, and just three of them focused on the role of fire in the local or regional context. Conversely, in the process of updating the Research Plan of the Ecological Station, still in progress, we have identified in the last five years (IFM period) at least 30 studies carried out resulting on publications – from journals and book chapters to conference proceedings. Now, the use of fire for Cerrado management is the main subject of these recent publications, focusing on the relation between fire management and biodiversity.

This has been seen as a great opportunity to have professionals from different research areas investigating a common topic – fire use for Cerrado management – in a protected area, at a large scale, and willing to discuss their questions and results with local stakeholders. This is one of the guidelines for advancing biodiversity research in the country, when it in fact aims to influence public policies and biodiversity conservation (Ribeiro *et al.*, 2019), and also in the rest of the world (Kueffer *et al.*, 2012).

Final considerations

Serra Geral do Tocantins Ecological Station went through a challenging trajectory from the anti-fire policies to integrated fire management. The authors' enthusiasm with the current results from the actual management approach, such as the effective achievement of the first objectives of IFM (wildfire reduction, creation of a mosaic of burned areas, increased dialogue with the community), is evident.

On the other hand, we recognize that new challenges are arising from this new reality, as it is expected for complex systems. To guarantee the perception and criticality to the new unfolding information, it is fundamental to maintain multi-institutional and multicultural debates in different forums, welcome professionals from different areas and pursue agreements over objectives.

Another observation is that, in recent events about fire management held in the country, such as the 7th Wildfire Conference, we noticed that researchers, the communities and environmental technicians are often using the term *MIF*, the

acronym in Portuguese for IFM, to refer to prescribed burns. Fagundes (2019a) also noticed the use of the expressions *mifar* [to IFM] and *fazer MIF* [doing IFM] among consultants, environmental managers and fire brigade members when referring to the implementation of prescribed burns to manage Cerrado protected areas.

This understanding announces risk to disregarding the “I”, from the integrated approach, proposed by Myers (2006), in which fire issues should take into account biological, environmental, cultural, social, economic and political interactions. Thus, we must be aware to acknowledge the *intercultural* approach, as suggested by Bilbao *et al.* (2019), for the *integrated fire management* in Brazil, avoiding the regress to a technocratic understanding of fire management, disconnected from the ecological and social components.

The experience with IFM in Serra Geral do Tocantins Ecological Station, with special emphasis on an intercultural approach, has been inspiring paradigm shifts in fire policy in other protected areas in Brazil, serving also as a reference for the institutionalization of IFM within the scope of ICMBio.

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