Playing with fire: the vital influence of traditional knowledge on the socio biodiversity of the Pantanal

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Keywords: Pantanal; human occupation; fire; land management.

ABSTRACT – The Pantanal is a fire-prone biome with natural flooding regime coupled with periodic drought, which creates unique features that has shaped its environment, biodiversity, its people and the way they live, based upon their intimate connection with its natural dynamics. Fire has been used locally for managing landscapes for thousands of years by indigenous populations and, as the region was being occupied by different groups, their knowledge pertaining the best way to manage the land was passed on to the newcomers, the farmers. These practices are embedded in the local traditions and lifestyle, to the point that they became an important aspect of Pantanal's cultural heritage. However, changes in the land use and management in the last 50-60 years had caused significant impacts that threatens the sustainability of the region and the future of the biome.

Brincando com fogo: a influência vital do conhecimento tradicional na sociobiodiversidade do Pantanal

Palavras-chave: Pantanal; ocupação humana; fogo; manejo de paisagem.

RESUMO – O Pantanal é um bioma dependente do fogo com um regime natural de inundação, criando uma região com características peculiares que moldaram seu meio ambiente, sua biodiversidade, seus habitantes e a maneira como eles vivem: intimamente ligada à dinâmica natural do local. O fogo tem sido utilizado no Pantanal como ferramenta de manejo de paisagens há milhares de anos pela população indígena e, à medida em que a região foi sendo ocupada por outros grupos, o conhecimento foi passado para os novos habitantes, os fazendeiros. Essas práticas estão incorporadas nas tradições e no modo de vida

local, chegando ao ponto de se tornarem um aspecto importante do patrimônio cultural do Pantanal. Entretanto, mudanças culturais e na ocupação e uso da terra nos últimos 50-60 anos têm gerado impactos significativos que ameaçam a sustentabilidade da região e o futuro do bioma.

Jugando con fuego: la influencia vital del conocimiento tradicional en la sociobiodiversidad del Pantanal

Palabras clave: Pantanal; ocupación humana; fuego; gestión del territorio y conservación de la sociobiodiversidad.

RESUMEN – El Pantanal es un bioma propenso a incendios con un régimen de inundaciones naturales junto con sequías periódicas, lo que crea características únicas que han moldeado su medio ambiente, su biodiversidad, su gente y su forma de vida, basándose en su íntima conexión con su dinámica natural. El fuego ha sido utilizado localmente para gestionar el paisaje durante miles de años por las poblaciones indígenas y, a medida que la región estaba siendo ocupada por diferentes grupos, sus conocimientos sobre la mejor forma de gestionar la tierra se transmitieron a los recién llegados, los agricultores. Estas prácticas están arraigadas en las tradiciones y el estilo de vida local, hasta el punto de que se convirtieron en un aspecto importante del patrimonio cultural de Pantanal. Sin embargo, los cambios en el uso y gestión de la tierra en los últimos 50-60 años han causado impactos significativos que amenazan la sostenibilidad de la región y el futuro del bioma.

Introduction

The Pantanal is the world's largest freshwater wetland, located in the upper Paraguay River Basin, with portions in Bolivia (18%) and Paraguay (4%), but mostly within the Brazilian states of Mato Grosso (27,3%) and Mato Grosso do Sul (50,7%) [1][2][3][4][5]. The majority of Brazilian Pantanal, approximately 90-95% of its territory, is located in private properties, the cattle ranch farms [1][2][3][4].

The Pantanal floodplain is surrounded by plateaus, which have an essential role in the maintenance of the region's flooding regime and hydrological processes, as they are fed by precipitation on the plateau headwaters [1][5][6][7][8][9].

Its natural flooding regime slowly moves from north to south [4][10] and, in association with periodic droughts and fire, created unique features that has shaped its landscape – consisting of a mosaic of grassland (floodable and/or nonfloodable), open woodlands, forests and aquatic habitats (temporary or permanent) [1][11] – and biodiversity, its people and the way they live, based upon their intimate connection with its natural dynamics [1][12].

As a fire-prone biome, Pantanal has evolved with the presence of fire and have adapted to it, in other words, its ecosystems benefit from fires for maintenance of their biodiversity and ecological processes, depending upon it to prosper [10][11][13][14][15][16][17][18][19][20]. In Pantanal, there are two well-defined seasons: the dry season, from April to September, with its peak between June and August and the wet season, from October/November to March [1][4][10][11][18]. Natural fires in the region usually occur between April and June, which are transitional months between seasons [10][11][13][19]. Under normal conditions, natural fires are usually of low intensity, hence is unlikely they would spread too much or become very destructive, as they tend to die out quickly [10][13][14][15][16][17][18][21][22].

In fire-prone environments, fire stimulates resprouting and accelerates the growth of some plants, increasing food availability for animals; it consumes the understory without significantly changing the soil properties [10][13][15][23][24][25] and, it removes excess dead biomass, reducing the flammability of the system, thus the intensity of future fires [10][13][14][15][22][26][27].

Besides natural fires, another source of ignition is anthropic, in other words, fires lit by humans [9][10][14][15][16][17][22][26][27][28][29][30][31][32][33]. Indigenous people have been using fire for millennia and their traditional practices [11][17][26], based upon their profound knowledge about the

about the local natural dynamics [12][25][27][34], usually achieve similar effects of natural fires [11][17] [12][25][26][27][34].

Regardless, in the past centuries, science has had an understanding that fire is a bad thing [16][17]. According to Pyne (2021), the shift in the perception of fire happened by the time northern European nations became the centre for modern science; as they had no basis for natural fire, they perceived it with suspicion and, in their eyes, after the creation of industrial combustion, fire itself became a symbol of primitive and undeveloped economies [16][17] [25]. At this point, these nations were in a position to influence fire's history across the globe and as a result, fire was something that should be extinguished everywhere and in every possible way whatsoever [17]; any belief or practice that establishes otherwise should not be taken into account, and it has been considered obsolete or simply useless and ignorant [17][25].

For centuries, fire suppression policies were enforced in many countries [10][35], with completely different natural features, thus reaching different outcomes [17][32][33]. Although it has had positive results for fire-sensitive biomes, such as tropical forests, in fire-prone biomes it has proven to be a disaster [10] [36]. The absence of fire in places that usually burn led to alterations in the structure, distribution and function of plants' communities, increasing the flammability of the system, thus altering fire behaviour and ultimately leading to catastrophic events worldwide [8][9][10] [13][19][33][36].

Human occupation of Pantanal

There are three main groups in Pantanal's current population: indigenous ethnicities, the traditional communities and the landowners. They are the result of the land occupation process throughout time [18].

Indigenous population

Human presence in Pantanal is very ancient with registers dating of 8000BP and its first inhabitants were indigenous hunter-gatherer peoples [37][38]. The occupation of the region was consolidated between 3.000 – 1.300BP by ethnicities Macro-Jê, Chamacoco, Guarani, Mbayá-Guaikuru, Aruak from which descended the Terena, Xaraés, Kadiwéu, Guató, Bororo, amongst others [38][39][40][41] [42][43][44]. They each had their own territory and their lifestyle was based on fishery, hunting, and a rudimentary polycultural agriculture [27][38][42][45] [46][47][48].

In the mid-1900s, started the creation of the Indigenous Territories (T.I.), for the remaining indigenous population. Currently there are five indigenous territories with their land tenure regularized:

- located in Mato Grosso, the T.I. Perigara (with 104 inhabitants) and T.I. Tereza Cristina (with 506 inhabitants), both of Bororo ethnicity [44] [49][50];
- located in Mato Grosso do Sul, T.I. Guató (with 198 inhabitants of Guató ethnicity), T.I. Cachoeirinha (with 4.920 inhabitants of Terena ethnicity) and the RI Kadiwéu (where 1.697 inhabitants of the Kadiwéu, Terena and Guarani-Kaiowá Chamacocos ethnicities live) [44][49][50].

The first indigenous territory regularized was the T.I. Tereza Cristina, in 1969, followed by the T.I. Kadiwéu (1984), T.I Perigara (1991), T.I. Guató (2003) and T.I. Cachoeirinha (2007) [49].

Other two indigenous territories, T.I. Baía dos Guatós (with 202 inhabitants of Guató ethnicity), located in Mato Grosso and T.I. Taunay/Ipegue (with 4.090 inhabitants of Terena ethnicity), located in Mato Grosso do Sul) are currently in different phases of the land tenure's regularization process [49]. The data of the populations' size are from 2010 and indicate that from the original inhabitants of all ethnicities a bit over 12.000 are left, of which 9,000 are of Terena ethnicity [49]. To this day, these populations face similar threats of those of 500 years ago [51], such as acculturation [50][51][52][53] and invasion of the territories for:

- land-grabbing and/or appropriation for sale and occupation by third parties, in at least 4 of the above TIs – Tereza Cristina, Cachoeirinha, Kadiwéu and Taunay/Ipegue [49],
- logging, in at least 5 of the above TIs – Tereza Cristina, Cachoeirinha, Kadiwéu, Taunay/Ipegue and Baia dos Guatós [49],
- mining (lawsuits, disputes and/or requests) in at least 2 of the TIs (Cachoeirinha and Guató) and illegal charcoal production (in TI Cachoeirinha) [49] and

- fishery, considered as a possible threat by Funai for TI Baía dos Guatós and TI Guató [49].

Traditional communities – *o pantaneiro*

At the beginning of the 16th century, the region was briefly occupied by the Europeans colonizers, whose arrival led to a massacre of the indigenous population and the expulsion of the survivors. However, some of the tribes were able to recolonize the region a few decades later, as the Spanish left [38][42][46].

By the time of the establishment of the Iberian Union in 1580, Portugal was already expanding its occupation from the coast towards the centre of the territory. It was then that cattle were introduced into the region [4][54] and, according to Wilcox (1992), by the end of the seventeenth century, some tribes had become ranchers themselves, raising these animals for their subsistence.

At the beginning of the 18th century, a new migratory wave took place with the arrival of Portuguese colonizers and pioneers from São Paulo (*bandeirantes paulistas*) and Minas Gerais to explore gold mines in Cuiabá and/or activities correlated with the mining business [52][55], by which time enslaved Africans were introduced in the Pantanal. Once again, the indigenous people were killed or expelled of their territories, with the survivors being used as forced labour for mining or inside the farms [52][55][56][57].

In the 19th century, the Paraguayan War (1864-1870) took place, with battles happening within the Pantanal and the Paraguayans occupied several areas of the region for 4 years [18][58][59]. Some indigenous groups, as the Guaikurus (Kadiwéu ancestors), known as great knights and aggressive warriors, participated actively in the war and reportedly fought against Paraguay, helping the Brazilian government to win it [59][60]. Soon after the war ended, the farmers reoccupied the land and around the same time, in 1888, it was promulgated the slavery abolition [56]. Concomitantly, Paraguayans immigrants seeking a better life and the newly freedman joined the remaining indigenous families, mostly of the Guatós' ethnicity [18].

The miscegenation among these groups generated a population strongly dependent on their *habitat*, deeply connected with nature and with an identity of its own, the *pantaneiro* [12]. Their families are considered to be the traditional communities in Pantanal [18].

There are familiar groups clustered in settlements dispersed mostly alongside the Paraguay River known as the riverine (*ribeirinhos*), whose main source of income is fishing, followed by tourism related activities. Currently, in the region, there are about 30-50 riverine familiar settlements with ~6000 people [18][46][61]. Another group of *pantaneiros* live and work in the farms, sometimes for generations. They are the cowboys (peão), who usually live most of the time isolated in the farms, taking care of the ranching activities particularly the cattle [62].

The farmers – landowners

Currently about 90-95% of the Pantanal biome are in private properties – the farms – and most of them are (approximately 80%) used as extensively managed cattle ranches [1][63][64].

Cattle ranching as an economic activity started at the beginning of the 18th century, when non-indigenous people (mostly the pioneers – *bandeirantes paulistas* – and Portuguese colonizers) forcefully occupied the indigenous territories, conquering the ownership to land**,** and established the first farms and ranching operations in the northern Pantanal in 1737 [4][54][55][56][65].

In the 19th century, there was another influx of immigrants from São Paulo, Minas Gerais and Cuiabá attracted by the possibility of occupying unclaimed land (*terras devolutas*) in Southern Mato Grosso, up to the border of Paraguay [4][59][66]. Concomitantly, those already established in the northern Pantanal were expanding their domains towards the south [4][66]. By around the mid-1800s, the extensive livestock farming in the Pantanal was consolidated [66]. A short time later, the Paraguayan War (1864-1870) took place, with battles happening within the Pantanal and the Paraguayans occupied several areas of the region for 4 years [18][58][59]. Soon after the war ended, the farmers reoccupied the land and during the period from 1870-1920 the agrarian elite of Southern Mato Grosso was formed and new areas of the Pantanal in the southerly direction were occupied [18][66].

At this point, the ranching activity was rudimentary, low-cost and demanded minimal care, with low cattle densities in a continuous grazing system, where the animals forage relied on the open

native pastures, with a relatively low environmental impact [4][63]. Its foundation was based on empirical experience, and it had to be adapted to the seasonal flooding of the region, during which time large areas are inundated. The solution was to move the livestock to dry pastures, in the upper part of the floodplain (the *cordilheiras*), with men travelling very long distances by horse [4][18], in journeys that could last between three to four months. This mechanism was crucial not only to avoid losses during the wet season but also commercially, as it was not possible to transport the animals otherwise [4]. For almost two hundred years, this practice was carried out without significant changes, to the point it became part of the local identity [18][66][67].

As it gained more economical importance, the displacement of the livestock became more structured, organized in *comitivas* where each one has its predetermined function [2][67][68][69]. By the beginning of the 20th century, the dried meat industry started developing in the region and by 1950 it was thriving due to exportation during Second World War and following recession [2][63], enabled by the construction of small dirt roads and the navigation on the Upper Paraguay river.

By the 1970s, the cattle ranching business and the region itself experience an accelerated process cultural, technological and social changes [2][4][18][63]. Ranchers' profile starts to change with younger generations administrating or even taking over the farms after the parents' retirement or death; the bond with the land was still strong but beings to lessen as many studied and/or lived in urban centres or abroad [18]. They introduced new production methods and the usage of less sustainable formats, such as machinery [70], intensive livestock production, expansion of the area available for cattle through deforestation and/or replacement of native pastures for exotic species [2][4][18][63][70]. Traditional practices such as the *comitivas* start to lose ground to transporting the cattle by trucks (*gaiolas boiadeiras*), enabled by the construction of the Transpantaneira road [18].

Concurrently, infrastructural facilities such as dams, power plants, roads, etc, were being widely implemented across the Pantanal [1][5][63]. At the surrounding plateaus, a series of human interventions including the rapid a) agricultural expansion, with 65% of the vegetation have been converted into cultivated crop and pastureland [1][6]; b) deforestation [1][6][63] and c) implementation of large transportation and energy infrastructure projects were taking place and led to several disruptive impacts [1][5][6][8][63]. Amongst these impacts, the most important and damaging is probably the alteration of Pantanal's hydro-ecological processes, affecting its flood pulse [1][5][6][7]. Other significant impacts include (but are not restricted to) silting, pollution of river and streams and destruction or degradation of habitats [1][5][6][7].

By the 1990-2000s, came into being the tendency of reducing the properties' sizes, with ranches subdivided among family members or heirs after their parents' death, increasing the number of medium-sized ranches [4][18][63]. Many heirs live in big cities or abroad and had no interest whatsoever of working or living in the farm, hence resulting in an exodus of traditional ranching families [18]. Some decide to keep it as a source of income, delegating its administration to third parties – the managers or foremen (*capatazes*); others, who are not willing to invest neither time nor money in the farms, either abandon the property or sell them [18].

In this context, a new kind of landowner appears, the "new *pantaneiro*" ("*pantaneiro-novo*"), as the locals call the new people, mostly outsiders, who are buying the land as an investment option and are not familiar with the dynamics of the region [18]. Their objective is to maximize profits and, to achieve that, they introduced new production methods and increasing the usage of less sustainable formats such as intensive livestock production, expansion of the area available for cattle through deforestation and/or replacement of native pastures for exotic species [6][18][63].

Playing with fire

It is safe to say that the ability to control fire was one of the most remarkable achievements of mankind and it was essential to human existence [16][26][71][72]. Throughout the time, the relationship between men and fire has changed many times [16][17][73]. It has been both admired and feared, adored and fought over [16][17][73], seen as a force of nature and as one of the four elements of life (earth, water, fire and air). Customs, traditions and societies were crafted around it [16][17].

For thousands of years fire was the synonym of empowerment, until modernizing economies shifted this perception and distanced people from fire [17]. Its usage has been considered as primitive and ignorant by science and society [16][17][25][26], and as such,

it should be extinguished or at least contained [16] [17]. Fire was broken down into its components and its presence had been sublimated, thus even when is absent, it shapes modern civilizations and to this day it is embedded in most cultures worldwide [16][17].

Fire cultural presence and usage in Pantanal throughout time

Probably the most significant aspects of the local culture are the empiric knowledge of their people, based upon their intimate connection with the natural dynamics and surroundings, and their unique interpretation of what they observe [12][33][74].

For the indigenous populations and the traditional communities, the perception of the "environment" and natural phenomena may not clearly distinguish between natural and supernatural, so despite the empirical knowledge of these events, they are often explained by symbolical and/or imaginary representations [73][75][76][77]. For them, mythology is not a fantasy, it is the true history of the world passed down orally through generations [39] [74][78].

In the Pantanal, fire seems to play a secondary role in their mythology as everything in the regions revolves around water, many (if not most) of the local myths, supernatural creatures and/or symbolical representations relates to it [75][79][80]. Nevertheless, fire is part of some religious/spiritual rituals or ceremonies, such as the naming of a child or the initiation of young boys, to scare away ghosts or evil spirits, before and during health treatments and funerals [30][81]. According to the Bororo and Kadiwéu traditions, for example, the belongings of the dead should be incinerated at the end of all rituals of the funeral [82].

Furthermore, fire is a frequent subject of traditional oral narratives told by Amerindians (all the indigenous peoples living in South and North America) and there are two legends that are spread all round the country and became part of the local cultural heritage: the *Boitatá* and the myth of the theft of fire [77][78][83].

The *Boitatá* (*Mbói-tatá*) is a legend related to the luminous phenomenon *ignis fatuus,* a flame of bluish colour that glows without heat and has been witnessed in the region over the centuries [77][84] [85]. It sparked their imagination, with different stories recounting the sudden appearance of a flame floating above the land or marshes, leaving a trace of light without burning it, moving in a way that resembles a snake [77][78][83]. This "walking fire" was believed to be a creature known as the *Boitatá*, depicted as a big fiery serpent who lives near the water and protects the forest of people who try to burn or cut it down [85][86].

According to legend, the snake woke up after a deluge and left its shelter in search for food, only to find the land devastated. It had to feed from the eyes of dead animals, absorbing their light. It is said that the creature can turn into a flaming wooden trunk to trick and kill the humans who set fires to the forests. Although the *Boitatá* legend is attributed to the Guaranis, the first register of it was in 1560 by Padre Jose de Anchieta, thus it is possible that it was brought by the Portuguese at the time of colonization and spread all over the country, later becoming one of the most important characters of Brazilian folklore [77][78].

The myth of the theft of fire attempts to explain the process through which men acquired the ability control and use fire to their benefit. Historically, in the Pantanal, the first human inhabitants were familiar with the existence of fire, but didn't fully understand or know how to use it. Eventually, throughout time, they learnt to capture it from their surroundings and use it, however according to Pyne (2021) "they could only burn as their environment permitted". There are different versions of the myth depending on the ethnicity or location [39][74]: most stories tell that fire was owned by an animal (sometimes the jaguar, the vultures, the woodpecker or a deer) and it had to be stolen, as fire meant power and it was something to be conquered [39][87][88].

One version as recounted by an elder Apapokúva – the tribal self-designation of the Nhadeva's ethnicity, one of the many ethnicities descendant of the Guaranis that lived at Mato Grosso do Sul, near the Paraguayan border at the beginning of the 19th century [90][91] – tells that once upon a time, man had no fire as it was in the possession of the vultures (the Lords of Fire). The hero Ñanderýkeý ("Our Brother of All") decided to steal it from them; he gathered some animals (including birds and a frog *kururú-í*) and announced he would die in the *barreiro*. He went there, died and rotted attracting the vultures, who lit a big fire. When there were lots of ember, the vultures threw Ñanderýkeý in the fire. Ñanderýkeý then stood up, shook his body, scared off the vultures and told the animals he gathered to catch the fire. The only one who did it was the frog, by

swallowing it. The frog released the ember and as it was still burning, Ñanderýkeý made fire. Ñanderýkeý then instructed the others to search for a specific wood and taught them how to light a fire [87][89].

The Bororos apparently had different tales about how humans acquired the ability control and use fire. One is about a time when the indigenous were birds and they were often killed by both the Sun (Meri) and the Moon (Ari). One day Meri sent wind and rain, putting out the fire of the indigenous, who demanded it to be lit again. They had to swim to the other side of the river to retrieve the embers and to return without extinguishing it, despite of the strong wind Meri sent. The good ones managed to do it but the bad ones burnt their feathers and that's why birds like the vultures and the jabiru are bald [87]. Another version says that, instead of being stolen, fire was simply given to men by a monkey, who possessed the fire and taught men how to produce it in the same way, rubbing two wooden sticks [83][92].

As for the Kadiweus, Terenas and Guatós (three of the main local indigenous ethnicities), apparently there are no such myths or legends [44][47][53][81] [93][94].

Despite of mythological or religious aspects, for thousands of years, the indigenous people have been using fire on their daily basis as a source of heat, for protection, cooking and socializing [10][14][16][17] [26][29][72]. Maybe more importantly, they already had the ability to manipulate fire to improve the surroundings to their advantage altering the landscape and potentializing the usage of natural resources [14] [16][17][26][29].

Their traditional burnings, known as *queimadas*, have different purposes:

- clear the land, to remove excess dead biomass or unwanted species, eliminate wastes, kill pests and/or to open pathways to facilitate walking around [11][15][16][17][22][25][26]
- slash-and-burn systems for swidden agriculture and/or *shifting cultivation*, where the vegetation is cut down, left to dry (usually right before the rainiest part of the year) and then burnt to improve the quality of the soil and stimulate vegetation's resprouting, regrowth, flowering, and fruiting [10][13][14][19][25][27]
- to select useful species changing forest composition and structure [10][11][14][19] [25][26][27]
- hunting [14][27][28], where usually burns are made in two parallel lines (with the distance between them being determined based on the number of hunters), taking place in previously selected locations, and only during one to three weeks [25]
- for protection of their houses and surroundings [14][25][26]
- to collect honey [14]

The burns are done carefully and take place in previously selected locations within a certain window of opportunity (usually in the transitional months between the seasons, April to June, coinciding with the natural fire regime), so it would not interfere very much with the timing of animal reproduction [10][25] [27]. The resulting fire would achieve similar effects of natural fires, being usually of low intensity and even if it tends to spread a little, it was not likely to become very destructive [10][14][17][21]. The location, intensity, frequency and time of the burns would depend upon the purpose. Their profound knowledge about the best timing for burning, types of fire, the quality of the ashes or technics to control wind driven fires are often in the hands of the elderly or the *pajés* – for some Brazilian indigenous tribes, pajés are the equivalent of the North American shaman, a member of the community who stands in a respected position of spiritual and/or political leaders, frequently a healer and whose practices are somewhat vague and often associated with indigenous magic [96][97] – and it is passed down through generations [25][27].

With the arrival of the European colonizers, at the beginning of the 16th century, fire suppression policies (e.g.: *Ordenacões Afonsinas*, 1466; *Ordenações Manuelinas*, 1521), started to be instated all around the country, as fire was not considered something favourable to their economic interests (such as hardwood exploitation or agricultural production in the Atlantic Forest area [10]. Regardless of such policies, large-scale fires were used in the region by the colonizers and immigrants during initial occupation of the territory* [10].

Once the first cattle ranches were installed in the Pantanal, in the 1700s, farmers adopted many of the indigenous traditional practices to manage the landscape, including the usage of fire [4][30] [95]. For a long time, according to Wilcox (1992), burns were used mostly for managing the landscape, at times of emergency need for pasture and/or to eliminate excess or unwanted vegetation where cattle had not grazed, but apparently only became

common in the years following the Paraguayan War. Furthermore, Wilcox (1992) states that large-scale burning in the western Pantanal has been attributed to rubber collectors who, in 1899, were allowed to enter and explore the Nhecolândia region, in Mato Grosso do Sul, by its patriarch (Joaquim Eugenio Gomes da Silva – Nheco). Despite of the increasingly economic importance of cattle ranching, for the next two centuries, the business was carried out without significant changes [18].

It is not possible to determine the exact moment when farmers started to alter the timing or frequency of the burns, in relation to traditional/indigenous practices and natural fires [18][33]. According to Pivello et al. (2021), cattle ranching fires are set in towards the end of the dry season because the pasture regrows quickly with the onset of rains, providing quality feed for the cattle. They are more intense than natural fires and due to the absence of rain can spread over greater extensions and last for longer periods of time [10][14][20][22].

Throughout the time, this interference in the fire regime started to cause alterations on vegetation's structure and composition, soil degradation and the presence of invasive species [4][8][14][20][35][98].

It is important to note that, although according to the First and Second Forest codes, from 1934 and 1965 respectively, the use of fire for land management was still utterly prohibited nationwide, locally it remained the being widely used [10][18][22][95].

By the 1970s, the traditional cattle ranching system began to shift for the cattle husbandry system through the implementation of technological changes, such as the increase in the use of fire for deforestation and substitution of native pastures for exotic species, thus not adapted for the local dynamics [6][18][63]. According to Tomas et al. (2019), that led to the landscape simplification, causing severe negative impacts, such as fragmentation and loss of natural *habitats*, affecting local biodiversity and environmental services.

At the 1980-1990s, the enforcement of fire suppression policies were strengthened nationwide; although the main objective was to reduce deforestation in tropical forests like the Amazon [10][27], those policies ended up being executed everywhere, including in fire-prone biomes, ignoring local specificities and/or traditional knowledge [33]. In the Pantanal, indigenous territories discontinued the usage of fire [35], as well as many landowners, but many others kept burning [10][18]. On top of that, according to Eloy et al. (2021), the anti-fire agenda was also a strategy of the agribusiness players to contest the rights of indigenous and traditional populations [27][99].

Meanwhile, the suppression of fire and/or abandonment of many properties that remained unattended, without cattle grazing and/or land management, led to large amounts of biomass accumulated rapidly, causing alterations in the structure, distribution and function of plants' communities and increasing the flammability of the system [11][13][18][33]. The combination of all these factors resulted in fires becoming increasingly more intense and destructive [1][10][14][98][100] and, according to Batista et al. (2019) as a consequence instigated discussions about potential solutions for managing fire and stimulated research related to the presence of fire in Brazilian savannas [1][10][20][33][98][99].

The Decree n. 2.661/1998 was the first step to legalize and regulate agricultural burns. It was followed by the Law no. 12,651/2012 (also known as the new Forest Code of 2012), which enabled the introduction of a pilot project for prescribed burns in some National Parks and Indigenous Territories [22][31][33][101][102]. The first prescribed burn in Brazil took place in 2014 in three UCs: the National Park of Chapada das Mesas (Parque Nacional da Chapada das Mesas – PNCM), Parque Estadual do Jalapão (PEJ) e Estação Ecológica Serra Geral do Tocantins (EESGT) [106]. In the Pantanal, the first area to be burned intentionally was the T.I. Kadiwéu, in Mato Grosso do Sul, in 2015, having achieved very positive results [98][103].

Concurrently, prolonged extreme droughts worsen the context that has been developed throughout the previous decades, created the scenario of a perfect storm, ultimately resulting the megafires of 2019 and 2020 [1][10][33][100][104]. In 2020, a guide to the application of fire as a management tool at farms in Pantanal was published by Embrapa Pantanal [19] in order to help landholders.

In 2021, the National Policy for Integrated Fire Management (PNMIF) was approved, following the global trend of a more comprehensive approach to fire management [18]. It is a new strategy that, according to Myers (2006), analyses possible technical decisions and actions available to prevent, maintain, control or use fire in a given landscape. The IFM takes into account ecological, technical, cultural and socioeconomic factors to evaluate threats, damages

and/or benefits of fire within the context of the natural environments where they occur [10][11][19][20][22][27][33][35][100][104][105][106]. The first burns in the Pantanal as part of the IFM happened in October, at the Sesc Pantanal in Mato Grosso [18].

Discussion

Considering the fact that, for at least the last 300 years, most of the Brazilian Pantanal is located in private lands, comprising 90-95% of its territory, it is just natural that the landowners become the main actors in the conservation status of the biome [2][4][18].

Pantanal's traditional cattle ranching format has had a relatively low environmental impact in the local ecosystems and biodiversity for almost two centuries [2][3][4][18][63]. That was only possible because their lifestyle and business system were based upon their empirical knowledge of its natural features and dynamics [3][4][18]. The extensive ranching format was rudimentary, low-cost and demanded minimal care [4] and fire was the main tool for managing the landscape; their traditional practices allowed the balance between economic activity and the preservation of its natural features [3][4][11][19][27][95].

It can be said that, until the 1960s, Pantanal was as an example of sustainable economy [3][18]. However, from the 1970s on, a completely different business concept starts to spread locally, where the natural features of the Pantanal (the abundance of native pasture, the floods cycles, the presence of fire and the local biodiversity) either had lost value or became an obstacle and are no longer desired or appreciated [18].

Alterations inside the floodplain and at the surrounding plateaus led to severe alterations in Pantanal's natural features and impacts on its hydrological dynamic, compromising its balance and making it more vulnerable [1][6][7][18][63]. Hence, it is safe to say that changes in the land use and management in the last 50-60 years are not compatible with a system of low environmental impact and ecological sustainability in the Pantanal is threatened [18][63].

At the same time, in addition to these negative impacts, recent megafires in the region [1][10] made it clear that the anti-fire narrative of widely employed fire suppression policies [33][34] did not work in the Pantanal. It brought into light the need to acknowledge that Pantanal is a fire-prone ecosystem and, as such, fire is not only expected but plays a determinant role on the local natural dynamics, hence its presence is essential for the maintenance of the ecological balance of the region and the ecosystem services it provides [1][6][7][10][11][13][15][16][17][18][20][27][33][98][106]. This is a crucial premise when analysing long-term conservation results and ecological impacts of land use and landscape management, both locally and in the surrounding plateaus [1][6][7][13].

The connection between historical land use and occupation and the use of fire as the ma is clear, as illustrated in the figure below (Figura1).

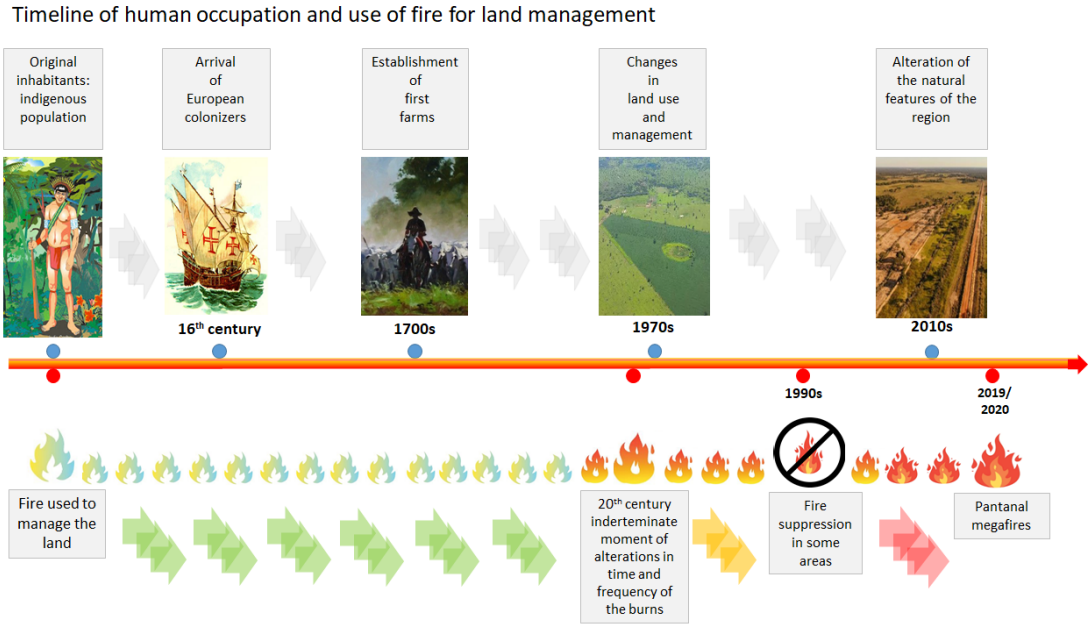

Figure 1 – Timeline of human occupation and use of fire for land management in the Brazilian Pantanal.

When considering the integration of the social (historical occupation and land use) and ecological (fire-prone ecosystem with a natural flooding regime) factors which, together, resulted in the landscaping, biological and cultural richness of today's Pantanal, the implementation of actions towards the Integrated Fire Management (IFM) could be the most effective path to avoid future catastrophic wildfires [11][19][20][22][27][33][35][100][104][106].

In order to achieve that, future management policies or directions must take into account not only the farmers [94], but also the indigenous populations and traditional communities, as both fire users and strategic partners to protect local socio biodiversity [25][26][27][60][98][99][106]. Their knowledge has a crucial role in understanding the natural world and, instead of being dismissed, it should be embraced by both science and society, in order to optimize the effectiveness of conservation actions [27][60][106].

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