

Market-based Options for Supporting Sustainable Fire Management of Fire-prone Cerrado (Savanna) Remnant Landscapes

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ABSTRACT – Sustainable fire management of remnant Cerrado (savanna) vegetation faces many challenges in Brazil and regionally, including: the legacy of imposed colonial fire suppression policies; massive fragmentation of the Cerrado biome through agricultural and pastoral development; loss of cultural fire management knowledge and experience; occurrence of severe late dry season wildfires given general lack of appropriate prescribed fire management. As context for addressing these challenges, we first provide illustrative examples of a successful market-based program implemented in fire-prone north Australian savannas, and recent establishment of a complementary pilot program in wildfire-prone savanna in Botswana. We then outline the need and opportunity for developing an analogous fire management approach in Brazilian Cerrado, noting that: (a) there is considerable potential for implementing supportive and incentivized fire management on frequently wildfire-affected lands, especially Indigenous Territories; (b) as demonstrated by Australian experience, such development can be achieved rapidly under conducive policy conditions. Perhaps the key to such rapid transformation is to recognise that everyone benefits – global climates, regional ecological sustainability, and local people both culturally and financially. The paper provides a contextual summary of presentations and technical workshop discussions associated with the conducting of a Special Session of the 7th International Wildland Fire Conference, Campo Grande, Brazil, focused broadly on the theme described by this paper's title.

Keywords: Fire regimes; wildfires; prescribed burning; indigenous fire management.

Oportunidades de Mercado para Apoiar o Manejo Sustentável do Fogo em Paisagens com Remanescentes de Cerrado (savana) Pirofíticos

RESUMO – O manejo do fogo sustentável da vegetação remanescente do Cerrado (savana) enfrenta muitos desafios no Brasil e regionalmente, incluindo: o legado de políticas coloniais impostas de supressão do fogo; fragmentação massiva do bioma Cerrado por meio do desenvolvimento agropastoril; perda de conhecimento e da experiência cultural de manejo do fogo; ocorrência de incêndios severos no final da estação seca devido à falta de manejo apropriado com queima prescrita no geral. Como contexto para enfrentar esses desafios, primeiro fornecemos exemplos ilustrativos de um programa bem-sucedido, com base no mercado, implementado nas savanas do norte da Austrália, pirofíticas, e o recente estabelecimento de um programa piloto complementar em savanas suscetíveis a incêndios em Botswana. Em seguida, delineamos a necessidade e oportunidade de desenvolver uma abordagem análoga de manejo do fogo no Cerrado brasileiro, observando que: (a) há um potencial considerável para a implementação de manejo do fogo com apoio e incentivo em áreas frequentemente queimadas por incêndios, especialmente em territórios indígenas; (b) conforme demonstrado pela experiência australiana, esse desenvolvimento pode ser alcançado rapidamente em condições políticas favoráveis. Talvez a chave para essa transformação rápida seja reconhecer que todos se beneficiam – climas globais, sustentabilidade ecológica regional e população local, tanto cultural quanto financeiramente. O artigo fornece um resumo contextual de apresentações e discussões em Oficina Técnica associadas à Sessão Especial da 7ª Conferência Internacional sobre

Incêndios Florestais, em Campo Grande, Brasil, focada de modo geral no tema descrito no título deste artigo.

Palavras-chave: Regimes de fogo; incêndios; queima prescrita; manejo do fogo indígena.

Oportunidades de Mercado para Apoyar el Manejo Sostenible del Fuego en Paisajes con Remanentes del Cerrado (Sabana) Pirofíticos

RESUMEN – El manejo sostenible del fuego de la vegetación remanente del Cerrado (sabana) enfrenta muchos desafíos en Brasil y a nivel regional, incluyendo: el legado de las políticas coloniales de supresión de incendios impuestas; fragmentación masiva del bioma Cerrado debido al desarrollo agrícola y pastoril; pérdida de conocimientos y experiencias culturales en el manejo del fuego; ocurrencia de incendios forestales severos al final de la estación seca dada la falta general de un manejo apropiado de quemadas prescritas. Como contexto para abordar estos desafíos, primero proporcionamos ejemplos ilustrativos de un programa exitoso basado en el mercado implementado en sabanas del norte de Australia propensas a incendios, y el reciente establecimiento de un programa piloto complementario en una sabana propensa a incendios forestales en Botsuana. A continuación, describimos la necesidad y la oportunidad de desarrollar un enfoque análogo de manejo del fuego en el Cerrado brasileño, señalando que: (a) existe un potencial considerable para implementar el manejo del fuego con apoyo e incentivo en tierras frecuentemente afectadas por incendios forestales, especialmente territorios indígenas; (b) como lo demuestra la experiencia australiana, ese desarrollo puede lograrse rápidamente en condiciones políticas favorables. A lo mejor la clave para una transformación tan rápida es reconocer que todos se benefician: el clima global, la sostenibilidad ecológica regional y la población local tanto cultural como financieramente. Este artículo proporciona un resumen contextual de las presentaciones y las discusiones del taller técnico que se realizó en una Sesión Especial de la 7ma Conferencia Internacional sobre Incendios Forestales, Campo Grande, Brasil, enfocada ampliamente en el tema descrito por el título de este documento.

Palabras clave: Regímenes de fuego; incendios forestales; quemadas prescritas; manejo indígena del fuego.

Introduction

Savannas constitute the most fire-prone ecosystem on Earth, currently annually accounting for almost 90% of global burned area (Giglio *et al.*, 2018) and 62% of global fire carbon emissions (van der Werf *et al.*, 2017), and are home to 20% of the human population and most livestock (Lipsett-Moore *et al.*, 2018). The great majority of savanna fire extent occurs in Africa, followed by substantially lesser savanna fire extent in South America then Australia (Giglio *et al.*, 2013, 2018). Despite recent centuries of European colonial fire policy prohibiting customary fire management practices in all fire-prone continental settings (Pyne, 1997; Moura *et al.*, 2019), many rural populations living in savanna environments continue to be dependent on a variety of fire practices for their agricultural, livelihood and cultural requirements. Ecologically, in interaction with rainfall and fertility gradients, disturbances (e.g. strong winds, grazing), and accelerating industrial influences (e.g. climate change, atmospheric CO₂ enrichment), savanna fire regimes have major effects on the long-term

balance/trajectory of tree and grass cover, regional biodiversity and associated environmental impacts (e.g. soil erosion, water quality), carbon stocks and greenhouse gas emissions.

In Australia, building on opportunities created initially through the Kyoto Protocol, since the late 1990s there has been significant ongoing development of accredited landscape-scale ‘savanna burning’ greenhouse gas emissions abatement and carbon sequestration accounting methodologies – essentially commercially incentivizing the undertaking of strategic integrated fire management under conservative early dry season (EDS) fire-weather conditions in order to reduce the extent and ecological impacts of typically more severe late season fires (LDS) and resultant emissions. The approach builds essentially on traditional Indigenous (aboriginal) fire management practice developed over millennia. Currently, formally registered savanna burning projects occur over a quarter of Australia’s 1.2Mkm² northern savannas with significant employment, cultural and ecological benefits – especially for indigenous (aboriginal) communities and landowners (Russell-Smith *et al.*, 2013a, 2019).

Since 2018, Australian and Botswanan Governments have been undertaking a feasibility assessment of the Australian savanna burning greenhouse gas emissions (GHG) abatement methodology for application in Botswana under similar LDS-dominated regional fire regime conditions. Preliminary results of that assessment, undertaken under the auspices of the International Savanna Fire Management Initiative (ISFMI), demonstrate that an analogous GHG accounting approach is technically readily feasible, but requires substantial complementary medium- to longer-term investment to develop: supportive national fire policy given current focus on fire suppression – like Brazil until recently (Durigan & Ratter, 2018; Schmidt *et al.*, 2018; Moura *et al.*, 2019; Schmidt & Eloy, 2020); fire management capacity of local communities and institutions; associated project governance arrangements; an effective independent MRV (Monitoring, Reporting, Validation) system – similar to Australia’s fire mapping and emissions accounting North Australia Fire Information (NAFI – www.firenorth.org.au); and appropriate market instruments (see also: Russell-Smith *et al.*, 2013b; Lipsett-Moore *et al.*, 2018; ISFMI – www.isfmi.org).

In this paper we provide a brief background to the fire regime contexts of savanna burning GHG initiatives being undertaken in Australia

and southern Africa, and then address the potential and associated challenges involved with developing and implementing similar incentivized fire management programs in South American Cerrado systems, focused especially on Brazil. For the latter assessment we draw particularly on workshop proceedings and presentations associated with the special session on Savanna burning challenges and opportunities, from the 7th International Wildland Fire Conference, Campo Grande, Brazil, October 2019.

Australia

Australia’s 1.9Mkm² tropical savannas, representing 26% of Australia’s land area, constitute the most fire-prone biome of a notoriously fire-prone continent (Figure 1a). Fires are lit predominantly by people and occur mostly in the late dry season (LDS), Aug – Nov, as extensive (>100km²) wildfires under progressively deteriorating fire-weather conditions (Figure 1b). On average, fires occur every five years over the entire 1.9Mkm² savanna region, and once every two years in higher rainfall (>1000mm mean annual rainfall [MAR]) regions (Whitehead *et al.*, 2014; Edwards *et al.*, 2015).

The current LDS-dominated seasonal fire pattern resulted from the breakdown of traditional

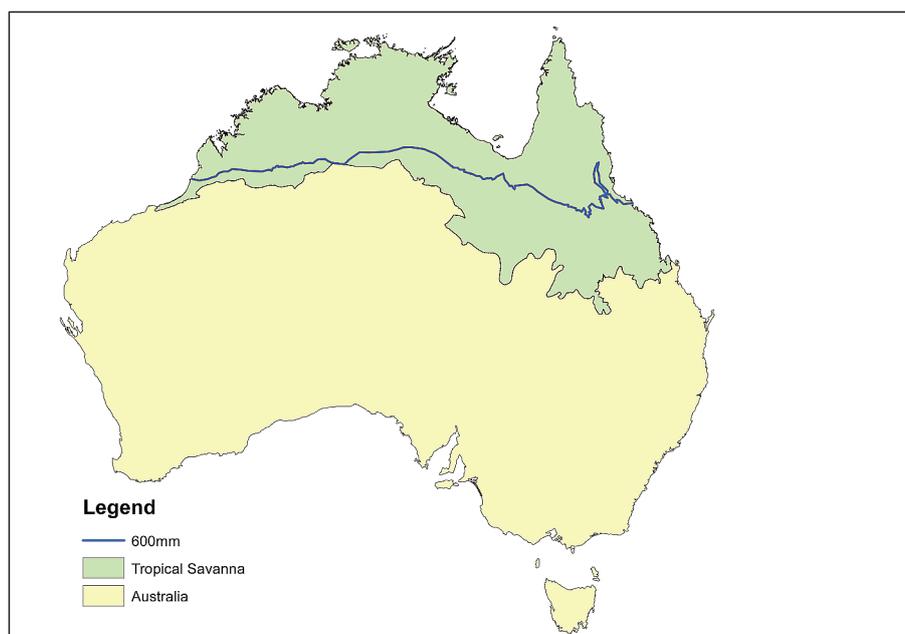


Figure 1(a) – Location of Australian tropical savannas highlighted in green. The blue line is 600mm annual rainfall isohyet with less than 50mm rainfall in the driest quarter (<http://www.bom.gov.au/jsp/awap/rain/index.jsp>). Savanna burning methodology applies above the 600mm rainfall isohyet.

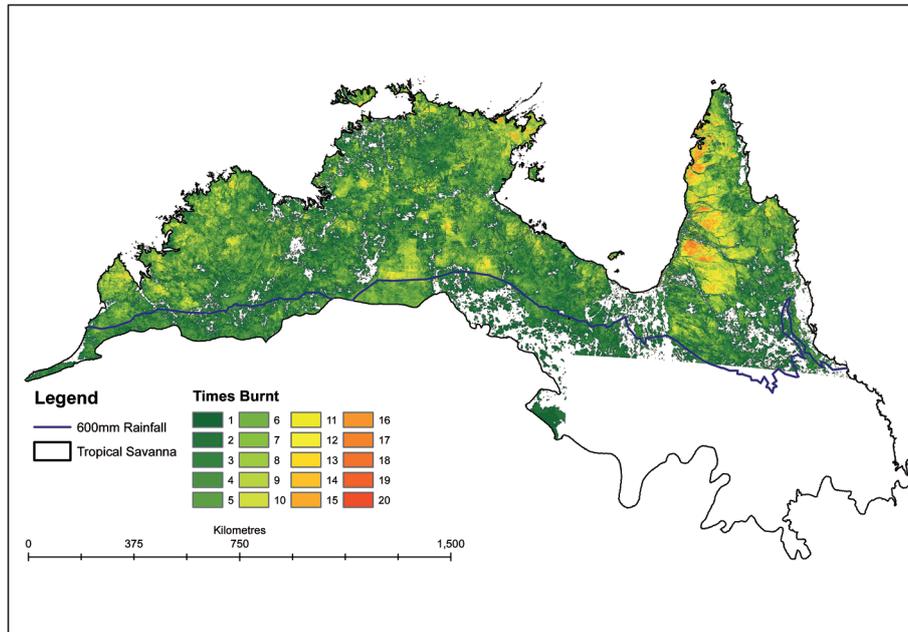


Figure 1(b) – Late dry season (August-December) fire frequency, 2000 – 2019, derived from the Northern Australia Fire information (NAFI) (<https://firenorth.org.au/nafi3/>) portal using MODIS 250x250m data for areas above the 600mm rainfall isohyet. Black hashed boxes are current (May 2020) savanna burning projects.

Indigenous (aboriginal) modes of fire and resource management, commencing in the late 19th Century associated with the advent of European pastoralism and disruption of relatively fine-scale (multi-hectare) burning practices undertaken progressively throughout the year (Russell-Smith *et al.*, 2003). The ecological impacts of such contemporary Australian savanna fire regimes are increasingly well documented and understood, including significant deleterious impacts on: soil erosion and water quality (Townsend & Douglas, 2004); fire-vulnerable vegetation types, especially those supporting fire interval-sensitive taxa (i.e. obligate seeders) (Bowman & Panton, 2003; Russell-Smith *et al.*, 2012); and fauna (invertebrates, vertebrates), especially those with restricted home ranges and specialised habitat requirements (Woinarski *et al.*, 2005; Ziembicki *et al.*, 2015).

Today, the vast majority of regional land use involves extensive (i.e. free range) beef cattle pastoralism which, in fire-prone northern savanna regions, typically is undertaken on very large (median >100,000ha) properties. Landscape-scale fire management has proven problematic given the very sparse regional population density (0.14 persons km⁻² outside of towns), associated

limited infrastructure and management resources, and generally flat to undulating terrain with few natural (e.g. permanent water courses) and built (e.g. roads, tracks) barriers restricting fire spread, especially under relatively severe LDS fire-weather conditions (Dyer *et al.*, 2001).

A significant opportunity for incentivising landscape-scale fire management in fire-prone Australian savannas emerged in the late 1990s with adoption of the Kyoto Protocol; namely, the provision that participating Tier 1 (developed economy) countries were required to account for emissions of the greenhouse gases (GHGs: specifically the long-lived chemical species CH₄, N₂O) from 'prescribed burning of savannas'. Subsequently, although Australia didn't ratify the Kyoto Protocol until 2007, substantial research was undertaken from the early 2000s focused on developing a nationally creditable Savanna Burning GHG emissions accounting methodology in partnership with Aboriginal land managers in Western Arnhem Land, northern Australia.

The 28,000km² Indigenously managed West Arnhem Land Fire Abatement (WALFA) project effectively commenced in 2007 under a 17-year contractual arrangement with a multinational energy corporate, with the

requirement to abate 100,000t.CO₂-e annually with respect to the prior ten-year pre-project mean emissions baseline, through the implementation of a prescribed, early dry season (EDS), fire management program adopting customary fire management practice (Garde *et al.*, 2009) and contemporary management tools (e.g. aerial ignition, GIS, remote sensing technologies). WALFA has continued to meet (and substantially exceed) its contracted GHG abatement, fire management, and social targets (Russell-Smith *et al.*, 2015; Ansell *et al.*, 2020).

Over the past decade significant policy, methods development, and project implementation advances have been made concerning savanna burning activities in Australia. In 2012, establishment of a national emissions trading scheme, the Carbon Farming Initiative (CFI), enabled savanna burning projects utilising Australia's first nationally approved savanna burning methodology for seasonal savannas receiving >1000mm MAP (CoA, 2013), to trade accredited carbon credits to large industry polluters requiring offsets. In 2014, the current Australian Government replaced the CFI with the taxpayer-funded Emissions Reduction Fund (ERF), which offers long-term (7-25 years) public contracts to registered projects delivering GHG emissions abatement or C storage utilising approved methods. Essential details describing Australia's GHG emissions accounting methodology are summarised in Russell-Smith *et al.* (2013).

Savanna burning methods continue to be refined, including extension of the creditable region to 1.2Mkm² of northern savannas receiving at least 600mm MAR (CoA, 2015; Murphy *et al.*, 2015), allowance for C sequestration of dead woody components (Cook *et al.*, 2016; CoA, 2018), and planning for a major revision in the near future to account for sequestration in living tree biomass, dead stem biomass longevity, and associated remote sensing of fire severity. As at early 2020, there were 76 registered savanna burning projects, including 26 on indigenous lands, covering a total 307,000km², or 25.6% of the entire higher rainfall savanna region (Figure 1b). Over the period 2013-19, registered savanna burning projects have abated 7 Mt CO₂-e and earned ~AU\$100M under contractual arrangements with the Australian Government (DoEE, 2019), and significant additional payments from voluntary industry partners.

A recent assessment of the effectiveness of Australia's savanna burning program for delivering fire management and associated ecological outcomes has found that, over the period 2013-2019, savanna burning project sites have resulted in a statistically significant decrease in LDS wildfires (from 31% to 16%), through significant increase in prescribed EDS fires (from 15% to 24%), and slight but non-significant reduction in burnt area overall (from 46% to 40%). At the same time there has been no overall improvement at sites where savanna burning has not been undertaken (Edwards *et al.*, submitted).

Botswana

Given the evident early successes of the Australian savanna burning methodology to incentivize the undertaking of landscape-scale fire management for reducing GHG emissions, in 2013 the Australian Government contracted the United Nations University to undertake a feasibility assessment of the potential application of the approach in other fire-prone global savanna settings focused especially on Africa, Latin America and Asia. That report (UNU, 2015) found that one of the most promising regions for application of the method was the southern African Kavango-Zambezi (KAZA) sub-region including parts of Angola, Botswana, Namibia, Zambia and Zimbabwe, and the Luangwa Valley subregion of Zambia. A recent independent study has also identified southern Africa, including this same region, as being highly prospective for implementing an adapted version of the Australian methodology (Lipsett-Moore *et al.*, 2018).

In late 2018 agreement was reached between the Governments of Botswana and Australia to implement a trial of the Australian savanna burning methodology at selected Pilot Sites to help address significant fire management issues in those areas. Preliminary field assessment and development of a savanna burning GHG emissions abatement structured on the Australian method were undertaken in 2019 at two relatively high rainfall (500 – 600mm mean annual rainfall; Figure 2a) and fire-prone sites (Figure 2b), Tsodilo in north-west Ngamiland, and Chobe in the north-east. As with north Australian savannas, annual fire regimes in Botswana are dominated by relatively intense and extensive LDS fires.

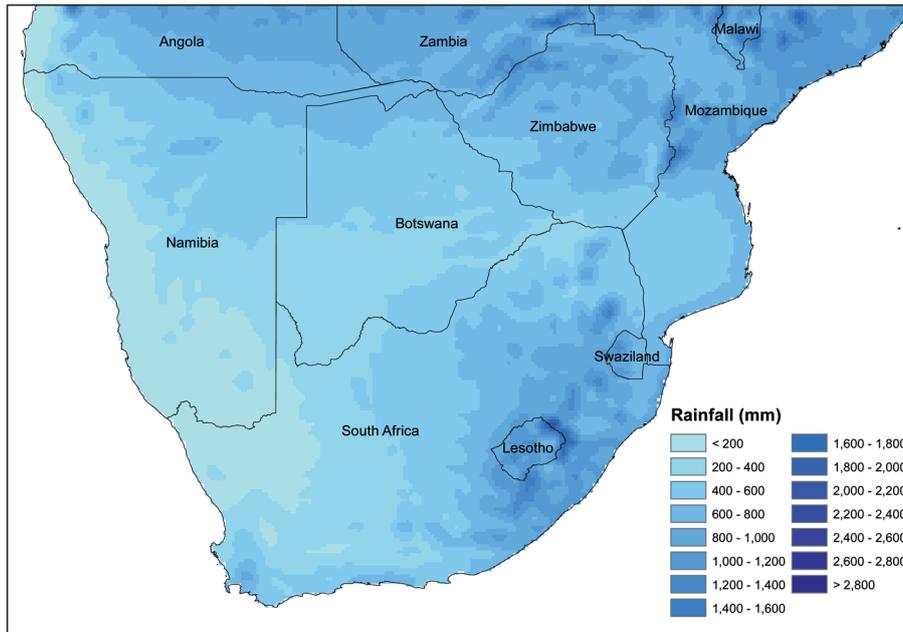


Figure 2(a) – Annual rainfall for southern Africa aggregated from ERA5 monthly averaged data 1979 – 2019 total precipitation.

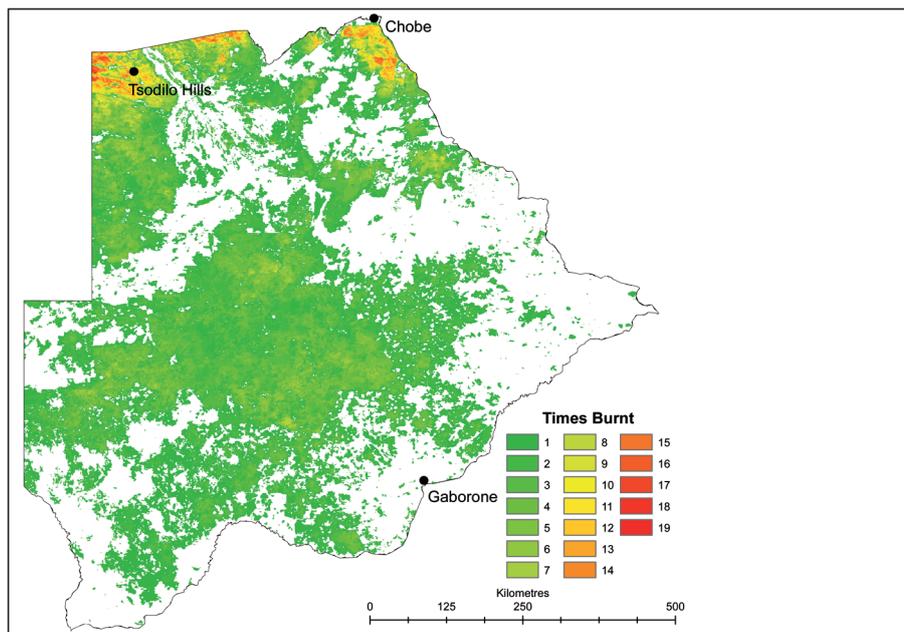


Figure 2(b) – Late dry season (July-December) fire frequency for 2001 – 2019 derived from MCD64A1 MODIS Burned Area Monthly Global 500m Version 6 product. The Tsodilo Hills and Chobe Pilot Sites, along with location of the capital city, Gaborone, are also given.

Although results to date are preliminary and further fieldwork in 2020 has had to be curtailed given the current COVID-19 pandemic, it is already evident that application of the Australian methodology, parameterized for local Botswana conditions, is entirely feasible. With further work we are confident that the approach can be applied

generically to assist more effective management of fire-prone savannas in neighbouring countries. A paper outlining results to date is in advanced preparation.

Despite this positive preliminary technical assessment, substantial challenges will be involved with the implementation of an effective

commercialized savanna burning approach, including: addressing Botswana’s current fire suppression policy; building the fire management and governance capacities of local and/or regional community structures; developing a supportive MRV (monitoring, reporting, validation) portal for fire management and emissions accounting purposes analogous to southern Africa’s formerly well-supported AFIS (Advanced Fire Information System: www.afis.co.za) or north Australia’s current NAFI (North Australia Fire Information: www.firenorth.org.au) system; developing appropriate robust GHG accounting Standards and associated market-based instruments allowing for trade of carbon (and potentially other ecosystem services) credits. Such challenges are detailed in an earlier assessment (Russell-Smith *et al.*, 2013b) addressing similar opportunities for neighbouring Namibia.

Evidently, developing regional approaches for implementing incentivized savanna burning opportunities requires long-term commitment.

Brazil

The Brazilian savanna (Cerrado), the most fire-prone biome in the country, occupies over 2Mkm² in 12 states, corresponding to 24% of Brazil’s territory (IBGE/MMA, 2004; Figure 3a). Considered the most biodiverse and threatened of the world’s savanna regions, it is a hotspot for conservation priorities (Myers *et al.*, 2000), being home to more than 12K native plant species, over 2.3K animal species and three of South America’s major river basin springs (Sawyer, 2018). Despite this international recognition, only 8.4% of the Cerrado is under a Brazilian protected area



Figure 3(a) – Location of Cerrado in Brazil, dark blue area highlighting Cerrado and light blue Brazil.

category – the equivalent of 167.5Kkm² (MMA, 2019). Agriculture and livestock land uses comprise 43% of the biome's area; rapid, uncontrolled agricultural expansion deforested 6.5Kkm² of native vegetation in 2019 (INPE, 2019).

The expansion of extensive monoculture plantations and pastures together with almost half a century of suppressive fire policy are the principal causes of disastrous large wildfires in the Cerrado (Schmidt & Eloy, 2020). These wildfires prevail in the LDS (Durigan & Ratter, 2016), when

extreme fire weather and cured fuels load create perfect flammable conditions (Fidelis *et al.*, 2018). The lengthy dry season is usually distributed in six months with some monthly variations along the year according to regional climate settings (Figure 3b). Before fire prohibition, Indigenous and other traditional communities commonly used fire throughout the dry season for managing their territories, applying techniques developed over millennia to support their livelihoods and manage wildfires (Falleiro *et al.*, 2016; Melo & Saito, 2012; Moura *et al.*, 2019).

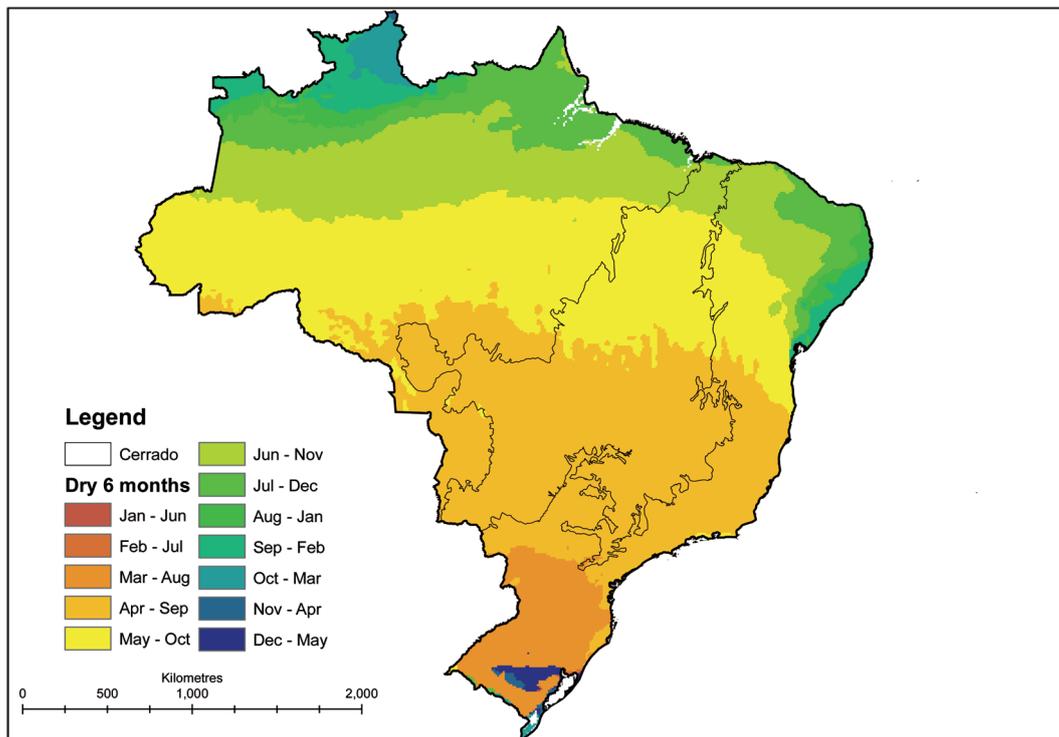


Figure 3(b) – Driest consecutive six-month period for Brazil, derived from ERA5 monthly averaged data 1979 – 2019 total precipitation. Cerrado outlined in black.

Areas with remnant native Cerrado vegetation are the most hit by frequent, large LDS wildfires; a setting which currently affects especially protected areas, Indigenous and other traditional (Quilombola, Geraizeiro, Vazanteiro, Quebradeira de coco Babaçu, etc), and local (small family farmers) communities (Figure 3c). The ecological impacts of such fire regimes have increasingly been documented (Durigan, 2020; Gomes *et al.*, 2018; Miranda, 2010) for fire adapted vegetation such as endemic rupestrian grasslands (Figueira *et al.*, 2016; Furst *et al.*, 2017), and especially for fire-sensitive vegetation including seasonal

semideciduous forests (Pereira *et al.*, 2017), riparian forests (Hoffmann *et al.*, 2012; Silva *et al.*, 2013), and scleromorphic forests – known as cerradão (Reis *et al.*, 2017).

Aiming to reduce these events, an Integrated Fire Management (IFM) programme commenced in 2014 through the support of the Brazilian-German Cooperation Project – Prevention, Control and Monitoring of Bushfires in the Cerrado (<http://cerradojalapao.mma.gov.br/projeto>). The IFM programme has been successfully encouraging traditional fire management practices and, by

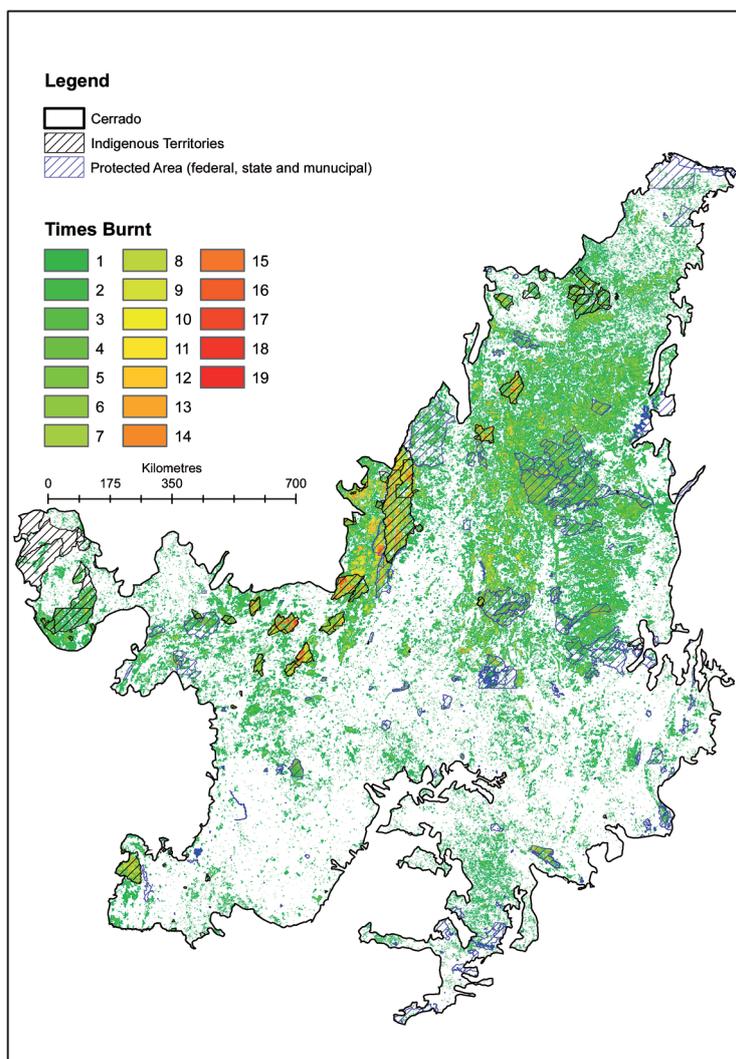


Figure 3(c) – Late dry season (July-December) fire frequency for 2001 – 2019 derived from MCD64A1 MODIS Burned Area Monthly Global 500m Version 6 product. Indigenous Territory in black striped areas and protect areas (federal, state, and municipal) in blue.

2019, was implemented in 32 Indigenous Reserves, 1 Quilombola Reserve (Prevfogo/Ibama, personal communication, 2020), and 40 federally protected areas (ICMBio, personal communication, 2020).

Despite these advances in fire management approaches, also including policy changes to incorporate EDS prescribed burning and participatory management with local communities, strengthening accompanying research and development of monitoring instruments (i.e. Franke *et al.*, 2018), these areas only cover a very small part of the remnant Cerrado. High risks of wildfire, constant pressure from agribusiness development, and little support for assisting traditional and local communities to implement sustainable management practices remain serious challenges.

After five years of the IFM programme’s implementation, the 7th International Wildland Fire Conference in Brazil framed an excellent opportunity for assessing and discussing the IFM approach and results. To facilitate these discussions, and in an effort to bring specialists, managers and researchers together, we arranged a Special Session addressing Savanna Burning Challenges and Opportunities Special Session, and an associated Technical Workshop, Challenges and Opportunities for Implementing Integrated Fire Management in the Cerrado. Twelve talks addressed the IFM approach and related issues during the Conference, and over 70 participants attended the Technical Workshop (Table 1). The key issues identified by combined conference

and technical workshop presentations concerning current challenges and opportunities facing fire

management in the Cerrado are summarized by sector in Table 2.

Table 1 – Presentations and workshop events contributing to the 7th International Wildland Fire Conference Special Session – Savanna Burning Challenges and Opportunities.

Presentations and events	Institutions
Conference presentations	
<i>Integrated fire management in Brazilian indigenous lands</i>	National Center for Prevention of and Combating Forest Fires (Prevfogo/Ibama, Brazil)
<i>Fire management and the interface with the territorial protection of the Xingu Indigenous Land Association (ATIX)</i>	Xingu Indigenous Land Association (ATIX) and Socioenvironmental Institute (ISA, Brazil)
<i>Fire management by the Javaé people in Ilha do Bananal</i>	Javaé Indigenous Organization Council of the Ilha do Bananal (Conjaba, Brazil)
<i>Parupa participatory and intercultural fire management network</i>	Simón Bolívar University (Venezuela)
<i>Overview of Integrated Fire Management Research in Brazil</i>	Forestry Institute of São Paulo State (IF, Brazil)
<i>Challenges of integrated fire management facing the academic knowledge gap to support forest fire management</i>	National Center for Prevention and Combat of Forest Fires (Prevfogo/Ibama, Brazil)
<i>Fire management in Brazilian federal protected areas: outcomes and perspectives</i>	Chico Mendes Institute for Conservation of Biodiversity (ICMBio, Brazil)
<i>The International Savanna Fire Management Initiative (ISFMI)</i>	International Savanna Fire Management Initiative (ISFMI) and 321Fire! (Mozambique)
<i>Australian experience with the development and application of Savanna Burning projects</i>	International Savanna Fire Management Initiative (ISFMI) and Charles Darwin University (Australia)
<i>Market-based instruments for incentivising sustainable fire management in fire-prone savannas</i>	International Savanna Fire Management Initiative (ISFMI) and Charles Darwin University (Australia)
<i>Selecting Savanna Burning demonstration sites – Examples from Australia and Brazil</i>	International Savanna Fire Management Initiative (ISFMI), Charles Darwin University (Australia), and Nature Institute of Tocantins (Naturatins, Brazil)
<i>Can integrated fire management deliver REDD+ results in Brazil?</i>	Ministry of the Environment (MMA, Brazil)
Technical workshop – Challenges and opportunities for implementing Integrated Fire Management in the Cerrado	Organized by the Institute Society, Population and Nature (ISPAN, Brazil), and International Savanna Fire Management Initiative (ISFMI)

Based on recent IFM Programme experience and related discussions emanating from the 7th International Wildland Fire Conference proceedings, it is evident that the IFM programme has considerable potential for broader sustainable management application in Brazil's Cerrado remnants (Table 2). Mean fire extent, 2000-2019, in the Cerrado biome was 5.3% (4.9% LDS, post-July), including 10.4% (9.4% LDS) in Protected Areas (federal, state, municipal), and 23% (21.7% LDS) in Indigenous Territories (Figure 3c).

Although the lack of human and financial resources, and ongoing fire suppression policies on State and other non-Indigenous land tenures, hinders upscaling of IFM more broadly, there is a significant opportunity and need for better engaging with private landholders to implement prescribed fire management practices methods to help avoid wildfires and resultant economic losses (Table 2). Global financial funding instruments such as REDD+ and the Green Climate Fund (GCF) are being used to promote sustainable and

conservation initiatives in Brazil and internationally, and could be adapted to support further IFM project development in the Cerrado. Exploring the feasibility of such initiatives would help advance

sustainable Cerrado fire management policy development, IFM implementation, increased multi-stakeholder engagement and participation, and steps towards establishment of a consistent, standardized emissions accounting methodology.

Table 2 – Summary of sectoral key issues, opportunities, and challenges for implementation of Integrated Fire Management in the Brazilian Cerrado, as identified in 7th International Wildland Fire conference presentations and associated discussions.

Sector	Key issues	Potential opportunities	Current challenges
National Protected Areas	National protected areas in the Cerrado are increasingly implementing Integrated Fire Management, starting in 2014 with two, and in 2019, two hundred presented implementation plans. The IFM Programme has enabled a paradigm shift from the former suppressive fire policy to acknowledgment that fire management is key to conserving many ecosystems. However, poorly informed conservative naturalists, civil society, landowners, among others, still consider fire to be unacceptable as a management tool.	The successful IFM Programme experience has encouraged its implementation in a growing number of protected areas and is being used to show the benefits and roles of fire management for hesitant stakeholders. The IFM Programme has great potential for replicability in different landscapes of the Cerrado.	There is a lack of human and financial resources to meet the growing demands of IFM implementation, including in state and municipal protected areas. After five years of the IFM Programme there is much to be done. Most Cerrado areas are still under fire suppression management. Unmanaged areas surrounding protected areas expose them to wildfires.
State lands (including Protected Areas)	Many state and municipal institutions are not yet familiar with the federal IFM Programme. Wildfires are still very frequent in many Cerrado regions (distributed in many different states, such as TO, PI, BA, MA, MG and GO), given the large number of state protected areas and conserved state lands which typically are occupied by unrecognized traditional communities. Fire suppression continues to be practiced.	The IFM approach needs to be brought to the state and municipal spheres to upscale the Programme to assist with decreasing the occurrence and extent of wildfires. Due to the recurrence of large wildfires, state and municipal authorities are beginning to recognize the need for improving fire management skills and techniques. State and municipal authorities typically are closely linked to the agribusiness sector and, therefore, could potentially be important partners for improving management methodologies to avoid wildfires and economic losses.	There is a lack of human and financial resources to expand the IFM approach to state and municipal scales. There is still no consensus over the implementation of prescribed burns to reduce wildfires among public institutions. The agribusiness sector is against the use of fire for managing the Cerrado landscapes, since wildfire threatens crop production.
Indigenous and Quilombola Territories	Although few Indigenous territories have been impacted by the fire suppression policy, many others, including Quilombola territories, have been prohibited from burning for centuries. With the recent IFM Programme many traditional communities feel stimulated to continue their burning practices and feel their knowledge and culture is finally being recognized by civil society and government. Encouraging local people in these territories to join fire brigades has been very successful in many situations, but there is still much to improve when it comes to encouraging the participation of local leaders in decision making processes. Currently, this initiative, which generates income to local communities, is limited to 42 Indigenous Territories and one Quilombola Territory. The initiative needs expansion both for Territories currently, and still to be, engaged.	Greater emphasis needs to be given to participatory implementation, monitoring and assessment, of prescribed burns, engaging local peoples to carry out protocols enabling specialized/context-specific evaluation. Increasing opportunities for the engagement of local communities in fire brigades to generate income and incorporate traditional knowledge in management techniques and implementation. The ecological services these peoples have been providing with their traditional fire practices has great potential for being recognised, accounted for, and financially remunerated.	Fire brigade members are currently only hired for six months with no guarantees of being hired subsequently. The work undertaken by local fire brigades (hired by the federal government) is not always in alignment with the expectations of Indigenous community leaders, often lacking consultation with and authorization for some operations. Some Indigenous people are dealing with serious environmental changes, influenced by global climate change, and are implementing adaptive measures requiring significant support. Currently, there is no direct payment for carbon mitigation undertaken as a national policy in Brazil.

Sector	Key issues	Potential opportunities	Current challenges
Other Traditional Territories	There are many territories in the Cerrado biome that are occupied and used by traditional communities, commonly not self-identified as Indigenous or Quilombola, and not recognized by authorities. Usually these territories are disputed with land grabbers, loggers and prospectors. Although these traditional peoples use fire as a landscape management tool, they have been prohibited to use fire for centuries and have not been included in the recent IFM Programme, which only allows for prescribed burns in protected areas and recognized Indigenous and Quilombola Territories.	In many communities fire is still used, even though illegally, but burning periods have changed and many traditions lost. There is a lot of interest from these people in implementing fire management activities to help prevent wildfires that are now more frequent under the national suppressive fire policy. Greater efforts in formulating proposals for the promotion of IFM from partner institutions, including NGOs, is needed.	A burning permit from authorities is obligatory to burn in this kind of territory, which is hard to get and usually limited to very small areas. Some/much traditional knowledge related to fire practices has been lost or changed to fit safeguards which are often harmful to the environment. Usually, to protect their extensive monocultures, farmers surrounding these territories force the communities not to use fire by threatening to report them.
Private Land (rural properties)	Wildfires are a common threat to many properties, including protected areas, traditional territories, industries, and private lands - from family farms to larger agribusinesses. Therefore, multiple stakeholders have a common purpose in reducing wildfire threats. Farmers are not yet familiar with the IFM Programme and its beneficial results, but are seeking new technologies and tools to help protect their assets. Feedback from conference participants indicates a keen interest in exploring IFM opportunities more broadly.	The IFM Programme has great potential for application in private areas, where Cerrado vegetation is still maintained. The IFM Programme would not only help reduce wildfire risk, but build local participatory engagement and understanding. At the same time, the private sector (such as large landowners and industries) has a key role in helping to promote the benefits of fire management activities.	There is a lack of human and financial resources for upscaling the IFM approach to the private sector. The use of fire management in Cerrado landscapes is mostly unsupported by this sector, given the misperception that all fires may potentially threaten their production livelihoods and economy.
Public Policies	There is a need to formulate inclusive policies for IFM activities and promote their economic sustainability. The ecological role of Cerrado ecosystems is still underestimated and undervalued and, therefore, environmental services, such as the beneficial roles of fire management, urgently needs to be acknowledged, discussed and supported by public authorities. National supporting strategies, like REDD+, only account for emissions from forest degradation and deforestation, especially in the Amazon.	Currently it is possible to measure, report and verify emission mitigation from IFM at a project scale. The sustainability of initiatives that can bring benefits nationwide are encouraged when well addressed. REDD+ is a financial mechanism which can be utilised to transfer donations from developed to developing countries to support sustainable forest management and conservation. This policy instrument could be adapted for the IFM Programme in Cerrado landscapes.	The Cerrado biome is not prioritized when it comes to formulating public policies related to environmental conservation. Policy makers still need to consider how the IFM approach could benefit Cerrado management and conservation. Historically, the Brazilian government has been against forest carbon offsets under the Climate Convention which subsidise developed countries in accounting for their emissions. However, it is recognised this policy position needs further discussion. The methodology for accounting of emissions needs to be carefully thought by specialists and be consistent with the Brazilian GHG Inventory.
Research	Monitoring and assessing the effects and consequences of fire suppression and alternative IFM approaches in Cerrado ecosystems is essential for informing improved fire management practice and outcomes. Indicators and criteria should be determined in partnership with researchers. Collaborative work with researchers is fundamental to finding better alternatives for achieving broader goals.	Many sites where the IFM Programme is being implemented are already being monitored and assessed at local and landscape levels. Prevfogo/Ibama, in partnership with the National Council for Scientific and Technological Development (CNPq), opened a call for proposals (in 2018) to support research initiatives related to monitoring the IFM Programme. Initiatives like these can be supported by different institutions and cooperation agreements.	There is inadequate financial support for the undertaking of essential research projects (field trips, equipment acquisition) and researchers (scholarship, human resource). Partnerships between researchers, governmental institutions, NGOs, CBOs, private sector, international cooperation, needs to increase to enhance understanding and implementation of appropriate fire management practices.

Conclusion

Our survey of contemporary fire regimes in three savanna/Cerrado southern Hemisphere landscapes illustrates that, despite significant socio-political differences, sustainable fire management in respective case study regions faces major challenges including substantial areas which are dominated by LDS fires. As demonstrated by Australian experience, the development of robust GHG emissions accounting procedures and incentivised markets can help transform savanna fire management, importantly including more effective engagement with and support for Indigenous and local community fire practices. While recognising that immense challenges face development of similar approaches in Botswana and southern Africa, and likewise in Brazil and South America, Australian experience demonstrates that, given conducive policy environments, such hurdles can be overcome very rapidly – in fact, in just a few years. Perhaps the key to such rapid transformation is to recognise that everyone benefits – global climates, regional ecological sustainability, and local people both culturally and financially.

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Note

There is a Portuguese version of this paper available at the websites:

Existe uma versão deste artigo disponível em português nos seguintes sites:

<https://www.isfmi.org/news-items/reflections-from-campo-grande-themes-emerging-from-the-7th-international-wildland-fire-conference-englishportuguese>

<https://ispn.org.br/manejo-integrado-do-fogo-em-savanas/>

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