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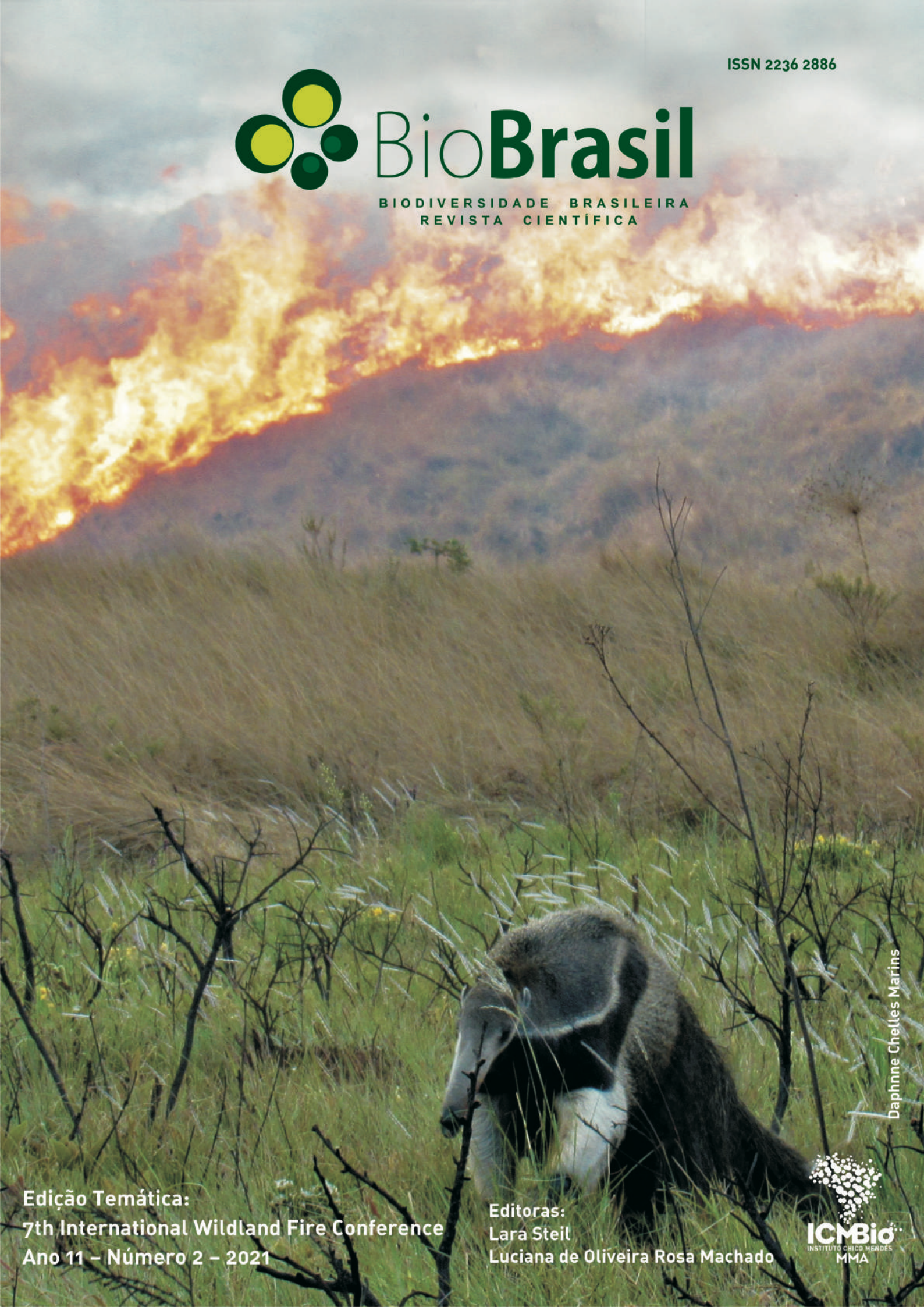

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7th International Wildland Fire Conference
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7th International Wildland Fire Conference

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Editorial

7th International Wildland Fire Conference

Lara Steil – Ibama/Prevfogo

Luciana de Oliveira Rosa Machado – MMA

This Special Issue is the third publication related to the 7th International Wildland Fire Conference – IWFC, held in 2019, in Brazil (https://www.ibama.gov.br/wildfire2019-eng). It comprises full articles written by the key speakers who participated at the Plenary Sessions, Special Sessions, and at the Technical Meeting on Criminal Investigation of Forest Fires.

The opening article, by Johann Goldammer, presents a retrospective on the series of IWF Conferences, from its first edition, held in Boston, USA, in 1989, until the seventh, in Brazil, after a circumglobal journey. The main advances and achievements along the three decades that separate these two Conferences are discussed, emphasizing the changes observed in the fire regimes around the world, influenced by world population growth, socio-economic developments, and climate change, pointing out the importance of international cooperation for landscape fire management.

The role of women in fire management, one original topic at 7th IWFC, is brought to discussion by Erika Garduño-Mendoza and collaborators. The article summarizes the main achievements, challenges, and experiences related to the inclusion of women in fire management activities in Mexico and Latin America. According to the authors, the efforts that have been carried out on this issue led to the creation of the first female brigade for preventing and fighting fires in Mexico, in 2019. The strengthening of women's technical and leadership capacities gives more visibility to their participation, reinforces the integrated fire management approach, and opens up new opportunities for professionals with different profiles and areas of knowledge.

In the same track of inclusion and improvement of the participation of human diversity in fire issues, John Scott, in his article, reviews the importance of indigenous knowledge on disaster risk reduction, flagging up that this knowledge has been used to reduce risks and mitigate the deleterious effects caused by uncontrolled fires. The article also draws our attention to the fact that when traditional practices are associated with contemporary experiences, they can reduce the vulnerability of these peoples and their communities to the risks arising from fire.

Four articles discuss, on a national or local scale, the implementation of integrated fire management in Brazil. In the first one, **Background, Assessment, Opportunities and Challenges of Integrated Fire Management in Brazilian Indigenous Land**, Rodrigo Falleiro and collaborators present the main outcomes of the implementation of the Federal Brigade Program in indigenous lands. The program is handled by the Brazilian Institute for the Environment and Renewable Natural Resources, through the National Center for Preventing and Fighting Fire (Ibama/Prevfogo) in partnership with the National Indian Foundation (Funai). The results demonstrate that the incorporation of traditional indigenous knowledge in the implementation of Integrated Fire Management (IFM) represents the factor of success to address the issue, emphasizing the importance of the sociocultural aspect in the management of fire in Brazil.

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The article **Implementation of Integrated Fire Management in Brazilian Federal Protected Areas: Results and Perspectives** developed by Berlinck & Lima, presents the main achievements and challenges in Brazilian protected areas that adopted IFM approach. Among them, the reduction of the area affected by uncontrolled fires and the conciliation of conflicts with communities living in or around the protected areas stand out. The text addresses in more detail three protected areas: Serra da Canastra National Park, Serra Geral do Tocantins Ecological Station and the Campos Amazonicos National Park, revealing positive examples of integration among government, researchers, and society.

Ana Carolina Barradas *et al*. – **Integrated fire management: Serra Geral do Tocantins Ecological Station's journey (2001 to 2020)** – and Pedro Paulo Xerente *et al*. – **Indigenous Approach to Integrated Fire Management in Indigenous Lands in the State of Tocantins/ Brazil** – show in detail how the paradigm shift from fire exclusion to the adoption of integrated fire management took place in two important Brazilian protected areas. The experiences of these areas highlight how fire can be used as a tool for participatory management and conservation of Brazilian socio-biodiversity. In addition to contributing to the empowerment of knowledge and the traditional use of fire by indigenous peoples and traditional communities.

Other experiences of integrated fire management are presented in the article **Market-based Options for Supporting Sustainable Fire Management of Fire-prone Cerrado (Savanna) Remnant Landscapes** by Russell-Smith *et al*. The authors illustrate the potential of economic and market tools of integrated fire management programs implemented in the savannas of Australia and Botswana, outlining the need and opportunity for developing an analogous fire management approach in Brazilian Cerrado, especially in indigenous lands. This paper is a summary of the discussions carried out at a Special Session on the same theme, held during the 7th IWFC.

Turning to technological aspects of fire management, the paper Remote Sensing and Geoprocessing as a Subsidy for Fire Management and Fighting Forest Fires in Federal Conservation Units (Kelly Resende Borges *et al*.) presents the importance of remote sensing and geoprocessing for environmental conservation and monitoring of environmental impacts caused by fires. The article underlines the elaboration of fuel load maps, which joint with the mapping of areas affected by fire, constitute a fundamental tool for planning and managing large territories, as is the case of most of the Brazilian protected areas. These geotechnologies identify the most prone areas to fire, the frequency of fire occurrence, indicating strategies to minimize damages in the most critical areas.

The gas emissions from landscape fires contribute to climate change and affect human health and security. In this regard, Alexander Baklanov *et al*. come up with the Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS) to provide guidance for addressing both smoke and fire danger. The paper also proposes the establishment of regional VFSP-WAS centers and shows potential examples of the VFSP-WAS concept in two regions (Southeast Asia and North America), where regional VFSP-WAS centers work in partnership with Regional Fire Monitoring/Fire Management Resource Centers.

More details of the Southeast Asia VSP-WAS example are presented in this edition by Saharjo *et al*., whose studies indicate that the increase in fires has caused serious threats to forests and to the health and safety of the populations of that region. The focus of the article is the peat fire, a quite common event in that region, particularly in Indonesia, which holds 36% of the world's tropical peatland. Peat fires are considered one of the most difficult types of fires to control. In addition, they are one of the main causes of environmental degradation and air pollution, being responsible for the emission of considerable amounts of CO_2 and other greenhouse gases, as well as particulate matter that causes serious damage to human health.

We end this publication with another original topic for this series of Conferences brought by the 7th IWFC. A technical meeting on the Criminal Investigation of Forest Fires was held at the Conference and the results of it are presented in Salvador Ortega's article. The paper addresses the growing need to include a criminal investigation of forest fires to establish effective preventive measures and to identify and punish who causes major forest fires. Therefore, it is necessary to improve the judgment processes by the justice bodies and inspection agencies that deal with such conduct, which is considered a crime in the criminal regulations of most, if not all, of the countries on the planet. The study describes the efforts of INTERPOL to contribute to the harmonization and improvement of criminal investigation processes worldwide and the development of training tools at the international level.

This special issue aims to contribute to spreading the experiences on fire management in different parts of the world. We hope the papers presented here can encourage the international fire community to keep strengthening the global debate on fire issues while looking forward to the next International Wildland Fire Conference in 2023, in Portugal.

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

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Thirty Years International Wildland Fire Conferences: Review and Achievements of a Circumglobal Journey from Boston to Campo Grande

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ABSTRACT – In 1989, the International Wildland Fire Conferences (IWFCs) were launched as a platform for sharing knowledge and expertise in wildland (landscape) fire science, management, capacity building and policy development. Three decades have passed between the First International Wildland Fire Conference in Boston, United States of America, in 1989, and the Seventh International Wildland Fire Conference in Campo Grande, Brazil, in 2019. During these three decades the international fire regimes – *sensu lato* defined as the ecological, managerial and policy regimes – have evolved under the influence of global population growth, socio-economic developments and climate change – a period during which the Earth system has undergone the most rapid changes in history and prehistory. This paper reviews exemplary of actors, which were involved in, and followed-up the recommendations of the IWFCs with emphasis on their activities between the conferences. During this circumglobal journey between Boston and Campo Grande regional to global networking have furthered the culture of international cooperation in fire management at the Science-Policy-Practitioners Interface (SPPI). Recent observations reveal that climate change and socio-economic developments are changing fire regimes globally. This trend is associated with an increasing vulnerability of society and the environment to wildfires as well as to excessive application of fire in land use and land-use change. It is timely to revisit the attempts of developing a global agreement on landscape fire management.

Keywords: Landscape fire policies; landscape fire management; international cooperation.

Trinta Anos de Conferências Internacionais sobre Incêndios Florestais: Revisão e Conquistas de uma Viagem Circunglobal de Boston para Campo Grande

RESUMO – Em 1989 foram iniciadas as Conferências Internacionais sobre Incêndios Florestais (IWFC) com o objetivo de estabelecer um fórum para compartilhar conhecimento e experiência em ciência, manejo, capacitação e desenvolvimento de políticas sobre fogo. Três décadas se passaram entre a primeira Conferência Internacional sobre Incêndios Florestais em Boston, Estados Unidos, em 1989, e a sétima Conferência Internacional sobre Incêndios Florestais em Campo Grande, no Brasil, em 2019. Durante essas três décadas, os regimes de fogo no mundo – definido *sensu lato* como os regimes ecológico, de manejo e político – evoluíram sob a influência do crescimento populacional mundial, do desenvolvimento socioeconômico e das mudanças climáticas. Um período no qual os sistemas terrestres passaram pelas mais rápidas alterações da história e da pré-história. Este artigo avalia exemplos de atores envolvidos com as conferências e que acompanharam as recomendações estabelecidas nas IWFC, com ênfase para as atividades desenvolvidas entre os eventos. Ao longo dessa jornada ao redor do globo entre Boston e Campo Grande, as redes regionais e a rede global fomentaram a cultura de cooperação internacional em manejo do fogo no âmbito da interface ciência-políticas-práticas, Science-Policy-Practitioners Interface (SPPI). Observações recentes mostram que as mudanças climáticas e socioeconômicas vêm alterando os regimes de fogo em nível global. Essa tendência está associada a um aumento na vulnerabilidade social e ambiental aos incêndios, assim como a uma excessiva utilização do fogo no uso da terra e em atividades de mudança do uso da terra. Nesse sentido, é oportuno revisitar as tentativas de desenvolver um acordo global sobre o manejo do fogo na paisagem.

Palavras-chave: Políticas de manejo do fogo na paisagem; manejo do fogo na paisagem; cooperação internacional.

Treinta Años de Conferencias Internacionales sobre Incendios Forestales: Revisión y Logros de un Viaje Circumglobal de Boston a Campo Grande

RESUMEN – En 1989, empezaron las Conferencias Internacionales sobre Incendios Forestales (IWFCS) con el objetivo de establecer un foro para compartir conocimientos y experiencia en ciencia, manejo, desarrollo de capacidades y de políticas de fuego. Tres décadas pasaron entre la Primera Conferencia Internacional sobre Incendios Forestales en Boston, Estados Unidos de América, en 1989, y la Séptima Conferencia Internacional sobre Incendios Forestales en Campo Grande, Brasil, en 2019. A lo largo de estas tres décadas, los regímenes de fuego a nivel global – definido *sensu lato* como los regímenes ecológico, de manejo y de políticas – han evolucionado bajo la influencia del crecimiento de la población mundial, los desarrollos socioeconómicos y el cambio climático. Un período en el que los sistemas terrestres han experimentado los cambios más rápidos de la historia y de la prehistoria. Este artículo evalúa ejemplos de actores que participaron y dieron seguimiento a las recomendaciones de las IWFC, con énfasis en sus actividades entre las conferencias. Durante este viaje alrededor del mundo entre Boston y Campo Grande, las redes regionales y la red global han fomentado la cultura de cooperación internacional en el manejo de fuego en el ámbito de la interfaz ciencia-políticas-prácticas Science-Policy-Practitioners (SPPI). Observaciones recientes muestran que el cambio climático y los desarrollos socioeconómicos están alterando los regímenes de fuego a nivel mundial. Esta tendencia está asociada con una creciente vulnerabilidad social y ambiental a los incendios forestales, así como a la aplicación excesiva del fuego en el uso de la tierra y el cambio de uso de la tierra. En este sentido, es oportuno revisar los intentos de desarrollar un acuerdo global sobre el manejo de fuego en el paisaje.

Palabras clave: Políticas de manejo de fuego en el paisaje; manejo de fuego en el paisaje; cooperación internacional.

Introduction

The First International Wildland Fire Conference "Meeting Wildland Fire Challenges: The People. The Land. The Resources" was held in 1989 in Boston, United States of America. The conference brought together more than 400 leaders of public and private organizations from around the world, to discuss issues, programs, and strategies to reduce serious wildland fire losses and to promote international cooperation in the decade of the 1990s and beyond. The outcomes suggested a continuation of the international dialogue. This was also expressed by the United Nations Disaster Relief Organization – the predecessor arrangement of today's UN Office for Disaster Risk Reduction, which is serving as secretariat of the UN International Strategy for Disaster Reduction and custodian of concerted international implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 – by officially recognizing the Boston conference as an activity of the UN International Decade for Natural Disaster Reduction. The Second IWFC, hosted by Canada in 1996, recommended "that a group formally established under the auspices of the United Nations to facilitate addressing global wildland fire needs". This recommendation was taken up by the Government of Germany, which provided the resources to establish the Global Fire Monitoring Center (GFMC) in 1998. The Interagency Task Force for Disaster Reduction of the UNISDR decided to establish the Working Group on Wildland Fire in 2001 and – as an outcome of its work – the Global Wildland Fire Network. In 2003 the international community of wildland fire scientists, managers and policy makers reconvened at the IWFC-3 in Sydney, Australia, and provided the stage for the International Wildland Fire Summit, at which an agenda was set for strengthening international cooperation in fire management for the coming years. Subsequently, the next IWFCs were hosted by Spain (2007), South Africa (2011) and South Korea (2015). The first circumglobal cycle of IWFCs ended in Campo Grande, Brazil. This paper highlights the goals and outcomes of the IWFCs and in particular the process between the conferences. Emphasis is given on the advancement of international/cross-boundary cooperation in fire management. The review focusses on actors who were actively involved in the IWFCs and regional to global networking to further the culture of international cooperation in fire management at the Science-Policy-Practitioners Interface (SPPI). This review cannot address all relevant initiatives in fire science and fire management, which evolved in the last years. For update information on the state

of knowledge in fire science – an integral part of Earth Science – and the innovative technological developments – notably the advancement of Earth Observation Systems for monitoring landscape fires and fire effects and the derived regional and global fire information systems – the readers are referred to the major global reviews and the background literature therein. The White Paper directed to the United Nations and International Organizations "Vegetation Fires and Global Change. Challenges for Concerted International Action", which was published in 2013 (Goldammer, 2013) or the more recent summary note of a global expert workshop on fire and climate change "Global Fire Challenges in a Warming World", which was convened by the International Union of Forest Research Organizations (IUFRO) in 2018 (IUFRO, 2018).

Material and Methods

The review of developments between 1989 and 2019 includes a narrative of the objectives and results of the seven International Wildland Fire Conferences. Specific documents quoted are provided in the list of references. The IWFCs are not organized as isolated events. Instead, they are considered milestones of a long-term, open-end process in which the international community of scientists, practitioners and policy makers in the different regions of the world are encouraged and challenged to drive development and to take individual and collective action. In other words, the IWFCs constitute an open platform for inspiration for innovation and action for the period ahead up to the next conference. This review includes examples of major advances inspired by the IWFCs and successively implemented. The countless initiatives within the regions and countries are manifested in a vast and rapidly increasing scientific and technical literature and in unpublished reports – the grey literature. The review refers to the conference materials on the IWFC website (GFMC, 2019a), the online archive of the Global Fire Monitoring Center (GFMC, 2019b) and the Global Wildland Fire Network (GWFN, 2019).

Results

In the following the highlights and outputs of IWFCs are reviewed and exemplary major events and advancements achieved between the conferences.

The International Wildland Fire Conference in Boston 1989

The International Wildland Fire Conference "Meeting Wildland Fire Challenges: The People. The Land. The Resources" was held in 1989 in Boston, U.S.A., co-organized by agencies of the U.S.A., Canada and Mexico. The conference brought together more than 400 leaders of public and private organizations from around the world, to discuss issues, programs, and strategies to reduce serious wildland fire losses and to promote international cooperation in the decade of the 1990s and beyond. While the Conference originally was not entitled as "first" IWFC, the outcomes suggested a continuation of the international dialogue. The United Nations Disaster Relief Organization (UNDRO) – the predecessor arrangement of today's UN Office for Disaster Risk Reduction, which is serving as secretariat of the UN International Strategy for Disaster Reduction (UNISDR) and custodian of concerted international implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 – officially recognized the Boston conference as a contribution to the UN International Decade for Natural Disaster Reduction (IDNDR).

It is most appropriate to quote the overview comments of Allan J. West, Deputy Chief, United States Forest Service, who served as Chair of the International Wildland Fire Conference in Boston in 1989. His statement provided the background and rationale for the first conference (West, 1990):

> *During the decade of the 1980s, wildland fires caused major loss of life, property and natural resources in Africa, North and South America, China, the Mediterranean, Australia, and parts of Europe. Expanding populations in areas of high fire risk and the accelerating demand for natural resources to supply basic human needs added a critical emphasis to this fire problem. Recognizing that the global nature of this problem required international attention, the United States Department of Agriculture Forest Service, Forestry Canada, the United States Department of the Interior, the Mexican Secretaria de Agricultura y Recursos Hidraulicos, the National Association of State Foresters, the United States Agency for International Development, and the National Fire Protection Association organized and*

sponsored the "Meeting Global Wildland Fire Challenges" conference in Boston, Massachusetts, 23-26 July 1989.

The conference focused on worldwide wildland fire problems and steps that can be taken by the international community to re verse the upward trend of wildland fire losses. The conference assessed the worldwide natural resource situation, examined the physical, biological, social, political, and economic issues of wildland fire management decision making. Several examples of successful international cooperation were highlighted and the key elements of successful international programs were discussed.

Highlights and results of the conference included:

- *An "International Survey of Fire Managers" identified problems throughout the world, which limit or impede international cooperation in wildland fire management. Based on this information, a working forum was developed, and each conference participant had an opportunity to help develop an "Action Plan," which would lead to enhanced international wildland fire cooperation;*
- *Almost 100 educational displays and exhibits presented the latest in technologies and information necessary for successful establishment of basic fire management programs;*
- *More than 400 leaders of public and private organizations from around the world were brought together to discuss issues, programs, and strategies to reduce serious wildland fire losses and to promote international cooperation in the decade of the 1990s and beyond;*
- *The United Nations Disaster Relief Organization officially recognized the conference as a "Pre-Decade" activity. It is important that wildfire be recognized as one of the natural disasters to be addressed during the United Nations International Decade for Natural Disaster Reduction (IDNDR).*

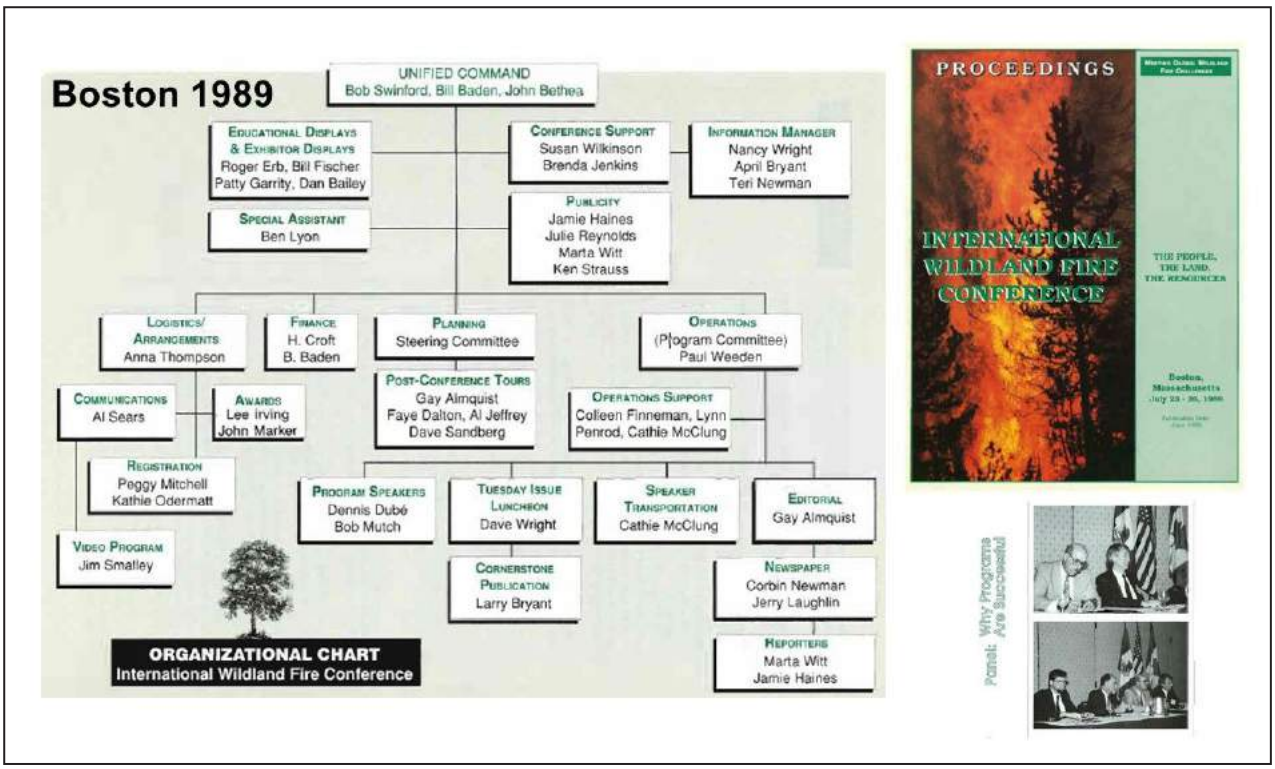

Figure 1 – Organigram of the Boston Conference – Following the ICS.

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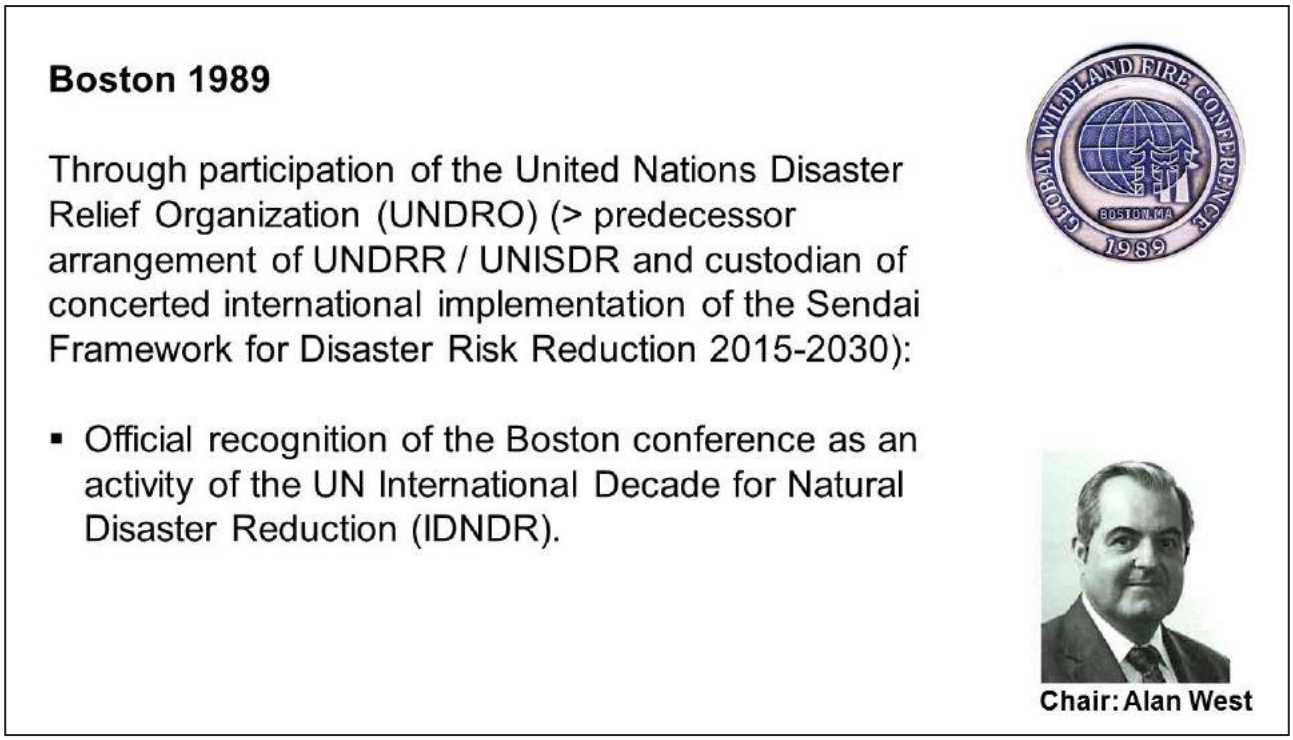

Figure 2 – The Boston Conference explicitly referred to UN-IDNDR.

The year 1989 indeed was quite decisive with regard to international activities in framing international agendas to address the role of fire in the global environment with all its associated problems. Preceding the Boston Conference by two months, the Fire Ecology Research Group (the predecessor institution of the Global Fire Monitoring Center) convened the first international conference "Fire in the Tropical Biota" (Freiburg, Germany, 16-20 May 1989). For the first time an interdisciplinary conference addressed the role of fire in natural and cultural ecosystems of the tropics and the role of fire emissions on biogeochemical cycles, the atmosphere and climate (Goldammer, 1990). The results of the conference, manifested in the "Freiburg Declaration on Tropical Fires", called for an action plan. The language of the statement resembles the calls of scientists thirty years later, e.g. the following calls:

- The International Geosphere-Biosphere Programme (IGBP) offers a promising channel for international cooperation in fire research, and the Intergovernmental Panel on Climate Change (IPCC), under the auspices of the United Nations Environmental Program (UNEP), will provide response strategies to these environmental threats;
- The questions of "fire for whom?" and "fire control for whom?" must be answered clearly if sound and fair policies are to be formulated. Policies must respect national sovereignties. Fortunately, the interests of different nations almost always point in the same direction: limiting deforestation is not only in the long-term interest of the people of the tropical countries where forests are being cleared, but is also beneficial to other nations concerned by the loss of biodiversity and by the danger of atmospheric impacts in temperate latitudes.

These results of the Freiburg conference were conveyed to Boston.

From Boston to Berlin 1992 and Geneva 1993

After Boston, a number of international scientific and technical conferences paved the way to the Second International Wildland Fire Conference. Three years after the conference in Freiburg and Boston, a first attempt was made to develop a synoptic synthesis of the role of fire in the Earth System. The Conference "Fire in the Environment: The Ecological, Atmospheric and

Climatic Importance of Vegetation Fires", held in Berlin in 1992, followed the model of the Dahlem Conferences – to promote interdisciplinary exchange and to define knowledge gaps and priorities for future research. Besides calling for new approaches in global transdisciplinary fire science, the results of the Dahlem Conference called for the development of a Global Fire Policy (Crutzen & Goldammer, 1993).

In 1993 the United Nations Economy Commission for Europe (UNECE) and the Food and Agriculture Organization of the United Nations (FAO) entrusted the Fire Ecology Research Group – the precursor institution of the Global Fire Monitoring Center (GFMC) – to take the lead of the UNECE/FAO Team of Specialists on Forest Fire, which has been set up in 1981 and functioned until 2014. The Team's main task was to serve the interface, communication and cooperation between the communities of fire scientists, fire managers and policy makers. The main activities embraced (i) the production of International Forest Fire News (IFFN) (the first international thematic journal published between 1989 and 2015); (ii) organization of seminars; and (iii) promotion of synergistic collaboration between governments, non-government institutions, and individuals, with emphasis on science and technology transfer, and support for developing fire management policies (GFMC, 2014a).

From Berlin to Yokohama 1994

The next step followed the recommendations of the Boston Conference – as summarized by conference chair Allan J. West – that wildfire be recognized as one of the natural disasters to be addressed during the United Nations International Decade for Natural Disaster Reduction (UN-IDNDR). The UN-IDNDR World Conference for Natural Disaster Reduction, held in 1994 in Yokohama (Japan), provided a platform to present and discuss a Statement entitled "Proposal for a Possible Role of the UN System in Fire Research and Wildfire Disaster Management" (GFMC, 1994). The Statement included the following recommendations:

> *On an international base, no system is available to monitor the extent and the consequences of vegetation fires on a global scale. Most countries in the developing world do not have adequate infrastructures, experience and hardware to manage wildfire disasters. Although bilateral assistance agreements exist and a number of field projects in fire management are carried out through national and international organizations, there are no facilities and/or mechanisms available to provide the necessary disaster management assistance on an international level on a permanent and quick-response base. Besides the UNECE/FAO Team of Specialists on Forest Fire, which has a restricted mandate and a regionally restricted area of influence, or some ongoing and planned regional fire research campaigns under the IGBP scheme, neither the UN system nor any other organization is providing adequate structures and mechanisms with international (global) responsibilities in fire management.*
>
> *In order to take the first necessary steps for clarifying the global importance of wildfires and for building international structures and mechanisms for mutual fire management support, it is recommended to entrust the UNECE/FAO Team of Specialists on Forest Fire, in close cooperation with FAO, UNESCO, IDNDR, and UNDRO, to develop a plan for the establishment of a UN-sponsored Global Fire Research and Management Facility, which includes a Global Vegetation Fire Information System and the capabilities to provide support on request to any nation in fire management and prevention and management of wildfire disasters.*

This proposal was carried forward to the next international events.

From Yokohama to Shushenskoe 1996

The next major interdisciplinary conference was held in March 1995 in Williamsburg, Virginia, USA. At the Chapman Conference "Biomass Burning and Global Change" (Levine, 1996), the scientists referred to the United Nations Conference on Environment and Development (UNCED), the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity, the objectives of the work of the UN-IDNDR and the UN Commission for Sustainable Development (CSD) and demanded (GFMC, 1995):

The participants in the 1995 Chapman Conference on Biomass Burning and Global Change, representing scientific investigators of biomass burning from many nations, recommend that the United Nations system support the establishment of an improved relational data system for the interdisciplinary assessment of the effects of fire on the global environment, and an appropriate scientific organization be involved in designing and evaluating the data system.

In following up Yokohama and Williamsburg, the UNECE/FAO/ILO Team of Specialists on Forest Fire and the Federal Forest Service of the Russian Federation jointly organized the UNECE/FAO Seminar on Forest, Fire, and Global Change in Shushenskoe, Russian Federation (4-9 August 1996). The participants of the seminar proposed a concept for the development of internationally agreeable standards and procedures for building a global database on wildland fires and an operational global vegetation fire monitoring system. The recommendations included the proposal to develop of a dedicated United Nations unit specifically designed to use the most modern means available to develop a global fire inventory, producing a first-order product in the very near future, and subsequently improving this product over the next decade. This fire inventory data would provide the basic inputs into the development of a Global Vegetation Fire Information System (UNECE/FAO/ILO, 1996).

Other dedicated scientific regional research campaigns and conferences of the 1990s addressed the role of fires in the different vegetation zones, e.g., boreal Eurasia (Goldammer & Furyaev, 1996; Kasischke & Stocks, 2000), the atmospheric impact of fires burning in tropical savannas and forests (Andreae *et al.*, 1996; van Wilgen *et al.*, 1997), or the prehistoric evidence of the sediment records of fire and global change (Clark *et al.*, 1997).

From Shushenskoe to Vancouver 1997

Six years after Boston the Second International Wildland Fire Conference "Wildland Fire '97" was hosted by Canada in Vancouver, British Columbia, in May 1997. The conference was sponsored by the North American Forestry Commission, Fire Management Study Group, as well as numerous government agencies and private companies. The conference was endorsed by the UN-IDNDR Secretariat, the FAO and the UNECE and attended by 565 delegates from 28 countries, representing a global cross-section of policy makers, managers, scientists, and private industry. In the outcome document, the conference participants recommended a number of proposal for global cooperation in fire science and fire management (GFMC, 1997). A specific recommendation addressed the call for the formation of a dedicated international group:

That a group formally established under the auspices of the United Nations to facilitate addressing global wildland fire needs.

The North American Forestry Commission, Fire Management Study Group, represented by Canada (Albert Simard), Mexico (Oscar Cedeño) and the U.S.A. (Mary Jo Lavin) formally endorsed specific outcomes of the Shushenskoe Conference in Russia 1996. This endorsement constituted an expression of increasing international cooperation in fire management and the intent to develop a global agenda in fire management.

Figure 3 – Wildland Fire '97 logo.

From Vancouver to Sydney 2003

The seven years between Vancouver and the Third International Wildland Fire Conference allowed the implementation of the recommendations of the first two conferences. A significant fire episode in Southeast Asia fueled this development. Only a few months after the Vancouver conference, insular South East Asia experienced the consequences of an extreme

El Niño and its related drought in the Maritime Continent of Indonesia. The drought favored the excessive use of fire in the conversion of tropical rain forests and peatland biomes in Indonesia to agro-industrial plantations. Widespread burning on more than five million hectares (ha) resulted in severe smoke pollution affecting the health of more than 250 million people living in the region, increased premature mortality and the net release of greenhouse gases to the atmosphere (Goldammer, 2006a). In early 1998, the Foreign Office of the Government of Germany internally discussed a proposal for the establishment of a "Regional Southeast Asia Fire Monitoring Center". The initial concept of a Regional Center focused on the creation of a science-policy interface for the development of informed fire management policies and support of decision making in fire management in Southeast Asia.

However, with reference to the recommendations of the Boston and Vancouver conferences the German Foreign Office suggested to expand the mandate and mission of the center to the global level. A "Global Fire Monitoring Center (GFMC)" would serve the philosophy of UN-IDNDR by addressing the accelerating fire problems globally. The German Foreign Office provided seed funding for the establishment and the first years of operations of the GFMC. The GFMC website and its online repository – including near-real time publication of spaceborne observation of landscape fires – was formally inaugurated at the opening of the FAO Meeting on Public Policies Affecting Forest Fires at FAO Headquarters, Rome, Italy, on 27 October 1998 (FAO, 1999).

Two years later, an International Expert Meeting on Forest Fire Management, organized by FAO in cooperation with the International Tropical Timber Organization (ITTO), was held at the FAO (Rome, 7-9 March 2001). The meeting concluded a 19-points catalogue of action including the recommendation to FAO for immediate action (FAO, 2001a):

> *Continue to actively participate in relevant, existing initiatives and mechanisms such as the Inter-Agency Task Force Working Group on Wildland Fire of the International Strategy for Disaster Reduction (ISDR); the United Nations International Search and Rescue Advisory Group (INSARAG); the Joint United Nations OCHA/UNEP Environment Unit. FAO should also continue collaboration with organizations such as the Global Fire Monitoring Center (GFMC), and support the development of joint programmes. Information and outputs from such work should feed into fora such as FAO's Committee on Forestry (COFO), the International Tropical Timber Council (ITTC) of the ITTO, and the Collaborative Partnership on Forests (CPF) and the UN Forum on Forests (UNFF).*

After the International Expert Meeting, the first Global Fire Assessment was conducted as a component of the Forest Resources Assessment (FRA) 2000. FRA 2000 became a cooperative venture with the GFMC (FAO, 2001b), followed five years later by FRA 2005 (FAO, 2006a). Other major international activities between Vancouver and Sydney included the development of the first international guidelines for fire management, e.g.:

- Guidelines on Fire Management in Tropical Forests (ITTO, 1997);
- Health Guidelines for Vegetation Fire Events of UNEP, WHO and WMO (Schwela *et al*., 1999);
- Plan of a coordinated international effort on global and regional vegetation fire monitoring from space (Ahern *et al*., 2001);
- FAO Guidelines on Fire Management in Temperate and Boreal Forests (FAO, 2002).

In 2000 the World Conservation Union (IUCN), the GFMC and the UNECE/FAO/ILO Team of Specialists on Forest Fire submitted a proposal to the Inter-Agency Task Force for Disaster Reduction (IATF) (UNISDR, 2000a) to create an interagency "Working Group on Wildland Fire". This proposal was in line with the afore-mentioned recommendations of international conferences during the last five years. This proposal intended to bring together both the technical members of the fire community and the authorities concerned with policy and national practices in wildland fire management to realize their common interests of fire risk management and disaster reduction at global scale. At its second meeting, the IATF agreed on 11 October 2000 to establish the "Working Group on Wildland Fire" (Working Group 4 – WG-4) (UNISDR, 2000b). Through WG-4, it was envisaged to establish an interagency and inter-sectoral forum of UN and other international agencies and programs, and

mechanisms of information and task sharing in the field of reducing the negative impacts of fire on the environment and humanity. Priorities to be addressed by WG-4:

> *Establishment of, and operational procedures for, a global network of regional-to national-level focal points for early warning of wildland fire, fire monitoring and impact assessment, aimed at enhancing existing global fire monitoring capabilities and facilitating the functioning of a global fire management working programme or network.*

The Working Group was launched at the 4th IATF Meeting (Geneva, 15-16 November 2001) (UNISDR, 2001). Three weeks later, the second meeting of WG-4 was convened and inaugurated at the World Meteorological Organization (WMO) (Geneva, 3-4 December 2001). WG-4 members included the conveners of the Boston and Vancouver conferences and representatives of major international groups addressing landscape fire science, management, technology development and policies (Figure 4).

Figure 4 – Members of the initial UNISDR Working Group 4 and constituting members of the International Liaison Committee of the International Wildland Fire Conferences. First row (from left to right): Johann Georg Goldammer (GFMC, convener), Ms. Etsuko Tsunozaki (UNISDR Secretariat), Eduard P. Davidenko (Russia); Brian J. Stocks (Canada). Second row: Christopher O. Justice (GOFC-GOLD, U.S.A.), Gary Morgan (SPOAC, Australia), Liisa Jalkanen (WMO). Third row: Stephen J. Pyne (Arizona State University, U.S.A.), Dieter Schwela (WHO), Denny Truesdale (U.S. Forest Service) and Peter G.H. Frost (Zimbabwe).

The key decision of the WG-4 meeting concerned the formation of the Global Wildland Fire Network (UNISDR, 2002):

> *In accordance with the terms of reference of WG-4 one of the priority activities to be addressed by the Working Group includes the facilitation of the establishment of, and operational procedures for, a global network of regional-to national-level focal points for early warning of wildland fire, fire monitoring and impact assessment, aimed at enhancing existing global fire monitoring capabilities and facilitating the functioning of a global*

fire management working programme or network. The network was finally designated "Global Wildland Fire Network". The timeframe for setting up the network will be January 2002 to July 2003. The 3rd Global Wildland Fire Conference (Sydney, October 2003) will be used as a platform to convene a summit of all regional networks.

The Second WG-4 meeting provided an opportunity for merging the interest of the IWFCs and the developments that had taken place after the first two conferences. Following the communication between the North American conveners of the Boston and Vancouver conferences and the partner organizations in the Australasian region – Australia and New Zealand – it was suggested to liaise with the emerging global network for a coordinated conceptualization of the future IWFCs. An International Liaison Committee (ILC) was established with a membership of representatives from the regions and the international organizations actively involved in fire management – the United Nations Food and Agricultural Organization/FAO, the International Tropical Timber Organization (ITTO) and the GFMC (ILC, 2018). The ILC decided to convene the 3rd IWFC in Sydney, Australia, in 2003.

The Third IWFC – Sydney 2003

The 3rd International Wildland Fire Conference was the first conference in the series outside of North America. The conference was held in Sydney, Australia, 3-6 October 2003, and was attended by one thousand delegates from 51 countries. The conference contributions revealed a forward jump of the community of fire scientists, managers and policy makers to address the socio-economic and environmental significance of landscape fires in the regions of the world. The abstracts and full papers presented at the conference are available on the website of the International Wildland Fire Conferences (GFMC, 2003a).

The International Wildland Fire Summit – Sydney 2003

Two days after the IWFC-3 the International Wildland Fire Summit was held in Sydney (8 October 2003). With the theme of the summit "Fire Management and Sustainable Development: Strengthening International Cooperation to Reduce the Negative Impacts of Fire on Humanity and the Global Environment" the organization of this event explicitly referred to the outcomes of the World Summit for Sustainable Development (WSSD) (Johannesburg, South Africa, 2002) (GFMC, 2003a, 2003b).

The summit theme was selected in order to address the increasing vulnerability of ecosystems and human populations to uncontrolled wildland fires as well as the inappropriate or excessive application of fire in land use and land-use change. High priority was given to define solutions aimed at enhancing international cooperation in the arena of wildland fire management. The endeavor was supported by high-level statements, which were delivered at the Summit (GFMC, 2003b):

- Summit Opening Address by the Under-Secretary General for Humanitarian Affairs;
- Message of the UN Secretary-General for the International Day for Disaster Reduction (Day of the Summit – 8 October 2003);
- Statement by the Executive Secretary of the UN Convention on Biological Diversity.

The summit recognized that solutions must be based on practical and realizable approaches and instruments leading to common strategies, frameworks for implementation and financing mechanisms. Most crucial is the development of mechanisms that will result in concrete action, including both informal and formal agreements at the bilateral and international levels. The agreed "Strategy for Future Development of International Cooperation in Wildland Fire Management" provided a number of recommendations aimed at harmonization and standardization of approaches and enhanced international cooperation. Two of the summit's outputs are particularly practical and ready for implementation:

- An international agreement template which can be used by agencies wishing to form a cooperative or mutual aid arrangement with one or more other countries for cooperation in wildland fire management;
- A recommendation that an Incident Command System/ICS should become the international standard for wildland incident management in international or interagency agreements and exchanges.

Figure 5 – The Summit was attended by 92 invited participants from 34 countries and 12 international organizations. Invitees included those providing expertise in wildland fire management and their capacity to influence the implementation of the outcomes of the Summit within their own domestic jurisdiction.

Figure 6 – Group photo of the Summit participants.

The complete documentation of the Summit is available on the IWFC website (GFMC, 2003a) and in a special issue of International Forest Fire News (GFMC, 2003c).

From Sydney to Sevilla 2007: Follow-up of IWFC-3 and the International Wildland Fire Summit

The Sydney conference provided an opportunity for a first joint meeting of international organizations, interest groups and consortia active in fire management at regional and global level. On 5 October 2003, the GFMC convened a side event, which the following groups attended (Goldammer *et al.*, 2003):

- UNISDR Working Group on Wildland Fire/ WG-4;
- The International Liaison Committee/ILC of the IWFCs;
- UNECE/FAO/ILO Team of Specialists on Forest Fire;
- UN Food and Agricultural Organization/ FAO;

- North American Forestry Commission, Fire Management Study Group;
- Forest Fire Group of FAO Silva Mediterranea;
- Global Observation of Forest Cover/Global Observation of Landcover Dynamics/ GOFC/GOLD Fire Implementation Team (a subset of the Global Terrestrial Observing System/GTOS).

A key output of the joint meeting was the recommendation to create a successor body of the working Group (which was limited to two years lifetime) under the auspices of the UN. The GFMC reported to the 8th Meeting of the UNISDR Inter-Agency Task Force for Disaster Reduction (5-6 November 2003) and recommended:

> *The Working Group suggests the IATF to support the further establishment and strengthening of the Global Wildland Fire Network as a key instrument to foster the international dialogue und efficient cooperation in the arena wildland fire. Given the inter-sectoral nature of wildland fire and the number of UN agencies and programmes involved, as well as other international organizations and civil society, it is suggested to maintain an advisory body for the UN within the IATF.*

The IATF accepted the proposal, which decided to create the Wildland Fire Advisory Group (WFAG) under the auspices of the UNISDR. The WFAG would represent an advisory body to the UN system aimed at:

- Providing technical, scientific and policy-supporting advice to the UN family through the International Strategy for Disaster Reduction/UN-ISDR and the IATF;
- Acting as a liaison between the United Nations system, the Global Wildland Fire Network/GWFN and its supporting partners.

Members and supporting partners of the WFAG would include:

- Leaders/representatives of the Regional Wildland Fire Networks;
- UN agencies and programmes;
- UN conventions (notably UNCBD, UNCCD, UNFCCC);
- Collaborative Partnership of Forests/CPF and the UN Forum on Forests (UNFF);
- Other international organizations;
- Non-government organizations;
- Government agencies;
- Inter-governmental institutions/Multilateral organizations;
- Civil society;
- Academia;
- International Liaison Committee (ILC) of the series of International Conferences on Wildland Fire;
- Global Fire Monitoring Center (GFMC) acting as convener and secretariat.

WG-4 mandated the GFMC to facilitate the formation and operational functioning of the Global Wildland Fire Network (GWFN) by supporting the establishment of Regional Wildland Fire Networks in regions where such networks did not yet exist. In the end, the GWFN constitutes an umbrella, which facilitates the dialogue between 14 independent Regional Wildland Fire Networks of different/individual origins and mandates. The overall GWFN mission is to:

- Reduce the negative impacts of landscape fires on the environment and humanity;
- Advance the knowledge and application of the ecologically and environmentally benign role of natural fire in fire-dependent ecosystems, and sustainable application of fire in land-use systems.

The post-Summit activities of the Global Wildland Fire Network between IWFC-3 and IWFC-4 are documented on the website of the Summit (GFMC, 2004f, 2005a, 2006, 2007a). One of the major activities included the cooperation between GFMC and FAO, formally manifested in a Memorandum of Understanding between the GFMC (Max Planck Institute for Chemistry) and FAO (23 December 2004). The intent of this joint effort followed suggestions of several United Nations agencies, programs and conventions, as well as governments and civil society, which were calling for developing synergies aimed at enhancing effectiveness and efficiency in wildland fire management. In a position paper "Framework for the development of an International Wildland

Fire Accord" – successively updated between May 2004 and April 2005 – it was proposed to develop an International Wildland Fire Accord to reinforce and strengthen international cooperation in wildland fire management (GFMC, 2005b).

The first joint meeting the ISDR Wildland Fire Advisory Group and the Global Wildland Fire Network (GFMC, Freiburg, Germany, 3-4 December 2004) prepared recommendations for the development of an International Accord on Cooperation in Wildland Fire Management (Goldammer, 2004a). These recommendations were submitted to the UN World Conference on Disaster Reduction (January 2005). At the 5th Session of the United Nations Forum on Forests (UNFF) (New York, 16-27 May 2005) a side event was held entitled "Development of a Strategy or Agreement on International Cooperation in Wildland Fire Management" (18 May 2005). The event provided the stage for contributions by the GFMC (on behalf of the ISDR WFAG/GWFN), the FAO, the U.S. Forest Service, and The Nature Conservancy (TNC)S.

The "Framework for the Development of an International Wildland Fire Accord" was presented to the FAO Ministerial Meeting on Forests (14 March 2005) and the 17th Session of the FAO Committee on Forestry (15-19 March 2005), in which 128 countries participated, represented by 40 ministers and 90 heads of forestry agencies; the UNISDR Secretariat was represented by the GFMC. A special volume of UNECE/FAO International Forest Fire News covering the activities of the Global Wildland Fire Network was prepared for and presented to the Ministerial Meeting and the UNFF Session (GFMC, 2004h; Goldammer, 2004b). The Ministerial Meeting and COFO came up with the following recommendations:

Ministerial Meeting

We further commit ourselves… to enhance international cooperation on forest fires. To contribute to the efforts by our countries, we call on FAO, in collaboration with countries and other international partners, including the International Strategy for Disaster Reduction, to develop a strategy to enhance international cooperation on wildland fires, that advances knowledge, increases access to information and resources and explores new approaches for cooperation at all levels,

FAO Committee on Forestry (COFO)

(28.) … requested FAO, in collaboration with countries and other international partners, including the United Nations International Strategy for Disaster Reduction, to develop a strategy to enhance international cooperation on wildland fire.

(53) … recommended that FAO continue its support for regional and national networks to combat fire as well as insects and disease, in collaboration with relevant organizations such as the United Nations International Strategy for Disaster Reduction and the Global Wildland Fire Network, and further requested that FAO work with partners to develop voluntary guidelines on the prevention, suppression and recovery from forest fire.

The recommendations of the Ministerial Meeting and COFO 2005 reveal that the proposal for developing an International Wildland Fire Accord was not accepted. Instead, FAO was requested to work with partners to develop voluntary guidelines on the prevention, suppression and recovery from forest fire. FAO took the challenge and convened several expert meetings to define the way ahead. Among the experts, there was a consent to develop a voluntary instrument called "The Fire Management Code". In May 2006, FAO convened an Expert Consultation on Fire Management, organized with support from the U.S. Forest Service and hosted by the General Direction of Biodiversity of the Ministry of Environment in Madrid, Spain. The consultation recommended that the "Strategy to Enhance International Cooperation in Wildland Fire Management" become the "Strategy to Enhance International Cooperation in Implementing the Fire Management Code". However, FAO Member States did not accept the terminology, i.e. particularly the term "Code" – since because in the context of national terminology of some countries and languages (e.g., France/French) a "Code" would be a legally binding instrument. Thus, in the end, the expert consultation agreed that a non-legally binding "Strategy to Enhance International Cooperation in Fire Management" would include four components (FAO, 2006b):

- Fire Management Voluntary Guidelines (FAO, 2006c);

- Implementation Partnership (FAO, 2007) (cf. below – the Fire Management Action Alliance);
- Global Assessment of Fire Management (2006d);
- Review of International Cooperation in Fire Management (Goldammer, 2006).

These tools had been tailored primarily for supporting land-use policy makers, planners and managers in fire management, including the Governments, the private sector and non-governmental organizations to assist in the formulation of policy, legal, regulatory and other enabling conditions and strategic actions for more holistic approaches to fire management. Their scope includes the positive and negative social, cultural, environmental and economic impacts of natural and planned fires in forests, woodlands, rangelands, grasslands, agricultural and peri-urban landscapes.

A strong partnership and cooperation between FAO and the Global Wildland Fire Network evolved during the preparation of the Global Assessment of Fire Management (FAO, 2006d). As a supplement and complement to the Global Forest Resources Assessment 2005, twelve regional reports published as Working Papers were prepared by regional and country contributing authors to provide a greater depth of data and information on fire incidence, impact, and management issues relating to the twelve Regional Wildland Fire Networks around the world. The working paper series analyzed the fire situation in each region and addressed institutional capacity and capability in fire management, including the roles and responsibilities of different stakeholder groups for prevention and suppression, particularly the unique role of community-based fire management (GFMC, 2006b). A narrative and a repository of official key documents, which reflect the cooperation between FAO and GFMC towards the development of the non-legally binding "Strategy to Enhance International Cooperation in Fire Management" (2005-2007) are provided by GFMC (2007b).

Parallel to the joint work with FAO, the GFMC was invited in 1999 to cooperate with the International Search and Rescue Advisory Group (INSARAG). INSARAG is a global network of more than 90 countries and organizations under the United Nations umbrella. INSARAG deals with urban search and rescue (USAR) related issues, aiming to establish minimum international standards for USAR teams and methodology for international coordination in earthquake response based on the INSARAG Guidelines (INSARAG, 2019). Related disasters, for instance wildfires affecting residential and peri-urban areas embedded in or bordering natural and cultural landscapes with high wildfire risk, so far had not been included in the INSARAG concept. Between 1999 and 2003, the GFMC was mandated to chair a Fire Working Group in the INSARAG Europe-Africa Region. At the foundation meeting of INSARAG Fire it was recommended:

- INSARAG-Fire is a global network of specialists in dealing with industrial fire, wildland fire and HAZMAT incidents affecting populations and the environment;
- INSARAG-Fire is organized in regional nodes;
- INSARAG-Fire has been initiated by a Starting Core Group of INSARAG Europe-Africa and will seek the establishment of Fire groups in the INSARAG Americas and Asia-Pacific regions;
- Activation of involvement of existing international structures by calling on wildland fire expertise of international organizations and individuals already in place will be coordinated through the Global Fire Monitoring Center (GFMC) network;
- Encourage a continuous exchange of information through the Internet, initially utilizing the Global Fire Monitoring Center network.

However, in 2002 the UN General Assembly Resolution 57/150 "Strengthening the effectiveness and coordination of international urban search and rescue assistance" (19 December 2002), which was supported by 58 governments, did not include a fire component of INSARAG (UNGA, 2003). Thus, the interim working group phased out in April 2004 (GFMC, 2004i). The end of this cooperation constituted a missed opportunity for the UN system to open an existing intergovernmental mechanism to address the accelerating problem of global fire problems by creating minimum international standards for wildfire response teams and methodology for international coordination in wildfire emergency response.

Despite the semantic discussions about the terminology of a voluntary or legally non-binding agreement ("accord" vs. "code" or "guidelines"): The international consultation process continued to define pragmatic solutions in cross-boundary cooperation in fire management. A first round of major regional consultations were organized in 2004 to follow-up the recommendations of the summit:

- Northeast Asia (Seoul, Korea, 5-6 March 2004) (GFMC, 2004a);
- Eastern Mediterranean, Near East, and Central Asia (Antalya, Turkey, 30 March – 1 April 2004) (GFMC, 2004b);
- Baltic Region (Helsinki, Finland, 10 May 2004) (GFMC, 2004c);
- South America (Curitiba, Brazil, 14-17 June 2004) (GFMC, 2004d);
- Central America and the Caribbean and Western Hemispheric Wildland Fire Conference (Costa Rica, 23 October 2004) (GFMC, 2004e);
- Regional Central Asian Forest Congress "Forest Policy: Problems and Solutions" (Bishkek, Kyrgyz Republic, 25-27 November 2004) (GFMC, 2004g).

Between 2005 and up to the 4th IWFC in Spain (May 2007) the regional consultations, network meetings and exercises continued. Detailed documentation is available in the GFMC repository (GFMC, 2005a, 2006b, 2007a). A few selected regional/global events and activities included:

- 2nd Meeting of the Northeast Asia Wildland Fire Network (Tohoku University, Sendai, Japan, 18 January 2005);
- Global Wildland Fire Network presentations at the UN World Conference on Disaster Reduction/WCDR (18-22 January 2005, Kobe, Hyogo, Japan);
- Regional Southeast Europe Wildland Fire Network: Regional Scientific and Technical Consultation 2005 (Ohrid, Macedonia F.Y.R., 4-5 April 2005);
- North American Forest Commission Fire Management Working Group, Fire Management Study Tour to Australia and New Zealand (1 April – 5 May 2005);
- Eastern European, Near East and Central Asian States Exercise on Wildland Fire Information and Resources Exchange – EASTEX FIRE 2005 (Haskovo, Bulgaria, 20-22 April 2005);
- Technical Workshop "Strategy for Cooperation in Fire Management in the Caribbean" (31 May – 2 June 2005, Ciudad de Santo Domingo, Dominican Republic);
- Technical Workshop "Strategy for Cooperation in Fire Management in South America" (21-23 June 2005, Curitiba, Brazil);
- Launch of the Regional Central American Strategy on Fire Management 2005-2015 (Estrategia Centroamericana para el Manejo del Fuego 2005-2015);
- Regional Central Asia Fire Management Study Tour and International Conference on Forest and Steppe Fires (Mongolia, Buryatia, Irkutsk Oblast, August-September 2005);
- 39th Annual Meeting of the North American Forest Commission, Fire Management Working Group (12-15 October 2005, Prince Albert, Saskatchewan, Canada);
- Report of the Wildland Fire Advisory Group/ Global Wildland Fire Network to the 12th Meeting of the ISDR Inter-Agency Task Force for Disaster Reduction (Geneva, 22-24 November 2005);
- Conference on Promoting Partnerships for the Implementation of the ASEAN Agreement on Transboundary Haze Pollution (11-12 May 2006, Ha Noi, Viet Nam);
- Regional SE Europe/Caucasus Wildland Fire Network Meeting (Zvolen, Slovakia, 22-26 May 2006);
- First International Northeast Asia Forest Fire Conference and 3rd Meeting of the Regional Northeast Asia Wildland Fire Network (28 to 30 September 2006, Khabarovsk, Russia);
- 40th Annual Meeting of the North American Forest Commission, Fire Management Working Group (24-26 October 2006, Fort Collins, Colorado. U.S.A.);

- Regional Wildland Fire Consultation on the Development of a Strategy on International Cooperation in Wildland Fire Management in the Regional South East Europe/Caucasus Wildland Fire Network (19-21 March 2007, Sofia, Bulgaria);
- Memorandum of Understanding and a Work Plan for Cooperation and Networking in Fire Management South America signed (March 2007, Brazil and COFLAC Secretariat);
- Foundation Meeting of the Regional South Asia Wildland Fire Network (2-3 April 2007, Kathmandu, Nepal).

The Fourth IWFC – Sevilla 2007

At the International Wildland Fire Summit the participants had accepted the invitation by the representatives of Spain to organize and host the 4th International Wildland Fire Conference in 2007. The first formal announcement of IWFC-4 was presented at the 17th Session of the FAO Committee on Forestry (Rome, 15 March 2005), and at the 5th Session of the United Nations Forum on Forests (New York, 18 May 2005). The Inter-Agency Task Force for Disaster Reduction of the United Nations International Strategy for Disaster Reduction (UNISDR) at its 12th Session (22 November 2005) welcomed the proposal that the 4th International Wildland Fire Conference be held in Spain in 2007 under the auspices of UNISDR and FAO. The conference was held in Sevilla, 13 to 17 May 2007, and was attended by 1531 participants from 88 countries.

Building on the objectives and outputs of the previous International Wildland Fire Conferences, the objectives of the 4th Conference included (GFMC, 2007c):

- Provide a forum for forest fire management leaders, politicians, professionals, researchers and practitioners from throughout the globe to discuss and work on critical fire issues affecting people, communities, resources and ecosystems in all Regions and work on a cooperative way in the consolidation of a Global Wildland Fire Management Strategy.
- Strengthen the effectiveness of the Regional Wildland Fire Networks and support their links into the UNISDR Global Wildland Fire Network.
- Provide a forum for the fire management industry, research organizations and fire specialists to display innovations, new technologies, products and methods for wildland fire management and interact with the Conference participants.

At the conference, the FAO presented the Fire Management Voluntary Guidelines and launched the "Fire Management Action Alliance" (FAO, 2007). The purpose of the Fire Management Actions Alliance, which was supported by an international Advisory Group and active until 2015, was to stimulate improved fire management and reduce damage from fire worldwide with the following objectives:

- Review and update the Fire Management Voluntary Guidelines;
- Encourage stakeholders at all levels to adopt and use the Guidelines;
- Review experiences from applying the Guidelines;
- Develop/provide global examples of documents that support the Guidelines;
- Strengthen international cooperation in fire management.

In the outcome document of IWFC-4 identified a number of pressing issues, which more than a decade later are considered key problems to be addressed (GFMC, 2007d):

- Consequences of, and the contribution to, climate change, resulting in increasing occurrence of extreme droughts in most regions, desiccation of wetlands, thawing of permafrost sites, and a general trend of increasing area burned, fire intensity, fire severity, and longer fire seasons;
- Human health and security threatened by increasing wildfire activity and land-use fires causing release of a greater amount of pollutants and resulting in greater public exposure to hazardous emissions, including transboundary transport of fire smoke pollution at regional to global levels;
- Human security and peace threatened by fires burning on radioactively contaminated lands, by fires on areas with unresolved conflicts, and on territories with post-war hazards such as landmines and unexploded ordnance.

Figure 7 – Regional Sessions provided a platform for exchange between countries sharing common landscapes, cultures and borders – here the Session Europe, Southeast Europe, Mediterranean North Africa and Caucasus. The session was co-chaired by Ricardo Velez (head of the Forest Fire Service, Ministry for Environment of Spain, and spiritus rector of advanced fire management in Spain) and Nikola Nikolov (coordinator of the Regional Southeast Europe/Caucasus Wildland Fire Network and later head of the Regional Fire Monitoring Center in Skopje, North Macedonia).

Further, the conference participants recommend, among other, that:

- The international wildland fire community pursue the development of a global-scale international resource sharing strategy to assist countries with fire management planning activities (including prescribed fire for ecological purposes and fuels management), and active support during periods of wildland fire;
- The FAO promote the global adoption of Incident Command System/ICS including the publishing of an annual list of countries which have implemented ICS;
- Regional strategies for fire management be developed and designed to the specific needs of regions;
- An international framework for fire management standards be developed and regional wildland fire training be supported, especially to meet the needs for capacity building in developing countries;

A complete documentation of IWFC-4 is available on the IWFC website (GFMC, 2007c) and in a special issue of International Forest Fire News (GFMC, 2007e).

From Sevilla to Sun City 2011

Between 2007 and up to the 5th IWFC in South Africa (May 2011) the regional consultations, network meetings and exercises continued to follow-up the implementation of the recommendations of IWFC-4. Detailed documentation is available in the GFMC repository and show increasing activities in bringing the state-of-the-art science to policy makers and the community of fire management practitioners (GFMC, 2007a, 2008, 2009, 2010, 2011a). Selected milestones of development in the regions included:

- Foro Centroamericano sobre Manejo del Fuego: Incendios forestales una realidad en Centroamerica (28 October – 3 November 2007, San Salvador, El Salvador);
- Symposium on Fire Management in Cultural and Natural Landscapes, Nature Conservation and Forestry in Temperate-Boreal Eurasia (25-28 January 2008, GFMC, Freiburg, Germany);
- First International Central Asian Wildland Fire Joint Conference and Consultation "Wildland Fires in Natural Ecosystems of the Central Asian Region: Ecology and

Management Implications", associated with the First Central Asian Forest Fire Experiment (30 May – 9 June 2008, Ulaanbaatar, Tunkhel, Mongolia);

- Regional Consultation 2008 of the UNISDR Regional Southeast Europe/Caucasus Wildland Fire Network (4-6 December 2008, Skopje, FY Republic Macedonia);
- Pan-Asia Forest Fire Consultation for the UNISDR Regional Wildland Fire Networks of Northeast Asia, Central Asia, Southeast Asia (ASEAN), and South Asia (1-6 February 2009, Busan, South Korea);
- Inauguration Meeting of the UNECE/FAO Team of Specialists on Forest Fire for the work period 2008-2013 (1 April 2009, United Nations, Palais des Nations, Geneva, Switzerland);
- Advanced Seminar "Wildfires and Human Security: Fire Management on Terrain Contaminated by Radioactivity, Unexploded Ordnance/UXO and Land Mines" (6-8 October 2009, Kiev and Chernobyl, Ukraine);
- SADC Regional Consultative Workshop "Development of a SADC Cross-border Fire Management Programme: A Contribution to Regional Disaster Risk Reduction in Response to Global Climate Change" (25-27 January 2010, Maputo, Mozambique);
- Regional conference on Transboundary Cooperation in Fire Management, hosted by the government of Russia, supported by GFMC, UNISDR and the UNECE/FAO Team of Specialists on Forest Fire, with participation of government agencies of China, Belarus, Ukraine, Kazakhstan, Mongolia, South Korea, U.S.A. (16-18 June 2010, Irkutsk, Russian Federation);
- International Conference "Forest Fires: Management and International Cooperation for Preventing Forest Fires in the APEC Region" (4-6 October 2010, Khabarovsk, Russian Federation);
- First Latin American Exercise for Mobilization of Forest Fire Brigades (Quarto Ejercicio Nacional y Primer Latinoamericano de Movilisación para Brigadas de Control de Incendios Forestales) (9-12 November 2010, Guayaquil, Ecuador).

The Fifth IWFC – Sun City 2011

The 5th International Wildland Fire Conference was held in Sun City, South Africa. The conference provided a platform to bring together members of the science community with those involved in the technical operational fire management. This also included those affected by fire and the authorities concerned and mandated with developing policies and strategies in wildland fire management. The goal of this collaboration is learning, innovating and sharing practices and lessons common to sustainable use of the environment, wildland fire risk management and disaster reduction at local, national, regional and global scales. The presentations, exhibitions and insights offered by international professionals and experienced fire management personnel appealed not only to fire and disaster risk management specialists, scientists and practitioners, but also to students, the conservation, commercial forestry and agriculture sectors, community leaders, policy and decision-makers.

The Conference Programme was arranged around the theme "Living with Fire – Addressing Global Change through Integrated Fire Management" and addressed:

- Adapting to climate change: Integrated fire management in the post-Kyoto period;
- Fire management and carbon management innovations;
- Community fire awareness, prevention and survival – revisiting "Stay or Go";
- Resource sharing and coordination;
- Best practices and new technologies in fire detection and suppression;
- Recent advances in fire science and fire management applications;
- Developing future leaders and leadership programmes;
- Using fire to sustain ecosystem services in fire adapted environments;
- Mitigation, wildfire risk reduction and vulnerability;
- Integrated fire management and poverty alleviation in developing countries;
- Institutionalizing application of the Incident Command System;

- International exchange and assistance programmes and protocols.

The conference was an Associated Event to the Third Session of the UNISDR Global Platform for Disaster Risk Reduction (United Nations Geneva, Switzerland, 9-13 May 2011). Both events were connected by a panel discussion via a video conference. Policy makers of about 180 countries attended the video conference.

The conference was opened by a message by the Secretary-General of the United Nations, Mr. Ban Ki-moon. In his message to the 500 delegates from 61 countries, which was conveyed by the Coordinator of the Global Wildland Fire Network, he welcomed the efforts of fire specialists from around the world to develop a spirit of global cooperation in addressing the role of fire in the global environment and its impacts on society (UNSG Ban Ki-moon, 2011):

United Nations
Secretary-General

Message to Fifth International Wildland Fire Conference

Sun City, South Africa, 10 May 2011

It is a pleasure to send my greetings to the participants in this important conference. The year 2011 has already seen a number of terrifying wildland fires in Western Australia, in the high mountain ecosystems of Nepal, in Mexico, the United States, Russia and, most recently, in Europe. Other disasters have made clear how vulnerable our cities and communities are and how much more effort is required to reduce our vulnerability.

Wildland fires destabilize ecosystems and the global atmosphere, and have clear implications for human health and security. Unlike other natural hazards, wildland fires are primarily caused by human activities. Measures to prevent them – such as education, awareness-raising and capacity-building – are well known and within reach. Community-Based Fire Management is particularly important.

The transboundary effects of wildland fires associated with long-range smoke transport and emissions are prompting the international community to strengthen cooperation in fire management. International organizations and civil society groups are working to build capacity, develop advanced technologies and promote sustainable land-use practices.

The UN system is strongly committed to this effort. Our work encompasses many aspects of fire management, including agriculture, forestry, health, science, the environment, emergency response and weather forecasting and monitoring.

We welcome the efforts of fire specialists to build a culture of prevention and to develop a spirit of global cooperation. This conference, held in conjunction with the Third Session of the Global Platform for Disaster Risk Reduction in Geneva, can galvanize our efforts to reduce risk and vulnerability. I encourage you to identify real solutions that will help communities and nations to better handle the adverse impacts of fires and to build safer, more sustainable societies for all. Please accept my best wishes for a successful conference.

Figure 8 – IWFC-5 Flag.

The conference participants elaborated on both the need for the wise use of fire in sustainable management of natural and cultural ecosystems, and on the adverse effects of wildfires at local to global scales. They expressed strong concern at the escalation of wildfires across the globe, many unprecedented in the modern era for the severe impact on communities, the environment

and the world economy. The conference participants acknowledged the benefits derived through collaboration in sharing information and researching new ways to tackle emerging issues. The conference participants, including the representatives of Regional Wildland Fire Networks and international thematic networks, concluded that efforts be strengthened in capacity building in wildland fire science and management, and that this can be fostered by international cooperation and sharing of expertise and resources. In the Conference Statement, the following recommendations addressed common international concerns and reflect the consensus that priority has to be given to the following (extract of the Conference Statement):

Areas of concern

Rural and industrialized societies have altered the natural environment and fire regimes. Vice-versa, humans are becoming increasingly vulnerable to the consequences of wildfires. This is calling for:

- *Increase of fire management efforts on terrain contaminated by radioactivity, unexploded ordnance, land mines and chemical deposits, notably in the regions affected by the nuclear fallout of the nuclear power plant failures in Chernobyl (1986) and Fukushima (2011);*
- *Increase of efforts on securing peat bog/ wetland ecosystems that are subjected to drainage and climate-driven desiccation to become affected by fire;*
- *Increase of effort to reduce unnecessary burning on croplands, fallow and other lands to reduce the negative impact of greenhouse gas and black carbon emissions on the regional, arctic and global environment;*
- *Address the increasing vulnerability of society at the wildland-urban interface by wildfires;*
- *Provide necessary awareness and means to protect human health and security from wildland fire smoke pollution.*

Figure 9 – IWFC-5 defined key areas of concern (I).

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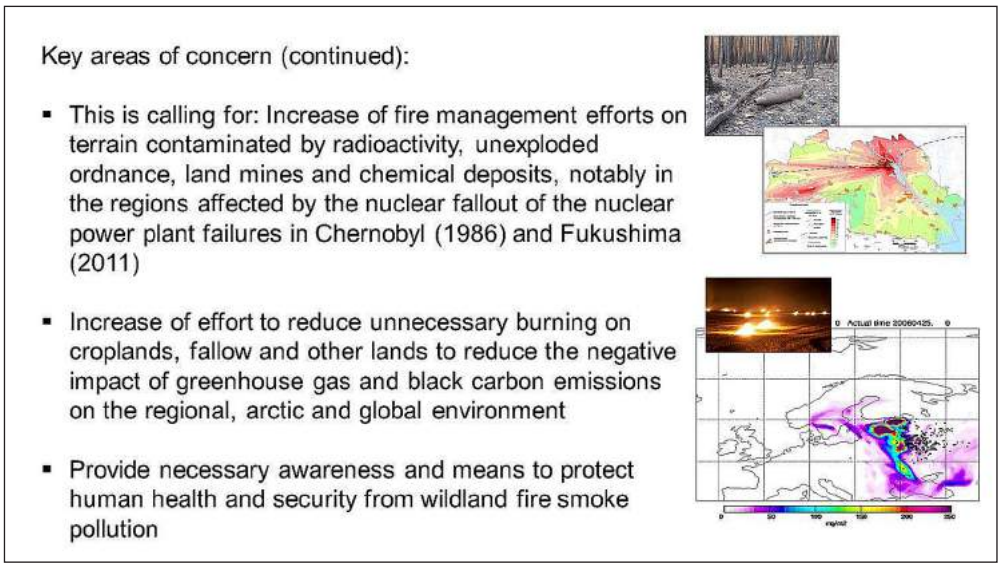

Figure 10 – Key areas of concern (II).

International cooperation

Experience of a number of successful bilateral and multilateral agreements on cooperation in fire management is calling for:

- *Promotion of bilateral and multilateral/ regional agreements on cooperation in wildland fire management and mutual assistance in wildland fire emergencies;*
- *Development of a proposal for a Global Agreement on Transboundary Cooperation in Fire Management;*
- *Further involvement of the six FAO Regional Forestry Commissions and the National Platforms for Disaster Risk Reduction in the implementation of principles as laid down in the fire management guidelines and the "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters".*

Development of policies addressing global change and fire

In response to global change (interaction of climate change, socio-economic changes, and land-use change) and taking into account that global warming is a reality and will lead to an increasing occurrence and severity of wildland fires globally, and increasing impacts of society. Thus, the following is recommended:

- *Development of adaptive fire policies and strategies for mitigation, adaptation and protection at national to international levels;*
- *Integration of fire management in the frame of natural resources/land management at landscape level, including use of plant biomass as a renewable and sustainable source for energy production for wildfire hazard reduction;*
- *Support of countries to conduct fire management assessments, formulate legal frameworks and strategies, build sustainable fire management capabilities and institutions, develop fire management plans and human resources.*

The contributions presented in the plenary and parallel sessions reflected the advances in wildland fire science and management globally. The abstracts of the presentations and other conference materials including a large photo gallery are available on the conference website (GFMC, 2011b) and in a special issue of UNECE/FAO International Forest Fire News (GFMC, 2011c).

From Sun City to Pyeongchang 2015

The outcomes of the South Africa conference were inspiring! Between 2011 and up to the 6th IWFC in South Korea (October 2015) the regional

consultations, network meetings and exercises continued to follow-up the implementation of the recommendations of IWFC-5. Detailed documentation is available in the GFMC (GFMC, 2011a, 2012, 2013a, 2014b, 2015a). Selected milestones of development in the regions included:

- 2nd UNSIDR Pan-Asia Wildland Fire Network Meeting and the 7th UNISDR Regional North East Asia Network Meeting (Sol Beach, Gangwon-do, Republic of Korea, 5-10 June 2011);
- First International Conference of Wildfire on Natural Resources Lands, Islamic Republic of Iran (Gorgan, Golestan Province, Islamic Republic of Iran, 26-28 October 2011);
- Conference on "Climate Change & Forest Fires in the Mediterranean Basin: Risk Reduction & Management" (Nir Etzion, Israel, 24-26 January 2012);
- World Health Organization/WHO Regional Office for Europe Workshop "Health aspects of wildfire smoke", organized in collaboration with the WHO European Centre for Environment and Health (WHO-ECEH) and the National Institute for Health and Welfare (THL), Finland, in conjunction with the 15th Meeting of the Joint Convention/WHO Task Force on Health Aspects of Long-range Transboundary Air Pollution (Bonn, UN Campus, Germany, 21 May 2012);
- Regional Pan-Asia/Pacific Consultation on Building Advanced National and Regional Capacities in Integrated Fire Management based on Participatory Involvement of Local Communities (Lalitpur, Nepal, 20-22 November 2012);
- SADC Regional Forestry Stakeholder Workshop, including presentation of the SADC Fire Management Programme, Regional Networking (SAFNet, Global Wildland Fire Network) (Birchwood, Johannesburg, South Africa, 11-13 February 2013);
- Workshop and development of the "Defense of Villages, Farms and Other Rural Assets against Wildfires: Guidelines for Rural Populations, Local Community and Municipality Leaders in the Balkan Region", supported by Council of Europe, the Regional Fire Monitoring Center SE Europe/Caucasus/RFMC, Regional Eastern European Fire Monitoring Center (REEFMC) and the UNECE/FAO Team of Specialists on Forest Fire (Athens, Greece, 13 May 2013);
- Meeting of the Pan-Asia Wildland Fire Network (Cluster of the UNISDR Regional Wildland Fire Networks of SE Asia, South Asia, Central Asia, NE Asia and Eurasia), hosted by the Korea Forest Research Institute (KFRI) (Seoul, Republic of Korea, 23-25 October 2013);
- Consultation on Transboundary fire management in preparation of Mongolian-Russian Government Agreement on Transboundary fire management cooperation (National Committee on Forest and Steppe Fire Protection and Ministry of Environment and Green Development, Ulaanbaatar, Mongolia, 09-10 June 2014);
- Regional Fire Management Training for the South Caucasus, Western Balkans and Eastern Europe/Central Asia in the frame of the regional project "Enhancing National Capacity on Fire Management and Wildfire Disaster Risk Reduction in the South Caucasus", sponsored by the Organization for Security and Cooperation in Europe/OSCE and the Environment and Security Initiative (ENVSEC) (Antalya, Turkey, 15-17 October 2014).

Several international events between 2013 and 2015 merit to be mentioned in detail.

In November 2019 the International Congress "Forest Fire and Climate Change: Challenges for Fire Management in Natural and Cultural Landscapes of Eurasia" was hosted by the Russian Federation in partnership with the Global Fire Monitoring Center (GFMC) in Novosibirsk, Russian Federation. The congress addressed the consequences of climate change on fire regimes and the resulting extremely dangerous fire situations in Eurasia. The participants released a strong warning directed to governments to decision-making bodies in countries of Eastern Europe and Central-Eastern Eurasia:

> *The governments of the region are alerted and warned by the scientific and the professional fire management community that the threat from wildfires in the region will become*

increasingly dangerous in the coming years as a consequence of climate change and socio-economic and demographic changes.

Furthermore, the congress outcomes included the following (selected) recommendations:

- *In order to reduce the negative effects on environment and human health and in complying with the Gothenburg Protocol to the UNECE Convention on Long-Range Transboundary Air Pollution (LRTAP) the extent of unnecessary burning of agricultural, pasture and steppe ecosystems must be reduced;*
- *Rural communities must be supported in the self-defense of rural assets (farms, villages, recreational sites, infrastructures) against wildfires by the by establishing structures for homeland defense against wildfires; provision of appropriate training, equipment and insurance of volunteers active in rural wildfire defense;*
- *Fire Management Resource Centers must be established at regional level, which will train professionals and volunteers in fire management, disseminate information to the public on early warning and real-time information on ongoing wildfires, and facilitate mutual support between neighbouring regions in wildfire emergencies.*

After the Novosibirsk congress the UNECE/FAO Regional Forum on Cross-boundary Fire Management was held at the United Nations Geneva, Switzerland, 27-29 November 2013 (GFMC, 2014a). This Forum was prepared in line with the objectives of work of the UNECE/FAO Team of Specialists on Forest Fire. In 2008, the Team had been mandated to provide guidance to the 56 UNECE Member States on forest fire management and forest fire policies, including on governance in bilateral and international cooperation. In cooperation with the UNECE-FAO Forestry and Timber Section, the GFMC prepared and facilitated the Forum – sponsored by the German Federal Ministry for Food and Agriculture based on a decision of the German Bundestag – and it's follow-up. Representatives of 22 UNECE Member States attended the Forum as well as representatives from other regions, non-government organizations, multilateral and international organizations (ASEAN Secretariat, SADC Secretariat, Council of Europe, and OSCE). The UNECE/FAO Forestry and Timber Section, FAO, UN Office for Disaster Risk Reduction/ UNISDR, OCHA Environmental Emergencies Section, Joint UNEP/OCHA Environment Unit, Emergency Services Branch, and the Secretariat of the UNECE Convention on Long-Range Transboundary Air Pollution represented the United Nations system.

The main objective of the Forum was to elaborate recommendations to UNECE member states and the international community to:

- Build resilience of nations and communities to wildfire emergencies and disasters by enhancing national and collective international fire management capability through exchange of expertise.

In preparation of the Forum, the GFMC and an advisory group prepared the following survey and studies (GFMC, 2013b):

- Study of the Contemporary and Expected Future Wildland Fire Problems in the UNECE Region;
- Proposal "Building Resilience of Nations and Communities to Wildfire";
- Evaluation of the International Fire Management Survey;
- White Paper on Fire Management Policies in the UNECE Region.

In addition, the White Paper directed to the United Nations and International Organizations "Vegetation Fires and Global Change. Challenges for Concerted International Action", which had been prepared between 2009 and 2013 by GFMC and 52 contributing authors, was provided to the Forum (Goldammer, 2013). Based on the preparatory documentation and the discussions, the Forum elaborated a number of recommendations addressing principles and envisaged international cooperation efforts in fire management – including this main recommendation (GFMC, 2013b):

Considering the increasing impacts and damages of fire on the one side, and the required investments in building fire management capacities at global level on the other side, the option should be explored of

whether a strengthened mechanism should evolve from the currently existing voluntary framework to a more formalized framework under the auspices of and support by the United Nations taking into consideration, and supportive of, bilateral and regional frameworks.

The Global Wildland Fire Network over the past decade has been promoting fire management and networking which is appropriate to continue and expand its role as the overarching framework at the global level to host a new, strengthened global mechanism of cooperation in fire management. This framework should ensure that voluntary initiatives and the wealth of experience of individual, national, regional and international actors be utilized and shared.

It is proposed to explore options to establish a UN Secretariat mandated with the implementation of a global fire management programme that should have a key role in facilitating the free and open global transfer of knowledge. A key task of such a Secretariat would be to host and implement the proposed International Wildfire Support Mechanism (IWSM) and the maintenance and application of the Fire Aviation Guidelines. It will be built on a common, coordinated approach with the UN agencies and programmes and those of other international organizations that are mandated or involved in addressing the problems. Funding for the secretariat and its associated Global Wildland Fire Network, the Regional Wildland Fire Networks and the emerging Regional Fire Management Resource Centers must be secured.

Figure 11 – The Forum attendants from UNECE Member States and regional, multilateral and international organizations provided inputs from different natural and cultural environments and institutional mandates.

In following up the recommendations of the Forum, the GFMC supported by an international advisory group, developed perspectives for action (GFMC, 2014c):

- *Long-term Perspective: Development of an International Agreement on Cross-boundary Fire Management:* During the preparatory process and at the Forum it was underscored that the role of fire (wildland fire/vegetation fire) would need to be addressed more explicitly in international (global, regional) legally binding agreements. The Forum called for the "development of a voluntary regulatory institutional and policy framework

aimed at building resilience of nations and communities within the UNECE region". During the preparatory process and at the Forum it was underscored that the role of fire (wildland fire/vegetation fire) would need to be addressed more explicitly in international (global, regional) legally binding agreements. The Forum called for the "development of a voluntary regulatory institutional and policy framework aimed at building resilience of nations and communities within the UNECE region". With the currently ongoing negotiations on a Legally Binding Agreement (LBA) on Forests in Europe, there may be a chance to address needs and obligations for sustainable integrated fire management based on best science and expertise. However, with it should be considered that the LBA would constitute a sectoral agreement limited to forests and forest management, whereas the recommendations of the Forum called for the application of a "holistic approach to wildland fire management at landscape level", i.e. including fire management on agricultural, pasture and other open lands, including wetlands and peatlands. The LBA on Forests in Europe, however, may serve as an entry point for an international agreement in the form of an Annex or Protocol on Fire Management. Since the negotiations are currently in a stage to address procedural and organizational issues, and not yet substantive details, it is recommended that the secretariat (proposed under Item 2) should observe, lobby and, if requested to do so, provide technical support to the process.

- *Medium-term Perspective: Creation of an International Wildfire Preparedness Mechanism (IWPM) and introduction of the "Voluntary Guidelines for Fire Aviation":* The Forum had proposed to establish an **International Wildfire Support Mechanism/IWSM** for the UNECE Region and globally, that will assist nations to improve their capacity and resilience to wildfire. The mechanism will provide a platform/framework from which to cascade improved knowledge, good practice, experience and training throughout the global wildfire community for the benefit of all. It was suggested to re-designate this proposed mechanism to **International Wildfire Preparedness Mechanism/ IWPM** to better reflect the overall intent of this endeavour. Furthermore, the Forum recommended that UNECE member states adopt in principle the Draft Fire Aviation Guidelines and support their continued development. The Forum recommended that in order to fully realize the potential benefits of consistent and standardized approaches in this field, the global wildland fire community consider adoption of the guidelines. These two proposed mechanisms should be installed at medium-term time scale as a voluntary process, preceding a possible future formal agreement. At the Forum itself no conclusions could be given. Instead, it was proposed to explore options to establish a UN Secretariat mandated with the implementation of a global fire management programme that should have a key role in facilitating the free and open global transfer of knowledge. A key task of such a Secretariat would be to host and implement the proposed IWPM and the maintenance and application of the Fire Aviation Guidelines. Since negotiations and success for a possible establishment of a Secretariat may require negotiations within the UN, it was proposed in Report 2 to the Forum "that the initial creation of the mechanism must be overseen and driven by an interim host and secretariat. The secretariat will in turn need to be supported by an advisory group". The IWPM is currently hosted by the GFMC, which is serving as **IWPM Interim Secretariat**.

While no advances have been made since the early 2000s and after the Forum to develop an international agreement on international cooperation in fire management – neither legally binding nor voluntary – the IWPM became instrumental as a broker for national agencies responsible for fire management, international organizations, NGOs, fire management projects or entrepreneurs seeking or offering expertise in fire management (GFMC, 2014d, 2014e). In this context, the GFMC is offering a number of tools for advising/supporting nations and the United Nations system in capacity building in wildland fire management and wildfire disaster risk reduction (GFMC, 2014f; UNEP/OCHA, 2014).

At regional level, the Regional Wildland Fire Networks play an increasing role in supporting relevant actors in building fire management capacities. In order to strengthen the outreach of the networks, the GFMC initiated the establishment of Regional Fire Monitoring Centers and Regional Fire Management Resource Centers. The main function of these Centers, which are established in independent academic entities (universities, scientific academies or similar institutions), is to:

- Contribute to informed political decision making and the development of relevant fire management policies;
- Build institutional capacities to implement;
- Support participating countries of the region to develop informal or formal agreements/ protocols for cross-boundary cooperation in fire management.

Technically, the Centers are tasked to:

- Develop internet-based information portals, which will include the science of vegetation fires and related scientific disciplines;
- Develop web-based documentation and information portals on the practices that are prerequisite for the application of scientific principles in informed fire management;
- Create an interface and promote the dialogue between services of specialized governmental institutions and civil society organizations;
- Provide advisory service for sustainable forestry & land management and relevant policies;
- Provide training in fire management (human resources and institutional capacities).

Before and after IWFC-6 the first five Regional Centers were established:

- Southeast Europe / South Caucasus (2010 – based in Skopje, North Macedonia);
- Eastern Europe (2013 – based in Kiev, Ukraine);
- Central Asia (2015 – based in Ulaanbaatar, Mongolia);
- South East Asia (2017 – based in Bogor, Indonesia);
- Central Eurasia (2019 – based in Krasnoyarsk, Russian Federation).

At that time, the conceptual framework for the establishment of Regional Fire Management Resource Centers for South America and Subsahara Africa were developed (cf. below).

The Sixth IWFC – Pyeongchang 2015

The 6th International Wildland Fire Conference was held under the auspices of the United Nations International Strategy for Disaster Reduction/UNISDR and the Food and Agriculture Organization of the United Nations/FAO in Pyeongchang, Gangwon Province, Republic of Korea, 12 to 16 October 2015. The event was attended by government officials, scientists, professionals from civil society from 73 countries, and by UN agencies and other international organizations. The conference evaluated global wildland fires of the past, the status and achievements of contemporary fire science and fire management, and looked into the future of a changing world and changing fire regimes. Conference participants discussed how science and management could address the challenges ahead, to contribute to the implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030, to assist countries to achieve the Sustainable Development Goal 15 and to deliver inputs to the 21st Conference of the Parties of the UN Framework Convention for Climate Change (COP 21) (December 2015).

Conference participants, while acknowledging some strides in international cooperation and fire management activities since the previous 5th International Wildland Fire Conference in 2011, continued to express strong concerns for a number of larger issues. Some of the most widely shared concerns were the impacts of climate and global change, the application of fire in land-use change, increasing impacts of fire in the wildland urban interface and of smoke on human health and security. Looking forward, participants expressed common hopes for increased international cooperation and response mechanisms, exchange of information and technical and scientific expertise, increased data collection and application of monitoring and early warning measures, and for strengthening (local) education efforts, capacity building in Integrated Fire Management/IFM and rural participatory, community-based initiatives.

The wildland fire management and scientific community shared reports with the conference

participants regarding the progresses made since the last conference in 2011. Within the regions and at global level, major advancements have been noted in fostering capacity building at national level and by enhancing cross-boundary cooperation in fire management. Many of the initiatives, however, were borne and realized as voluntary commitments and activities with limited financial support. Participants therefore stressed the need for more financial support and governmental commitments for national and regional fire management efforts, international policy mechanisms, and especially for greater application of community based fire management practices.

During the conference, the wildland fire community explored challenges relating to a number of general topic areas, notably including: international and regional cooperation, local and national fire management, regional and global climate change, socio-economic changes, capacity building, science and technology, politics, and general operational fire management limitations. Identified within these categories, the conference participants hereby highlight the following common concerns:

- Increasing impacts of climate change on climate variability, weather patterns, fuels and fire behaviour, particularly the lengthening of fire seasons, the size in area burned, and the extremity and frequency of fire occurrences;
- Insufficient political commitment and support for fire management and development of fire management policies;
- Impacts of smoke on human health and air quality as well as fire-induced professional and civilian injuries and fatalities;
- Impacts of fires from land-use change and agricultural/industrial clearing;
- Increasing impacts of wildfires at the interface with rural settlements and urban fringes
- Impacts of socio-economic and demographic changes, including consequences of human migration, on fire regimes;
- Insufficient fire management capacities – in terms of human, technical and financial resources;
- Insufficient use of fire as a positive force to address landscape-level fire fuel build up and bush encroachment.

Areas of special concerns

While most participants held common concerns and goals moving forward, some regions are experiencing unique and critical challenges that should receive special attention. These concerns include:

- Increasing occurrence of fire in ecologically and especially carbon-rich environments such as in tropical rainforests, peatlands, and in the arctic tundra; development of positive feedback loops leading to accelerated disturbances of the global system is of particular concern;
- Challenges associated with collateral damages due to armed conflicts;
- The resulting contaminated ground and unexploded ordnance which endanger fire management activities in these areas;
- Occurrences of fire on otherwise contaminated ground such as from radioactivity;
- Instances of frequent fatalities due to fire and also fire-smoke pollution;
- Lack of sufficient protective equipment, training, and response capabilities in some regions resulting in unnecessary risks and damages from fire;
- Lack of viable alternatives to fire as an agricultural and land-use change tool in some regions;
- Bush encroachment/ecological succession on former intensively cultivated or otherwise managed lands throughout the world and the resulting increased wildfire hazard.

Identified courses of action

In recognizing the concerns raised by the conference participants, the following courses of action were identified:

- Increase the application of existing international fire management and incident preparedness mechanisms;
- Utilize existing and further develop interoperability mechanisms, Standard Operating Procedures (SOPs), and protocols, e.g. the voluntary Fire Aviation Guidelines;
- Broaden the application of the Incident Command System (ICS) for application in

bi- and multilateral cross-border responses to wildfire emergencies;

- Enhance integrated fire management; promote multi-sectoral communication between related and relevant agencies, regionally and nationally;
- Strengthen legal and enforcement mechanisms to combat the illegal application of fire in land use and land-use change;
- Integrate fire management into initiatives like the Reducing Emissions from Deforestation and Degradation (REDD+) and use opportunities offered by the Global Environment Facility (GEF) and Green Climate Fund (GCF);
- Strengthen institutional and governmental capacity in fire management;
- Develop or make available alternatives for fire as a land-use change tool;
- Establish or improve vegetation fire monitoring data collection, analysis and early warning mechanisms;
- Develop fire management strategies for protected/sensitive areas and contaminated areas;
- Increase efficiency and effectiveness of transboundary cooperation, and preparedness and response mechanisms in fire management;
- Establish regional programs and/or resource centers for fire management where none currently exist;
- Take measures to reduce fire-induced greenhouse gas emissions;
- Develop measures for resilience and adaption in the face of a changing vegetation fire climate, including measures to respond to secondary disasters resulting from fire;
- Heighten the international exchange of information and cooperation;
- Promote the development and application of more science and technology, with emphasis to strengthen the link between fire management and science;
- Focus on prevention over suppression; increase the application of prescribed burning;
- Continue to place emphasis on community-based fire management practices by education campaigns and capacity building efforts in participatory fire management at local level to successfully reduce wildfire hazards, and enhance productivity and stability of land and the environment by:
  - Creation of operational environments where community decision-making and implementation balance traditional and contemporary fire management requirements
  - Management of fire for its benefits, through controlled burning, to improve livelihoods and health of local populations, and reduce greenhouse gases
  - Promoting the establishment of volunteer groups to assist state authorities in rural fire management

Envisioned implementation goals

In addressing these areas of concern and the priority actions, four implementation goals are envisioned, three representing fire management regimes in vulnerable, transitioning, and advanced settings, and a final goal to commonly prioritize addressing urgent global challenges:

Goal 1. *In developing fire management the global fire management community is encouraged to help the most vulnerable members to address fundamental threats posed by fires on human health and security; to lend support in the form of financial, technical, or operational measures; and to offer basic training and expertise for strengthening local education efforts, capacity building and rural community-based initiatives. This Goal acknowledges that local communities are the most vulnerable to the effects of a warming climate and of changing fire regimes.*

Goal 2. *In transitioning fire management settings where basic needs are met or institutional capacity are established, the fire management community is encouraged to continue supporting efforts recognized under Goal 1; establish regional programs and/or resource centers where needed; advance technical efforts such as fire detection, early*

warning and monitoring; enhance cross-border cooperation; further apply practical measures like standard operating procedures, the Incident Command System/ICS for use in bilateral and multilateral wildfire emergency response; and to strengthen participatory fire management approaches (community-based fire management, involvement of volunteers).

Goal 3. *In advanced fire management settings, efforts under Goals 1 and 2 shall be continually evaluated and improved as appropriate; emphasis shall be placed on further developing legal frameworks where desired; enhancing bi- and multi-lateral mechanisms for fire management expertise and resource sharing; share and advance science and technology; and when in the position, lend any and all forms of support to vulnerable and transitioning fire management communities.*

Goal 4. *The global fire management community explicitly recognizes the need to address several challenges, which include the role of vegetation fires on*

- *Climate change;*
- *Positive feedback loops of disturbances in the Global System;*
- *Ecologically sensitive and carbon-rich environments like tropical rainforests, peatlands, and arctic tundra;*
- *Agricultural systems and beyond (transboundary impact of agricultural fires such as long-range transport of Black Carbon);*
- *Environment and humans, stemming from armed conflicts (collateral damages);*
- *Contaminated terrain (industrial, unexploded ordnance and radioactivity);*
- *Human health and pre-mature mortality through fire-smoke pollution.*

Recommendations

Looking to the coming years, the conference participants emphasize the importance of and mutual gains to be achieved by supporting and participating in current, emerging, and planned initiatives in fostering the application of principles of Integrated Fire Management. These initiatives will contribute to realizing Sustainable Development Goal 15 (SDG 15) and meet the challenges of the Sendai Framework for Disaster Risk Reduction (SFDRR). These initiatives should receive immediate attention over the next years and their progress should be reported at the 7th IWFC in 2019.

Two major recommendations are directed to the international community and included in the Pyeongchang Declaration "Fire Management and Sustainable Development":

- ***International policies and concerted action:*** *Collective international efforts are needed to address impacts of vegetation fires that are of transboundary nature and currently affecting at an unacceptable level common global assets such as atmosphere and climate, natural and cultural heritage, and human health and security. Systematic application of principles of Integrated Fire Management/IFM, based on the wealth of traditional expertise and advanced fire science, contributes to sustainable land management, ecosystem stability and productivity, maintenance and increase of terrestrial carbon stocks, and reduction of unnecessary emissions of pollutants that affect human health and contribute to climate change. The COP 21 is encouraged to acknowledge the role and endorse the support of IFM as an accountable contribution to reduce greenhouse gas emissions, maintain or increase terrestrial carbon pools in all vegetation types and ensure ecosystem functioning.*
- *Capacitation of nations to address the challenges in fire management: In order to implement IFM there is a demand for capacity building, investments and outreach work at global level. Since traditional and advanced knowledge of IFM principles is available for all vegetation types, the systematic application of IFM, notably community-based fire management approaches, could be promoted by exchange of expertise between countries. The development of regional programmes and/or resource centres for capacity building including training in fire management should be supported by*

countries and international organizations. Bilateral agreements and multilateral voluntary exchange instruments should also be supported.

The conference materials are available on the conference website (GFMC, 2015b) and in a special issue of UNECE/FAO International Forest Fire News (GFMC, 2015c).

Figures 12-14 – IWFC-6 provided an opportunity to recognize the efforts and merits of the next generation of fire scientists (Best Student Research Awards), conference presentations of excellence (Best Paper Awards) and the merits of senior scientists like Winston Trollope and Stephen J. Pyne (Fig. 14 – right).

From Pyeongchang to Campo Grande 2019

Between 25 November and 8 December 2015 the GFMC and the Government of the Republic of Korea worked together to convey a brief message to the United Nations Framework Convention on Climate Change COP 21 (Paris, December 2015). The delegation of Republic of Korea delivered a Statement at the High-Level Segment of COP-21 in which the outcomes of IWFC-6 were presented to the Summit (Republic of Korea, 2015).

Between 2016 and 2019, the Global Wildland Fire Network followed-up IWFC-7 and the Paris Summit (GFMC, 2016, 2017a, 2018, 2019c):

- UNISDR Science and Technology Conference on the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030, with GFMC panellist Oyunsanaa Byambasuren (United Nations, Geneva, Switzerland, 27-29 January 2016);
- First International Fire Management Week, Islamic Republic of Iran, supported by GFMC, the Regional SE Europe/Caucasus Fire Monitoring Center/RFMC and the Fire Management Resource Center-Central Asia Region/FMRC-CAR (Mazandaran, Kelarabad, Islamic Republic of Iran, 9-12 May 2016);
- First Regional Symposium on Cross-Boundary Cooperation in Fire Management

in South America/Primer Simposio Regional de Cooperacion en Manejo del Fuego Inter-Fronterizo en Sudamerica, conducted by GFMC and the Regional South America Wildland Fire Network (Parque Nacional Santa Teresa, Uruguay, 29 May – 1 June 2016);

- International workshop and training course "Forecasting Emissions from Vegetation Fires and their Impacts on Human Health and Security in South East Asia", organized by WMO, IBBI, UNISDR/IWPM, GWFN/GFMC, UNU, GIZ, IGAC and BMKG (Jakarta, Indonesia, 29 August – 1 September 2016);
- Regional Consultative Workshop on Cross-Boundary Cooperation in Fire Management in South Asia, with GFMC contributions on the introduction of EuroFire Competency Standards to South Asia and the establishment of the Regional South Asia Fire Management Resource Center (Lalitpur, Nepal, 02-04 October 2016);
- Regional Consultation on Cross-boundary Cooperation in Fire Management, held under sponsorship of the Council of Europe/CoE, Secretariat of the Euro-Mediterranean Major Hazards Agreement/EUR-OPA (facilitator: GFMC) (Skopje, Republic of North Macedonia, 11 November 2016);
- Opening of the Regional Fire Management Resource Center – Southeast Asia Region (RFMRC-SEA) as the 4th Regional Center of GFMC, sponsored by the German Federal Ministry for Food and Agriculture based on a decision of the German Bundestag (Jakarta, Indonesia, 10 July 2017);
- Second Regional Consultation on Cross-boundary Cooperation in Fire Management in South America , sponsored by GFMC and the German Federal Ministry for Food and Agriculture (Viña del Mar, Chile, 2-3 October 2017);
- Regional Consultation on "Cross-Boundary Cooperation in Landscape Fire Management in Eastern Europe", organized by the Regional Eastern European Fire Monitoring Center (REEFMC)/National University of Life and Environmental Sciences of Ukraine (NULESU), GFMC, with participation of Belarus, Hungary, Moldova, Republic of North Macedonia (Kiev and Boyarka, Ukraine, 27 October 2017);
- Bilateral fire emergency response exercise between Belarus and Ukraine in the frame of the project "Improving Radiological and Environmental Awareness in Territories affected by the Chernobyl Accident in Belarus and Ukraine with a Focus on Wildfire Management", coordinated by the Organization for Security and Cooperation in Europe (OSCE), the Regional Eastern European Fire Monitoring Center/REEFMRC and GFMC (Gomel, Belarus, 17-18 May 2018);
- Regional Round Table and Consultation "Enhancing Regional Cooperation in Fire Management in South East Asia", organized by the Ministry of Environment and Forestry, Republic of Indonesia, the Regional Fire Management Resource Center South East Asia/RFMRC-SEA and GFMC (Jakarta, Indonesia, 06-07 June 2018);
- Joint meeting with the Secretariats of the Organization for Security and Cooperation in Europe/OSCE, the Council of Europe's European and Mediterranean Major Hazards Agreement/EUR-OPA, the United Nations Office for Disaster Risk Reduction/UNISDR and the Global Wildland Fire Network/Global Fire Monitoring Center/GFMC "Streamlining International Cooperation in Landscape Fire Management: Development of a Joint Agenda between UNISDR, Council of Europe/EUR-OPA, OSCE and GFMC (Office of the Coordinator of OSCE Economic and Environmental Activities, Vienna, 03 September 2018);
- Regional Workshop "Landscape Fire Management in South Eastern Europe", organized by the Regional Fire Monitoring Center For SE Europe/Caucasus/RFMC and GFMC, on behalf of the Office of the Coordinator of OSCE Economic and Environmental Activities (Skopje, Republic of North Macedonia, 17-19 December 2018);
- Opening of the Regional Eurasia Fire Monitoring Center (REFMC) und the auspices

of the Global Fire Monitoring Center/GFMC and the Global Wildland Fire Network, with support of the Council of Europe/EUR-OPA Major Hazards Agreement; Sukachev Institute of Forest (Krasnoyarsk, Russian Federation, 27 August 2019).

Campo Grande – The last Milestone on the 30-years Journey

The 7th International Wildland Fire Conference was held between 28 October and 1 November 2019. The conference focused on the theme "Facing Fire in a Changing World: Reducing Vulnerability of People and Landscapes by Integrated Fire Management" and herewith offered an international floor to address

- Role/contribution of civil society in Integrated Fire Management (IFM);
- IFM concepts for stabilizing fire affected landscapes and promoting resilient territories;
- Contribution of IFM to mitigate secondary impacts;
- Technological advances on prevention and fighting wildfires;
- IFM as key element of fire management policies.

The contributions to the conference, which are published in the first two volumes of the proceedings (Steil *et al*. 2019, 2020), reflect the advances made in the exploration and testing of Integrated Fire Management approaches – and to bring them to application. The conference organizers, hand in hand with the IWFC International Liaison Committee, solicited views and recommendations of the conference participants for formulating an agenda for the coming years. The recommendations are laid down in the Campo Grande Statement "Building Sustainable and Fire-Resilient Societies and Landscapes" – with the following key conclusions and recommendations:

The participants of the conference confirmed that in many regions of the world, wildfires are a growing threat to communities and to natural, cultural, rural, urban and industrial landscapes. The problem is increasing due to the consequences of social, economic and ecological change (land-use change, demographic change, ecosystem degradation), as well as climate change. This is impacting human health and security and resulting in the loss of public and private assets, including critical infrastructure. Current risk governance and institutional arrangements are inadequate to cope with this growing trend. Cross-sectoral approaches are required.

The paradigm of addressing the problem through individual and disconnected services and actions in fire prevention or suppression should be reframed. Unified and integral planning must ensure and strengthen societal, environmental and economic resilience to landscape fires by addressing:

- *Risk governance and ownership;*
- *Dialogue of knowledge, including traditional and indigenous knowledge;*
- *Gender, diversity and inclusion;*
- *Socio-economic innovation in rural landscapes, favoring nature-based solutions;*
- *Strengthening local action;*
- *Creation of resilient ecosystems and communities.*

Decision-making must be evidence-based and supported by monitoring and evaluation systems. Implementation should be coherent, cohesive and coordinated.

The integrated cross-sectoral approach described above supports the Sustainable Development Goals, the goals of the Paris Agreement and the Sendai Framework for Disaster Risk Reduction 2015-2030. This approach would be further strengthened by an appropriate United Nations instrument.

These recommendations provide guidance and call for action for the years ahead. Policy makers, politicians and international organizations are challenged to review and eventually reframe national and international agendas.

Figure 15 – Preparation of IWFC-7 by the Organizing Committee, the International Liaison Committee and the regional representatives of Global Wildland Fire Network (2018). These joint meetings of the organizing committees of the IWFCs, the ILC and the GWFN, held at GFMC in Freiburg (Germany) between 2008 and 2018, served the preparation and follow-up of the conferences.

Figure 16 – Opening session of IWFC-7 on 28 October 2019: More than a thousand government officials, scientists, practitioners, the private sector and civil society from 37 countries, and by UN agencies and other international and regional organizations attended the conference.

Recognizing the achievement of policy makers and politicians

In 2019, the Regional Fire Management Resource Centers serving the Global Wildland Fire Network/GWFN launched the Global Landscape Fire Award. The award is a non-monetary prize presented to policy makers (individuals or institutions) in recognizing "Successful Achievements in Reducing the Adverse Impacts of Landscape Fires on the Environment and Humanity and the Promotion of Sustainable and Safe Application of Fire in Land Use and Ecosystem Management". The first laureate was Dr. Ir. Siti Nurbaya, Minister for Environment and Forestry, Republic of Indonesia. In a letter directed to the President of the Republic of Indonesia, the Secretariat of the GWFN referred to the goals and commitments imposed by the Paris Agreement of 2015 and underscored that the Minister for Environment and Forestry has demonstrated to the international community that the Republic of Indonesia is on the right way to reduce the unnecessary, excessive and illegal of fire in land use and land-use change.

Figure 17 – The 2019 plaque of the Global Landscape Fire Award.

Progress in international interaction – major players

The Sendai Framework for Disaster Risk Reduction 2015-2030 provides guidance and opportunities for collective action to address the increasing risks of society and environment to become affected by disasters including wildfire disasters. As stated in the introduction, many actors – including those who did not explicitly work along with or through the International Wildland Fire Conferences – have achieved significant progress in fire science and technology development. This paper cannot list all activities of actors in countries or regions, regardless of explicit reference to the IWFCs or the Global Wildland Fire Network. The readers are referred to the regional reports or statements and the concluding summaries of the IWFCs 1989-2019 documented in the IWFC website (GFMC, 2019a). Among the initiatives and tools, which have not been mentioned above or in the IWFC website, the following activities merit to demonstrate progress:

The Global Observations of Forest and Land Cover Dynamics/GOFC/GOLD project

GOFC/GOLD is a project of the Global Terrestrial Observing System/GTOS program, sponsored by the Integrated Global Observing Strategy/IGOS. The main goal of GOFC/GOLD is

to provide a forum for international information exchange, observation and data coordination, and a framework for establishing the necessary long-term monitoring systems. The GOFC/GOLD-Fire Mapping and Monitoring Theme seeks to refine and articulate the international observation requirements and encourage the best possible use of fire products from existing and future satellite observing systems, for fire management, policy decision-making and global change research (GOFC-GOLD, 2019). The main objectives of Fire Implementation Team/Fire-IT are – inter alia – to encourage:

- Encourage the development of an operational global geostationary fire network providing observations of active fires in near real time;
- Encourage the development of operational polar orbiters with fire monitoring capability by providing (i) operational moderate resolution long-term global fire products to meet user requirements and distributed ground stations providing enhanced regional products; and (ii) operational high resolution data acquisition allowing fire monitoring and post-fire assessments;
- Encourage the creation of emissions product suites, developed and implemented providing annual and near real-time emissions estimates with available input data.

Currently, the GOFC Fire-IT is working with the Global Wildfire Information System/GWIS team to enhance global fire research and products (see below).

Global fire monitoring and early warning portals

The information portals have made considerable progress in providing real-time and near-real time Earth Observation data required for monitoring active landscape fires and fire effects (area burned, fire emissions) and meteorological data for modelling fire danger, such as the:

- The Fire Information for Resource Management System/FIRMS distributes Near Real-Time/NRT active fire data within 3 hours of satellite observation from both the Moderate Resolution Imaging Spectroradiometer/MODIS and the Visible Infrared Imaging Radiometer Suite/VIIRS. The active fire data can be viewed in FIRMS Fire Map or in NASA's Worldview, delivered as email alerts or downloaded in a suite of different formats (NASA, 2019a,b);
- The European Forest Fire Information System/EFFIS – a modular web geographic information system that provides near real-time and historical information on forest fires and forest fire regimes in the European, Middle Eastern and North African regions. Since 1998, EFFIS is supported by a network of experts from the countries in what is called the Expert Group on Forest Fires, which is registered under the Secretariat General of the European Commission. Currently, this group consists of experts from 43 countries in European, Middle East and North African countries (European Commission, 2019a);
- The Global Wildfire Information System/GWIS – a joint initiative of the GEO and the Copernicus Work Programs. GWIS builds on the ongoing activities of the EFFIS, the GTOS/GOFC-GOLD Fire Implementation Team, and the associated Regional Networks, complementing existing activities that are ongoing around the world with respect to wildfire information gathering (European Commission, 2019b);
- The Global Fire Early Warning System/Global Fire EWS provides 1-10 day forecasted Fire Weather Index/FWI System data, based on the Canadian Meteorological Centre's/CMC Global Deterministic Forecast System/GDPS. (Canadian Forest Service, 2019);
- The Global Fire Assimilation System/GFAS of the Copernicus Atmosphere Monitoring Service/CAMS assimilates fire radiative power (FRP) observations from satellite-based sensors to produce daily estimates of biomass burning emissions. FRP observations currently assimilated in GFAS are the NASA Terra MODIS and Aqua MODIS active fire products. GFAS data includes Fire Radiative Power/FRP, dry matter burnt and biomass burning emissions (ECMWF, 2019);
- The Global Fire Emissions Database/GFED combines satellite information on fire activity and vegetation productivity to

estimate gridded monthly-burned area and fire emissions, as well as scalars to calculate higher temporal resolution emissions. Most of the resulting datasets are downloadable from this website for use in large-scale atmospheric and biogeochemical studies. The current version 4 has a spatial resolution of 0.25 degrees and is available from 1997 onwards (GFED, 2019).

Cross-boundary cooperation in fire management

On the operational level of cross-boundary cooperation in fire management progress has been made in the coalition of North American-Australasian partners, in Europe, South America as well by other international or multilateral initiatives. To mention a few examples:

- The extreme fire season of 2000 in the United States of America prompted the U.S.A., Australia and New Zealand to develop International Arrangements on the Sharing of Wildland Fire Suppression Resources between these three countries (U.S. Forest Service, 2003). Since then, these cooperative efforts have been expanded, and exchange of personnel during wildfire crises has been proven effective and helpful;
- In the European Union, the Union Civil Protection Mechanism (UCPM) aims to strengthen cooperation between the EU Member States, six Participating States and the UK during the transition period, in the field of civil protection, with a view to improve prevention, preparedness and response to disasters. When the scale of an emergency overwhelms the response capabilities of a country, it can request assistance via the Mechanism. Through the Mechanism, the European Commission plays a key role in coordinating the response to disasters in Europe and beyond and contributes to at least 75% of the transport and/or operational costs of deployments (European Commission, 2019c);
- Along with the UCPM the European Commission has been funding research in the field of forest fires over the last two decades through its Framework Programmes and other funding instruments. About 60 research projects, from large-scale integrated projects to more traditional projects or Marie Skłodowska-Curie individual fellowships, received a total EU contribution of more than EUR 100 million (European Commission, 2018);
- In 1987, the Member States of the Council of Europe created the European and Mediterranean Major Hazards Agreement (EUR-OPA) as a platform for cooperation between European and Southern Mediterranean countries in the field of major natural and technological disasters. The field of action covers the knowledge of hazards, risk prevention, risk management, post-crisis analysis and rehabilitation. Since 2007, the theme of institutional capacity building in landscape fire management and policy development is addressed through the GFMC, the Regional Fire Monitoring Centers and the Eurasia Team of Specialists in Landscape Fire Management (ETSLFM). The ETSLFM constitutes an advisory group to the 47 member States of the Council of Europe and the Organization for Security and Cooperation in Europe (OSCE), with a focus on Eastern Europe, Caucasus and Central Asia. Activities include research and development work targeting capacity building and delivering problem-oriented products and solutions in:
  - Science and technology transfer in landscape fire management under different cultural, socio-economic and ecological environments;
  - People-centered (participatory) fire management;
  - Development of national policies and implementation strategies in landscape fire management;
  - Development of standards and training for enhancing interoperability in cross-boundary cooperation in fire management.

  The outreach work of the EUR-OPA Agreement in support of national and regional dialogue in fire management and the development of landscape fire management policies is documented online (GFMC, 2019c);
- In 2006, the involvement of the Organization for Security and Cooperation in Europe/ OSCE and the Environment and Security

Initiative (ENVSEC) in the field of landscape fire management was initiated by the OSCE-led Environmental Assessment Mission to fire-affected territories in and around the Nagorno-Karabakh region, followed by the Joint OSCE/UNEP Environmental Assessment Mission to Georgia in 2008. Both assessments showed that the damage caused by wildfires in the South Caucasus were partially attributed to the absence of effective forest fire management systems. To assist the South Caucasus countries in enhancing their fire management capacities, the OSCE within the framework of the ENVSEC Initiative launched in 2009 the project "Enhancing National Capacities on Fire Management and Wildfire Disaster Risk Reduction in the South Caucasus". The project was conducted in partnership with the Global Fire Monitoring Center (GFMC) and first focused on national and regional trainings within the UNISDR Regional Southeast Europe/Caucasus Wildland Fire Network. In the second phase, forest fire vulnerability assessments were conducted in all three countries and at regional level seminars and regional trainings were held in Antalya, Turkey in 2010 and 2015, with the participation of the South Caucasus countries, the Western Balkan and the near East. In the third phase, the project has been focusing on developing and implementing national fire management policies in the countries of the region. The last activity in the South Caucasus was the OSCE support for the development of a Regional Fire Danger Rating System and organization of regional trainings. In Eastern Europe, the OSCE and GFMC supported the development of policies and fire management capabilities on terrain contaminated by radioactivity in Ukraine and Belarus in the frame of the project "Improving Radiological and Environmental Awareness in Territories affected by the Chernobyl Accident in Belarus and Ukraine with a Focus on Wildfire Management". With the assistance of the Regional Eastern Europe Fire Monitoring Center (REEFMRC), which had been set up by the GFMC with financial support of the Council of Europe in 2013, management procedures, guidelines and training materials have been developed. In Central Asia, the OSCE through GFMC supported the establishment of the Fire Management Resource Center – Central Asia Region (FMRC-CAR) in Ulaanbaatar, Mongolia. With the 2014 OSCE Ministerial Council Decision 6/14 "Enhancing Disaster Risk Reduction", the OSCE Executive Structures and the OSCE Office of Economic and Environmental Activities (OCEEA) were tasked with DRR with emphasis on exchange of knowledge and experience in fire management;

- In following-up the fire emergency of 2017 in Chile and neighboring South American, the National Forest Corporation of Chile (Corporación Nacional Forestal – CONAF) and GFMC convened the Second Regional Symposium and Consultation on Cross-boundary Cooperation in Fire Management in South America in Viña del Mar, Chile. The Consultation was attended by delegates of organizations and agencies of Argentina, Bolivia, Brazil, Chile, Ecuador, Paraguay, Peru, Uruguay and Venezuela. The consultation reviewed existing rules and agreements on cross-boundary cooperation in fire management, including bilateral and multilateral cooperation during wildfire emergencies and developed a proposal for developing a set of guidelines, SOPs and protocols for joint capacity building and enhancement of interoperability in the preparedness of border-crossing cooperation during fire emergencies. The participants of the consultation released the "Declaración de Viña del Mar 2017 on Cross-Boundary Cooperation in Fire Management in South America". The Declaration is the basic document to develop an Addendum and a Manual of Procedures for International Cross-border Cooperation for Enhancing Preparedness for Managing Wildfire Emergencies in the Region, for its presentation on the part of the Chancelleries of the countries of the Region to the Union of South American Nations (UNASUR) (GFMC, 2017b). The 7th IWFC in Campo Grande conference provides an opportunity to further discuss a regional activity and agreement under the umbrella of the Amazon Cooperation Treaty Organization (ACTO);

- In line with the recommendations of the Viña del Mar process, the Regional Fire Management Resource Center – South America Region (RFMRC-SAR) was established in Gurupí, Brazil (CEMAF, 2019). The 7th Regional Center will serve Eastern Africa: The Regional Eastern Africa Fire Management Resource Center (REAFMRC) was established in Antananarivo, Madagascar, in 2020. The 8th Regional Center will serve the Western region of Subsahara Africa: The Regional Western Africa Fire Management Resource Center (RWAFMRC) was established in Kumasi, Ghana, in 2021;
- The International Fire Aviation Working Group (IFAWG) comprises representatives from countries and jurisdictions who regularly utilize aerial means in managing landscape fire, including for firefighting. The IFAWG operates as an advisory group of the United Nations International Strategy for Disaster Reduction. The group aims to improve the safety and effectiveness of aerial means by sharing information, experience and resources. IFAWG advanced its activities. Since December 2014, the International Fire Aviation Guidelines and the International Manual of Common Rules for Fire Aviation had been published and were open for review and comments. IFAWG opens a promising initiative to increase interoperability in aerial firefighting among international actors (IFAWG, 2019).

The Sendai Framework for disaster risk reduction 2015-2030

The Sendai Framework recognizes that the State has the primary responsibility to reduce disaster risk, but it also underlines the shared responsibility of other stakeholders including local government, the private sector, academia and civil society. UNDRR has been tasked to support the implementation, follow-up and review of the Sendai Framework. The Sendai Voluntary Commitments (SVC) initiative, was developed in response to the General Assembly resolution 68/211 (2013) and launched in the lead-up to the World Conference for Disaster Risk Reduction (WCDRR) in March 2015 to support the development of partnerships at all levels to implement the Sendai framework. The modalities of the SVCs were further elaborated by the General Assembly resolution 69/283 (2015): "Commitments by relevant stakeholders are important in order to identify modalities of cooperation and to implement the present Framework. Those commitments should be specific and time-bound in order to support the development of partnerships at local, national, regional and global levels and the implementation of local and national disaster risk reduction strategies and plans. All stakeholders are encouraged to publicize their commitments and their fulfilment in support of the implementation of the present Framework, or of the national and local disaster risk management plans, through the website of the United Nations Office for Disaster Risk Reduction." In 2018, the GFMC has registered the International Wildfire Preparedness Mechanism (IWPM) as a thematic contribution with emphasis on addressing the Sustainable Development Goals (SDG) 13 (Climate Action) and 15 (Life on Land) (UNDRR, 2019).

From Campo Grande to Portugal 2023

As was highlighted in the 30-years journey from Boston to Campo Grande, there is progress in building fire management capacities – including IFM capacities – throughout the world. However, there are also economic and political obstacles, which – in the figurative sense – do not always allow osmotic exchange of advanced fire and related sciences through the often semi- or non-permeable membranes separating the communities of scientists, policy makers and practitioners. Politics in many countries and of international organizations do not recognize the alarming signals of the Pyrocene (Pyne, 2015).

This is why the theme and the expected outcomes of the Campo Grande conference are critical for developing fire management options in a changing world. The experiences of IFM approaches presented by countries contributing to the conferences are encouraging, e.g.:

- **Brazil:** Parliamentary discussion on the development for a National Integrated Fire Management Policy (Brazil, 2018);
- **Portugal:** Establishment of the Agency for the Integrated Management of Rural Fires (AGIF) based on the Integrated System of Rural Fire Management (SGIFR) (Portuguese Republic, 2018);

- **Greece:** Development of a strategy "Future Management of Landscape Fires in Greece" – the recommendations of an Independent Committee tasked to Analyse the Underlying Causes and Explore the Perspectives for the Future Management of Landscape Fires in Greece" (GFMC, 2019f; Xanthopoulos *et al*., 2019);
- **South Africa:** LANDWORKS – An initiative in Southern Africa implementing ecology-driven, community-centric solutions to distressed environments, working with people in their environment to sustainably rehabilitate and generate natural ecosystems disrupted by fire, flooding, agriculture, mining and misuse (LANDWORKS, 2019);
- **Ecuador:** Establishment of a National Committee for Integrated Fire Management of Ecuador (Comité Nacional de Manejo Integral del Fuego el Ecuador – CONAMIF), tasked to develop a National Strategy for Integrated Fire Management (MAAE, 2020);
- **Ukraine:** Launch of the preparation of a State Strategy for the development of a National Landscape Fire Management System in support of the Parliament of Ukraine (Verkhovna Rada) (MENR, 2020).

Conclusions and Outlook

Looking back to thirty years between the first and the 7th IWFC in Campo Grande, I conclude that the process of preparing and following up the conferences provided opportunities for the cultivation of a global dialogue, for fostering international cooperation and inspiring new approaches in fire management. Paradigms in fire management have adjusted to the rapidly evolving changes of climate, environment and society. Technological innovations, reflections on traditional practices and newly arising concepts of ecosystem-based approaches in fire management are evolving. Nations and international organizations have recognized the need for addressing fire management solutions by cross-sectoral, transversal and cooperative approaches in landscape fire management by observing (GFMC, 2019f):

- **Scholarliness, Transdisciplinarity and Innovation:** Policy and strategic planning and relevant decision-making shall be based on sound scientific knowledge and considering technological capabilities and innovation;
- **Holisticness, Integration and Inclusion:** Policy development and strategic planning shall be holistic, i.e. address the fire problem at landscape level by including all relevant institutional mandates and the potential and capacity of contribution of civil society;
- **Coherence:** The mandates and activities in fire management of State institutions and other stakeholders shall be coherent (harmonized) and meet the overarching national fire management policy and implementation plan;
- **Cohesiveness:** National Fire Management Plans shall be considered cohesive (obligatory) for individual institutional/ sectoral planning and activities;
- **Coordination:** The implementation of actions under a National Fire Management Plan shall be monitored in a permanent basis and highly coordinated by all stakeholders.

In conclusion and looking forward: In the figurative sense, during a time-period of thirty years key actors in fire management have been trying to balance two prevailing paradigms: The grey versus the green approach. In accordance with the Disaster Risk Reduction philosophy, for instance in water and flood management, "grey infrastructure" includes the technical and technological means to prevent flooding (building of grey concrete dams and other), whereas the "green infrastructure" favors the inclusion of ecosystem services. Nature-based solutions integrate functioning ecosystem services that are able to buffer extreme precipitation events, which may reduce the risk and probability of flooding. In analogy, the "grey approach" in fire management focusses on responsive and technical solutions for fighting wildfires. The "green approach" in Integrated Fire Management aims at addressing the underlying causes of wildfire vulnerability and risks, and advance the knowledge and application of the ecologically and environmentally benign role of natural fire in fire-dependent ecosystems, and sustainable application of fire in land-use systems. The ultimate goal of the "green approach" is to create fire-resilient natural, cultural and urban-industrial landscapes based on principles of Integrated Fire Management.

Proposal for Action: Towards Development of a Voluntary International Instrument

Recent observations reveal that climate change and socio-economic developments are changing fire regimes globally. This trend is associated with an increasing vulnerability of society and the environment to wildfires as well as to excessive application of fire in land use and land-use changes (Goldammer, 2013; IUFRO, 2018; E-STAG, 2020). It is timely to revisit earlier attempts of developing a global agreement on landscape fire management, e.g. the outcomes and the implementation of the recommendations of the UNECE/FAO Regional Forum on Cross-boundary Cooperation in Fire Management (GFMC, 2013b), the recommendations of IWFC-6 (GFMC, 2015b, c) and the conclusions of IWFC-7 as laid down in the Campo Grande Statement:

> *The integrated cross-sectoral approach … supports the Sustainable Development Goals, the goals of the Paris Agreement and the Sendai Framework for Disaster Risk Reduction 2015-2030.* ***This approach would be further strengthened by an appropriate United Nations instrument.***

Earlier attempts to develop a formal international instrument, as described in this review, could not be realized. Tentative explanation: The time was not yet ready for a global agreement, as the theme was not considered a priority. Most important, however, was the prevailing political reluctance for developing an instrument that would have a legally binding character, such as the failed endeavours to develop an "International Wildland Fire Accord" or the "Fire Management Code" (cf. above).

Several arguments, however, speak for reloading the discussion for the development of an international instrument:

- First, the increasing environmental and socio-economic problems resulting from wildfires and excessive application of fire in land use and land-use change have entered public and political perception, particularly since 2018;
- Second, three decades of international cooperative work in landscape fire science and landscape fire management provide accumulated experiences from the diverse ecological and cultural regions of the world;
- Third, voluntary international instruments have proven effective.

This review has highlighted several voluntary thematic and related initiatives, e.g.

- The Regional Fire Monitoring Centers/Regional Fire Management Resource Centers: These Centers are based in academic institutions and represent an independent epistemic community available to support the development of fire management policies and decision-making – living examples of knowledge transfer at the Science-Policy-Practitioners Interface (SPPI);
- The International Wildfire Preparedness Mechanism (IWPM), which offers a platform from which improved knowledge, good practice, experience and capacity building is cascaded throughout the global wildfire community by international exchange (based on voluntary offers and requests);
- The International Fire Aviation Working Group (IFAWG) and its International Fire Aviation Guidelines;
- The International Search and Rescue Advisory Group (INSARAG) and its Guidelines.

After the UN International Decade for Natural Hazard Reduction (IDNDR) in the 1990s, the UNISDR Inter-Agency Task Force on Disaster Reduction (IATF) established four Working Groups, one of which addressed the theme of fire management:

- Working Group 1: Climate and Disasters (Chair: WMO);
- Working Group 2: Early Warning (Chair: UNEP);
- Working Group 3: Risk, Vulnerability and Disaster Impact Assessment (Chair: UNDP);
- Working Group 4: Wildland Fire (Chair: GFMC).

The Global Wildland Fire Network (GWFN) and the Wildland Fire Advisory Group, which emerged from Working Group 4, took advantage of the cross-sectoral and transdisciplinary nature of the UNISDR system and the Global Platforms for Disaster Risk Reduction. In the frame of

the "Hyogo Framework for Action/HFA 2005-2015: Building the Resilience of Nations and Communities to Disasters" the GWFN provided substantial support to countries and regions to develop fire management policies and capabilities through sharing knowledge and resources. This work is continuing under its successor instrument, the "Sendai Framework for Disaster Risk Reduction 2015-2030" (Sendai Framework). The Sendai Framework is the first major voluntary, non-binding agreement of the post-2015 development agenda and provides Member States with concrete actions to protect development gains from the risk of disaster. The Sendai Framework works hand in hand with the other 2030 Agenda agreements, including The Paris Agreement on Climate Change, The Addis Ababa Action Agenda on Financing for Development, the New Urban Agenda, and ultimately the Sustainable Development Goals. Following the 2015 Third UN World Conference on Disaster Risk Reduction (WCDRR) the Sendai Framework, endorsed by the UN General Assembly, advocates for:

> *The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.*

The UN Office for Disaster Risk Reduction (UNDRR) supports the implementation of the strategic goals of the Sendai Framework. As an international voluntary framework for disaster risk reduction, the Sendai Framework provides a unifying global platform to address environmental and humanitarian problems arising from global change in a cross-sectoral and transdisciplinary approach.

The so-called Voluntary Commitments/ SVCs to the Sendai Framework already provide an opportunity for thematic initiatives to become recognized as implementing partners (UNDRR, 2015). The SVC Initiative was developed in response to the General Assembly Resolution 68/211 (2013) and launched in the lead-up to the World Conference for Disaster Risk Reduction/WCDRR in March 2015 to support the development of partnerships at all levels to implement the Sendai Framework. The modalities of the SVC's follow-up were further elaborated by the UN General Assembly Resolution 69/283 (2015):

> *Commitments by relevant stakeholders are important in order to identify modalities of cooperation and to implement the present Framework. Those commitments should be specific and time-bound in order to support the development of partnerships at local, national, regional and global levels and the implementation of local and national disaster risk reduction strategies and plans.*

To respond to the request from the General Assembly Resolution, UNDRR has established an online platform as a mechanism to mobilize, monitor and take stock of commitments from multi-stakeholders for the implementation of the Sendai Framework until 2030 (UNDRR, 2015). The International Wildfire Preparedness Mechanism (IWPM) has been recognized as one of the first SVCs (UNDRR, 2019).

As many of the current voluntary arrangements on international cooperation in landscape fire management have matured and proven successful under the patronage of the UNISDR, it is now timely enlarge the scope and participation of countries, organizations and institutions in a global agenda. Therefore, it is proposed to create a voluntary International Landscape Fire Management Framework under the patronage of the UNISDR/UNDRR as an enlarged voluntary contribution to the implementation of the Sendai Framework.

The objectives of the framework could follow the overall principles laid down in the mission statement of the UNISDR Global Wildland Fire Network as quoted above:

- Reduce the negative impacts of landscape fires on the environment and humanity;
- Advance the knowledge and application of the ecologically and environmentally benign role of natural fire in fire-dependent ecosystems, and sustainable application of fire in land-use systems.

Specifically, the recommendations of the 6th and 7th International Wildland Fire Conferences would provide guidance for furthering the development of informed policies. The recommendations refer to application and approaches, which offer solutions for fire management in the context of sustainable land management and climate change mitigation as well as the creation of sustainable and fire-resilient landscapes and society.

The proposed International Landscape Fire Management Framework would provide an enlarged international platform for exchanging information, data, knowledge and expertise in landscape fire management in which – in addition to the already existing voluntary networks and mechanisms – governments, multilateral and international organizations and agencies would be invited to participate as well as stakeholders of civil society.

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Achievements, Challenges and Experiences of Mexican Women in Wildland Fire Management

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ABSTRACT – In Mexico, the participation of women in paid positions is still far below that of men due to many factors such as discrimination in hiring practices, compensations, opportunity and promotion; inflexible work requirements; insufficient services such as childcare, as well as inadequate distribution of family tasks at home, among others. In the forestry sector, this is further accentuated, particularly in the area of wildfire protection and ecosystem fire management. Faced with this situation, government, academic and civil society organizations in Mexico and the United States have made an effort to strengthen the technical and leadership capacities of women in Mexico and Latin America to promote their inclusion. This path has challenges, but it has been possible to improve visibility of women working on fire issues, to provide an opportunity for training on the subject, to generate a space for reflection and exchange of knowledge and experiences for women in Mexico and Latin America, and expand the network of women working on fire in the region. One of the main obstacles identified in this analysis continues to be the retention and promotion of the women who were initially trained. Remaining institutional, cultural and budgetary challenges have limited further progress. The objective of this document is to describe the advances and challenges that have been identified for women in fire management in Mexico.

Keywords: Training; gender; capacity building; women in fire; official and community crews.

As Conquistas, os Desafios e as Experiências das Mulheres Mexicanas no Manejo do Fogo

RESUMO – A participação das mulheres em trabalhos remunerados no México continua sendo menor que a participação dos homens, devido a fatores como a discriminação nas práticas de contratação, remuneração, mobilidade e promoção, condições de trabalho inflexíveis, disponibilidade insuficiente de serviços, como creches, e distribuição inadequada das tarefas familiares em casa, dentre outros. No setor florestal isso se acentua ainda mais, particularmente na área de proteção contra incêndios florestais e manejo do fogo nos ecossistemas. Diante dessa situação, organizações governamentais, acadêmicas e da sociedade civil do México e dos Estados Unidos vêm se empenhando em fortalecer as capacidades técnicas e de liderança das mulheres no México e na América Latina para promover sua inclusão. Esse caminho tem desafios; entretanto, tem sido possível melhorar a visibilidade das mulheres que trabalham em temas relacionados aos incêndios e oferecer oportunidades de capacitação no tema, gerar espaços de reflexão e intercâmbio de conhecimentos e experiências para as mulheres do México e da América Latina, ampliando a rede de mulheres que trabalham com fogo na região. Um dos principais obstáculos identificados nas análises continua sendo a permanência e promoção das mulheres que foram inicialmente treinadas. Os desafios institucionais, culturais e orçamentários que persistem têm limitado os avanços. O objetivo deste documento é descrever os progressos e desafios identificados para as mulheres no manejo do fogo no México.

Palavras-chave: Treinamento; gênero; capacitação; mulheres no fogo; equipes oficiais e da comunidade.

Manejo del Fuego Forestal: Logros, Retos y Experiencias de Mujeres Mexicanas

RESUMEN – En México, la participación de mujeres en el trabajo remunerado sigue siendo muy por debajo a la participación de los hombres, debido a factores como la discriminación en las prácticas de contratación, remuneración, movilidad y ascenso, condiciones de trabajo inflexibles, insuficiencia de servicios, como guarderías y la distribución inadecuada de las tareas familiares en el hogar entre otros. En el sector forestal, esto se acentúa aún más, particularmente en el área de protección contra incendios forestales y la gestión de éstos. Ante esta situación, organizaciones gubernamentales, académicas y de la sociedad civil de México y Estados Unidos han hecho un esfuerzo por fortalecer las capacidades técnicas y de liderazgo de las mujeres en México y América Latina para promover su inclusión. Este camino tiene desafíos, pero ha sido posible mejorar la visibilidad de las mujeres que trabajan en temas de incendios para brindar una oportunidad de capacitación en el tema, generar un espacio de reflexión e intercambio de conocimientos y experiencias para las mujeres de México y América Latina, y ampliar la red de mujeres que trabajan en el fuego en la región. Uno de los principales obstáculos identificados en este análisis sigue siendo la retención y promoción de las mujeres inicialmente capacitadas. Los desafíos institucionales, culturales y presupuestarios que persisten han limitado los avances. El objetivo de este documento, es describir los avances y desafíos que se han identificado para las mujeres en el manejo del fuego en México.

Palabras clave: Capacitación; género; creación de capacidades; mujeres en el fuego; equipos oficiales y comunitarios.

Introduction

There are several concepts of fire management that define it as part of ecosystem management (Christensen *et al.*, 1996; Jardel *et al.*, 2008). In Mexico, as in most countries of the world, wildfire suppression has been a focal response. However, in the last 12 years, the National Forestry Commission (CONAFOR) has implemented the conceptualization of fire as a component of some forest ecosystems and has carried out activities focused on fire management, with a new definition, where fire is considered as a factor that ecologically affects or favors different types of ecosystems (CONAFOR, 2019). In addition to the change in government policy by institutions managing forests and natural protected areas, the scientific community, civil associations and indigenous communities identify fire as an essential part of maintaining some ecosystems and therefore necessary for the survival of some species (Jardel *et al.*, 2010).

According to Jardel (2009), fire management consists of a series of technical, institutional, and communication interventions that are planned to: 1) maintain or restore the fire regime of a given management unit (which may be a protected area); 2) use fire as a tool to control the structure and composition of vegetation and fuel loads as part of forestry, habitat management, grassland management, or agriculture; and 3) prevent, mitigate, or remediate the negative environmental impacts of forest fires (Jardel *et al.*, 2010).

CONAFOR is the official government institution in Mexico that is responsible for addressing all forest issues, including wildfire. However, other government institutions such as the National Commission of Natural Protected Areas (CONANP) and the state governments are also mandated to prevent, combat and communicate fire management activities. In addition to the work carried out by government institutions, there are civil organizations that work to conserve natural resources and biodiversity in Mexico.

Recent research has documented and identified the various components of fire management specifically for Mexico (Martinez *et al.*, 2018), where the complexity of the country's socioecosystemic structure suggests a restructuring of this concept to achieve greater success and acceptance among the actors involved in fire management. These actors are government institutions at all levels of government, ejido and/or communal authorities (uses and customs of indigenous peoples), civil society, academic institutions, communicators, ecologists, etc.

In Mexico and Latin America, the paradigm has shifted from suppression to a new vision, which integrates the diverse actors and factors of fire occurrence in part of the ecosystems; and allows better attention to and management of wildfires. Fire management, including prevention, planning, restoration, research and information has opened the doors to women and men with diverse profiles, areas of knowledge, and experience.

The new concept of fire management has given rise to professionals from various areas and profiles, with useful and timely knowledge. Within the range of activities and actions, spaces have been opened for women who, historically, had been relegated or not considered with equal employment opportunities in the fire sector.

Although fire management is still considered to be mostly managed by men, in recent years (2017-2020), the United States Forest Service-International Programs (USFS-IP); federal and state government institutions (CONANP and CONAFOR and the Jalisco Ministry of Environment and Territorial Development (SEMADET)); academia, including the Institute for Research on Ecosystems and Sustainability of the National Autonomous University of Mexico (IIES-UNAM); and civil society, particularly the Mexican Fund for the Conservation of Nature, A.C. (FMCN) and Alternare A.C.; have become involved in strengthening the capacities and training of women in fire management in Latin America. These efforts have fostered visibility for the activities, achievements, and challenges that women working in this field have faced throughout their professional careers.

The objective of this document is to describe the advances and challenges that have been identified for women in fire management in Mexico. It presents a critical path of the various actions and activities that have been carried out from the perspective of inclusion and diversity for activities carried out by women. It is important to mention that this report of experiences does not seek to divide fire management teams, but rather to analyze factors that contribute to minimize the training gap and increase opportunities for participation of women and other minorities in this area, in order to achieve inclusive teams. Likewise, the areas of opportunity and challenges that women have for participation of fire management, under the current conditions of the country, are analyzed.

Methods

A review and analysis of data from technical reports, research project results, press releases, and projects financed by various government, academic, and civil organizations was carried out. The goal was to identify the main activities carried out, such as courses, workshops, exchange of experiences and training that have taken place in Mexico. Specific activities that promoted the inclusion and participation of women in fire management in Mexico for the period 2008-2019 were identified.

A virtual survey was conducted, aiming Latin American women who have participated in activities coordinated by CONAFOR, the United States Forest Service – International Programs, the Mexican Fund for the Conservation of Nature A.C. and the Ecology Laboratory for the management of forest resources of the IIES-UNAM, between 2017-2019. The survey was conducted via GoogleForm, with 28 questions, which addressed three main aspects: the characteristics of the group surveyed, activities carried out in forest fire management in Mexico and the permanence in the fire management program of the participants.

The last stage of information analysis describe the process implemented by various government, academic and civil organizations in Mexico to include women in fire management. It describes the achievements and challenges faced by women who are working on fire management. It presents a summary of activities and processes that have been carried out to strengthen the training and permanence of women in fire management.

Results and Discussion

Mexico has made progress in the design of legal instruments and public policies on gender equality, as well as in the signing of international commitments related to this matter, the environment, and climate change. Since 2001, institutions and programs have been created such as the Directorate of Gender Equality and the program Towards Gender Equality and Environmental Sustainability; General Law for Equality between Women and Men (2006) and a mandate to include gender considerations in the Federation's Expenditure Budget (2007). The National Development Plan 2013-2018 called for the mainstreaming of the gender perspective in all sectoral, institutional, regional and special programs. Following this recognition of women's participation and their role in the access, use, management and control of natural resources, Mexico set the goal of incorporating the gender perspective throughout the environmental sector.

However, the goal of incorporated gender perspective has not been easy to operate. Historically, firefighting and fire management has been an area which women have had very little access or opportunity. Numbers show that the participation of women in this area still does not reach even 5%. In 2017 in Mexico, there were 1,731 forest fire fighters, of which only 58 were women (3.3%) and almost all of them performed office work; in 2020 CONAFOR has 1,740 fighters and 73 are women (4%).

The State Government of Jalisco, Mexico, since 2008, has made collaboration agreements with Alberta Canada, to deploy firefighters to Canada during the critical part of the fire season. It is recorded that during the first deployment in 2008, three women participated; who were the first Mexican firefighters certified to fight forest fires in Canada (SEMADET Archives, 2020). From that year on, women's participation in direct firefighting activities became evident.

After updating Mexican Standard NMX-R-025-SCFI-2015, which seeks to recognize workplaces that demonstrate the adoption and compliance with processes and practices in favor of labor equality and non-discrimination, CONAFOR was the first institution in the environmental sector to be certified in November 2016 and made progress in establishing selection processes with equal opportunities, spaces for breastfeeding, agreements with daycare centers, flexible schedules and paternity leave, among others.

Another result of this certification was the formation of a brigade of 13 women within the National Fire Management Office of CONAFOR at the end of 2016. They were trained in basic firefighting and fire management issues, but their tasks were mainly limited to office and/or dispatch activities. Although this group of women continued to carry out activities related to fire management, there is no record of the permanence of this first brigade.

Around the same time, the United States Forest Service, CONAFOR and the Mexican Fund for the Conservation of Nature held the first workshop-exchange in Tucson with women from Latin America working on forest fire issues. The collaborating institutions have more than two decades of international technical cooperation to strengthen national and local capacities in Mexico for the protection of forest fires. They noted the historically low participation of women in trainings, and recognized the challenges faced by women firefighters in the United States. CONAFOR had special interest after the recent certification in the Standard on Labor Equality and Non-Discrimination.

Through this international collaboration between Mexico and the United States, three *Women in Fire Management* exchanges have been held to date in Tucson, Arizona (2017, 2018 and 2019). A total of 61 women participated in these exchanges, 34 from Mexico and 27 from other Latin American countries. The objective of these meetings has been to promote the application of new tools and knowledge about fire management, identify leadership tools to strengthen the role of women in fire management, describe concepts of fire management, including prevention, fuel management and coordination between agencies, and strengthen the participation and leadership role of women.

Also, two specialized courses have been conducted, entitled: Followership to Leadership L-280 (Merida 2017 and Guadalajara 2019), specifically for women from Mexico and Latin America. A total of 47 women participated. These courses are part of the catalog of courses at the international level; they are an introduction to leadership for people who work on fire management. This course was written with male leadership perspective and examples. Content was not modified to be taught to women. This course should be restructured to make the content inclusive, to address examples of men and women who have historically been leaders in various issues and to consider gender equality issues for men and women that are applicable to fire management activities.

Parallel to the official training activities, during the year 2018, the IIES-UNAM, in coordination with the CONAFOR´s Michoacan State Office, Alternare A.C., FMCN and USFS-IP, carried out the first course for women in the State of Michoacán. Basic firefighting and Incident Command System 100-200 level courses were taught, with the participation of 25 women as students, five women and four male. Additional topics of gender equality, the role of women and research in fire management were included.

In 2019, these same institutions with support from SEMADET, carried out the first "Workshop-

Training for Women: Generating Field Capacities for Fire Management", with the objective to generate capacities not only for frontline firefighters, but also for diverse areas of management, planning, operations, logistics, research, and coordination, with a socio-ecosystemic perspective. Thirty-nine students and eight instructors (all women and four men of support) from various institutions and countries such as México, Colombia, Costa Rica and the United States participated. This workshop and training is not part of any official institutional course catalog and was designed according to the needs identified in previous activities with women in fire management.

In 2019, SEMADET, through a public call, formed the first brigade of women wildland firefighters in the state. The brigade includes 12 members who have a job security and adequate training for wildland fire response. In addition, USFS-IP supported a workshop to strengthen institutional best practices in gender equality to raise awareness among new female crew members, men and leaders of the institution they belong to.

Additional individual training opportunities have opened up. A total of five women have had the opportunity to join United States Forest Service brigades for periods ranging from two weeks to three months to develop their fire-line skills, to train for the design and implementation of prescribed burns (TREX Prescribed Fire Training Exchange) or to develop their leadership.

In order to follow up on all these activities and especially the women who have participated, some surveys and interviews have been conducted to identify changes after their participation. A key element on which almost all these women agree is that having the opportunity to be with other women facing similar challenges has resulted in an empowering experience. The participants have gained understanding to exercise their leadership skills and seek opportunities and mentors. This has allowed some to access new trainings and occupy new spaces. These meetings and trainings have also triggered the creation and expansion of a network of women in the region who work in fire. For this, the commitment of these women with other women has been key for strengthening capacities and skills; this they call 'sorority'.

Digital surveys conducted for this research obtained 26 responses from women who participated in the official activities (Workshops in Tucson, Arizona and the two L-280 courses in Mexico). The profiles of the participants were women between 24 and 54 years old. Respondents have three to 24 years of experience in fire management. They have academic training from high school to doctorate, with profiles in Forest Engineering and Biology, as well as Humanities. Currently, 18 women continue to work in the fire management sector, two women are unemployed and six more women are working on other activities that are not related to fire management.

Of the women who continue to work on fire management, 90% of those surveyed remain in the same job positions. Among the achievements recognized by the respondents, some specific issues are mentioned such as: 1) the modification of the current legislation, where the equal participation of women in all activities of daily life in Mexico is indicated, although it is recognized that it is far from being fulfilled; 2) commitment on the part of some governmental institutions to strengthen the abilities of women in the subject; 3) greater interest of women to participate in fire activities; 4) bonds of training and mutual aid among women have been strengthened; and 5) greater visibility of the diverse activities that women carry out within fire management. It is observed that there is a greater number of women wildland firefighters, but they are not counted because they do not belong to the official brigades, but rather to community and/or temporary brigades.

The main obstacles identified in Mexico for women in the area of forest fire management are (1) unattractive working conditions, mainly to be able to belong to the official brigades, since the job is inherited from father to son, (2) in Mexico there are temporary brigades, which are hired during some months of the year (3-6 months per year) and where there is no job security or continuity in the training, coaching and rehiring process; (3) there is still machismo on the part of some businessmen, who consider that it is an activity only for men due to the physical demands required for jobs; 4) lack of recognition of the role of women in the various areas of forest fire management; 5) labor inequality in the training processes (field activities) at the institutional levels and; 6) currently there are other areas of fire management that are more attractive to women than suppression.

As part of the International Conference-Wildfire 2019 in Campo Grande Brazil, a special session on the sub-theme 'the role of women in fire management' expanded the collaborative networks at the international level, with the participation and leadership of Mexican women, Latin American colleagues, and the United States Forest Service. This special session was attended by 46 women and five men, with the objective to give visibility to the role of women in fire and expanding opportunities for women's leadership development and networking by sharing the successes and challenges of current efforts in Latin America.

The comments and observations derived from this workshop focused on three main aspects:

1. Outreach and recruitment: raising awareness and understanding of the context of women and diversity in the fire management sector is important. There is machismo, where men do not allow women to work in a male environment. Around 85% of recruiters are men and may not like working with women, and end up hiring men. In indigenous areas, mixed brigades are not viable due to cultural issues (for example, being in a camp with men). It works to share examples of best practices in outreach and recruitment in local informal efforts such as volunteer and/or community brigades. In this context, women try to recruit and involve other women by sharing their experiences. Specifically, in Mexico, in the last three years, the number of women interested in working on fire issues has increased.

   Some recommendations to improve outreach and recruitment of women include work so that it is not a temporary position and that there is more job security; improve support for women, for example, flexibility for maternity since it is not easy to apply to a job that requires many hours away from the family and although this is the same for men, it is a reality that the tasks of the home and raising children fall on women, especially in Latin America; consider the multiple tasks of fire management, not just firefighting; make public the diversity of fire management activities; and conduct awareness campaigns in key locations where there are potential women candidates so that women know what the job is about and facilitate recruitment.

   Finally, make a great effort to position the issue of women's recruitment on the agenda of organizations and institutions and develop a strategy for it. Seeing the example of another woman is important, so it is worthwhile for women to do the outreach and recruitment. Setting a gender quota is important, because the obligatory nature and fulfillment of the regulations, for example in Mexico, makes it possible to break down paradigms.

2. Training and mentoring: we must begin to reflect on restructuring training towards fire management and not only suppression, that is, generate a paradigm shift where direct combat of forest fires, until today is the most important; we must promote mentoring in the context of women and diversity in the fire management sector, with physical training to develop the skills and abilities of men and women; conduct feedback at the end of fire seasons between men and women to encourage the exchange of knowledge and experiences learned in critical seasons, as well as to promote women's leadership in different management areas; recognize areas of opportunity that women may have in the subject and acknowledge that it is a process of training and inclusion in the areas of fire management; and encourage collaborative processes within the brigades and at the institutional level, of all minorities and gender diversities and form support networks among women for capacity building in various areas.

3. Retention policy: although this issue goes beyond the activities of a government institution, since it depends on various management processes such as budget allocation and fiscal year of government agencies, it is proposed that institutional policies related to women and diversity in the fire management sector be strengthened and promoted from the state and local governments. The cultural work environment, the attitude of the team, the opportunities for training and promotion are key to retention and should include, at least, maternity leave and the opportunity to rejoin after a maternity process. On the

other hand, it has been observed that, in indigenous communities, people living in fire-prone areas tend to be committed to work in the long term and although it is recognized that the willingness and interest in including women in fire management will vary depending on each place, institution and government, it could be strengthened and driven from federal government agencies.

Once the challenges faced by women in forest fire management in Mexico have been described, some institutional and social strengths have been identified in order to promote the process of women's participation in fire management. In particular, it is clear that the collaboration and sum of social and academic efforts have borne fruit, and this is reflected on the increased participation and visibility of women in the issue. It is important to emphasize that only with the sum of wills, the creation of support networks and knowledge exchanges, a real change of paradigm can be generated where only firefighting is considered a priority in fire management. Although there is no recipe that can provide the steps to reach a goal of equality and participation of women, men and gender minorities, it is recognized that the critical path of work that has been done in Mexico can serve as a guide for other countries in Latin America to strengthen and promote this issue.

Conclusions

It is recognized that Mexico is moving towards forest fire management, appropriate to the current conditions of the country. Government, academic and social institutions have carried out various activities to promote the participation and inclusion of women in fire management, from different management areas; however, it is still recognized that it is far from meeting international standards of inclusion and diversification of work.

The specific training for women seeks to close or reduce the gap in training, opportunity and permanence in the fire management program. Currently, the participation of women in fire management has been made visible through the dissemination of activities in which women participate. And considering the wide range of activities that involve fire management from a socio-ecosystemic perspective, which goes beyond fighting and suppressing forest fires.

One of the main obstacles identified in this analysis is the permanence and continuity of the women who were initially trained. There are no official statistics on the number of women who have been trained and who are currently engaged in other activities or are even unemployed.

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This document also serves as a recognition of all the peasant and indigenous women of Mexico who carry out fire management activities from a traditional perspective, in order to conserve their traditions and customs around fire.

Note

There is a Spanish version of this paper available at the website:

Hay una versión en español de este documento disponible en el sitio web:

https://usfs-public.app.box.com/s/p6zgzjx3xqnqzkoq1quzzdibtzukdym9

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Indigenous Knowledge and Disaster Risk Reduction

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ABSTRACT – This article attempts to shed light on challenges to native peoples use of indigenous knowledge to reduce risk and mitigate effects of natural hazards, including wildland fire, and calls attention to ways in which traditional practice, together with contemporary experience, may help indigenous peoples reduce vulnerability in their communities.

Keywords: Natural hazards; community resilience; racial and ethnic justice.

Conhecimento Indígena e Redução do Risco de Desastres

RESUMO – Este artigo busca lançar luz sobre os desafios que os povos nativos enfrentam ao usarem o conhecimento indígena para reduzir o risco e mitigar os efeitos dos riscos naturais, incluindo incêndios florestais, e chama a atenção para as formas em que a prática tradicional, assim como a experiência contemporânea, pode ajudar os povos indígenas a reduzir a vulnerabilidade em suas comunidades.

Palavras-chave: Riscos naturais; comunidade resiliente; justiça racial e étnica.

Conocimiento Indígena y Reducción del Riesgo de Desastres

RESUMEN – Este artículo intenta arrojar luz sobre los desafíos al uso de los conocimientos indígenas por parte de los pueblos indígenas para reducir el riesgo y mitigar los efectos de los peligros naturales, incluidos los incendios forestales, y llama la atención sobre las formas en que la práctica tradicional, junto con la experiencia contemporánea, pueden ayudar a los pueblos indígenas a reducir la vulnerabilidad en sus comunidades.

Palabras clave: Amenazas naturales; resiliencia comunitaria; justicia racial y étnica.

This time

There is a groundswell of change, an awakening or perhaps a reawakening of long-ignored issues of race and ethnicity that passionate, often youthful, voices insist must be addressed. Called to account, now, are privileged communities that have persisted in marginalizing indigenous people and others whose values and beliefs, whose culture and "worldview" is different from their own. Over time and at an increasing rate, the imposition of outside development is adversely affecting the environment of indigenous people, restricting traditional risk reduction practices and, at times, making indigenous knowledges irrelevant. Yet those traditional indigenous knowledges, values and cultures are, in themselves, important risk reduction tools and should be celebrated as such. The call for political and social change is echoing worldwide. Maybe this time change will be lasting.

What will this change look like and how deep will to go? And what should we hope will transpire between the 7th and the 8th International Wildland Fires Conferences?

From that introduction it may seem like a radical shift of topic to talk of risk reduction in indigenous communities. But the connection of these concerns to the vulnerability of indigenous

peoples to natural hazards is a good example of how complicated the issues of ethnic and environmental justice are and how much work there is to be done on so many fronts.

Throughout the world, colonizers and their successors have reaped the fruits of their dominance – opportunity, security, freedom and prosperity. The term structural racism is often used to describe the historical and contemporary policies and practices that create and maintain racial and ethnic injustice. Privileged communities, through intentional oppression, ignorance or benign neglect have persisted in marginalizing indigenous people and others whose values and beliefs, whose culture and "worldview" is different from their own.

Foundations for effective disaster risk management in indigenous communities are rooted in these cultural belief systems, these worldviews. However, there are few indigenous communities within which natural hazard risk reduction practices based on these cultural belief systems can be practiced. Implementing significant risk reduction strategies require freedoms that are not available to many marginalized Indigenous communities.

This is true with respect to wildland fire management, in particular. In their publication Indigenous Fire Stewardship (2019), Frank K. Lake and Amy Cardinal Christianson, with the help of several references, characterize the differences in the ways in which cultural burning was practiced historically under indigenous fire sovereignty and governance compared to modern fire governance and management:

> *The colonial worldview was that fires were destructive to the timber supply and dangerous to communities (Pyne, 2007). The process of colonization, in most instances, has severely limited indigenous fire stewardship practices (Kimmerer & Lake, 2001; Mistry et al., 2016; Lewis et al., 2018). Colonial fire management has limited and reduced the frequency, seasonality, extent, and magnitude of cultural burning through fire suppression policies and regulatory authorities (Murphy, 1985; Timbrook et al., 1993; Murphy et al., 2007; Christianson, 2015; Lewis et al., 2018). The legacy of colonization on indigenous fire knowledges from genocide, forced removal, relocation, and acculturation efforts to westernize indigenous peoples has substantially limited cultural burning (Eriksen & Hankins, 2014).*

More broadly, local capacity, practice, knowledge and tradition that have been developed through a close relation to their natural environment have helped communities cope with local hazards and thrive for millennia in highly at-risk areas. In many cases, however, these practices, otherwise highly sustainable, have been lost due to social, political or economic change, leading to increased vulnerability.

An explanation for the historical disregard of indigenous knowledges in established disaster risk reduction may include issues associated with power relations stemming from colonial times and the dominance of Western values and ideas. Given that knowledge is power, in this case the power over resources and how they are employed, indigenous knowledges have been largely ignored by those who protect their own interests and established political structures. In neocolonial times, it has not been uncommon for the language and religion of the colonizer to be forced on indigenous peoples (it's no accident that today many indigenous people, and in particular youth, do not speak their native language (Twitchell, 2018). Other insidious and long-term implications include the loss of stories and storytelling and similar traditions of an oral culture as well as an erosion of traditional decision-making customs that defined trusteeship of the land and environment and, by extension how communities lived in harmony with nature.

Another no less subtle explanation for the loss of indigeneity is the march-of-time. Mr. Girma H/Michael, a senior consultant in the field of indigenous knowledge documentation, has worked as director of National Disaster Management Policy and Programing for the then Disaster Prevention and Preparedness Commis-sion and now National Disaster Risk Management Commission in Ethiopia. According to him, a growing existential challenge to the continuing practice of traditional knowledge in Pastoralist communities is the "advent of modernity" and its influence on the attitudes of the young generation towards traditional systems. It is Mr. Michael's opinion that as drought and political decisions regarding land use reduce the ability to sustain traditional family practice, young people are moving away from the traditional systems of their parents. He explains that although many youth continue to live within the family unit many are increasingly exposed to non-pastoral employment opportunities, and moving out of their ancestral homes following these opportunities (Scott, 2019).

This calling to attention the effects of modernity is also echoed by Garth Harmsworth (Maori), an environmental scientist at Landcare Research (*Manaaki Whenua*), Palmerston North, New Zealand. Mr. Harmsworth observes (Scott, 2019) that the wider use of formal education and the exposure to other (Western) models, standards and values has contributed to a breaking down of traditional communication networks. This has also resulted in the undermining of the importance of elders within the society, allowing their knowledge to die with them.

Back to basics: indigenous knowledges and disaster risk reduction 101

Several key terms are used to discuss disaster risk reduction, including *hazard*, *risk* and *vulnerability*, and more recently, *resilience*. Although the terms *response, relief*, and *recovery* are not commonly associated with disaster risk reduction, they do figure in discussions surrounding disaster resilience and are more typically associated with post-event activities.

Wildland fires, for example, are natural *hazards* (though they can be caused or exacerbated by decisions and actions made by humans). The risk to a community associated with wildland fires is potential loss of life, injury, or destroyed or damaged assets. And a community is *vulnerable* to these risks if it lacks public awareness and engagement in prevention strategies as well as access to systems and infrastructure to deal with the detection and the combatting of fire; for example, sensor networks, GIS and satellite tracking as well as adequate telecommunications, aircraft and terrestrial vehicles and even basic tools such as water, fire retardants, axes, hooks, cutters and poles.

The *resilience* of a community is characterized by its ability to function throughout an event, or at least the ability to restore critical systems soon afterwards, thereby preventing or significantly mitigating disruption to lives, livelihoods and economies (resilience usually is not the result of luck. Rather, it is attributed to the development and implementation of community-specific risk reduction strategies). In the absence of resilience, communities can face severe consequences. Extreme economic, health and environmental costs associated with disaster events, include livestock loss, crop failure, hunger, disease, starvation and famine. Further, there is an equal, or even larger, existential, threat to indigenous cultures from wildland fires, climate change and other natural hazards: the loss of their way of living that has been passed down over millennia.

While these terms and definitions have currency within the professional disaster risk reduction community, they may not translate to indigenous understanding. Definitions, concepts and standards related to disaster risk reduction and response must reflect both indigenous and non-indigenous perspectives. And efforts must be taken to develop risk reduction strategies and messages appropriate not only to the linguistic but also the cultural practices of communities.

In the broader context of risk reduction in indigenous communities, it is also important to consider what might seem to be a paradox, that indigenous communities may simultaneously exhibit vulnerability and resilience. Uekusa and Matthewman (2017) suggest that resilience often comes from *earned strength* which, in time, may become traditional indigenous knowledge. That is, individuals and communities, through adversity, may become stronger than they originally were, simply as a means of surviving daily emergencies and struggles. This is a useful, if new, observation, as it gets away from the assumption that Indigenous Peoples are resilient through some sort of cultural *magic* (i.e. DNA and culture do not confer resilience).

Respect for indigenous knowledges

Returning to the theme of racial and ethnic justice and its effect on risk reduction in indigenous communities, the response to this new call to be "woke" should include efforts to ensure that indigenous Peoples have their own voice in creation of strategies to reduce risk and vulnerability and that that voice should be listened to. Traditional indigenous knowledges, values and culture are, in themselves, important risk reduction tools and should be celebrated as such. Many might be valuable if incorporated into national disaster plans. The practice of imposing centralized solutions to local problems (many of

which already have successful local solutions) can lessen the community's capacity to reduce risk and save lives.

An example of this can be found in Ethiopia. Pastoralism has developed over centuries out of the need to constantly adapt to the extreme climatic uncertainty and marginal landscapes of the dry lands and has been practiced for centuries. Pastoralists have sophisticated traditional methods to optimize water and land, moving and selling animals to deal with the effects of drought. Yet, in recent years, the dry lands of the Horn of Africa, of which Ethiopia is a part, have become some of the most vulnerable areas in the world. This is due in part to decades of political and economic marginalization, which has led to an erosion of pastoral assets. The imposition of these forces, over and above the existing environmental challenges, disrupt migration routes and access to dry season grazing areas and severely hinder pastoralists' abilities to move animals to different pasture, a key mechanism for coping with drought.

Other examples come from New Zealand. Garth Harmsworth, introduced earlier, explains that the change from the indigenous practice of well-managed subsistence gardening to widespread commercial cash cropping and the raising of livestock which has, in many cases, led to heavy land erosion, which in turn, has resulted in widespread destruction from flooding. Land that has been cleared to make way for larger plantations removes stabilizing vegetation that was previously protected under traditional Maori environmental management schemes.

It follows, then, that attempts to introduce "Western Science" and other external approaches to address natural hazard risk reduction needs in indigenous communities should not be the primary emphasis. Before attempts are made to bring indigenous communities into the mainstream "Western" risk reduction and resilience movement, if, indeed that proves to be the best course of action, attempts should be made to better understand the culture of risk reduction and resilience that has been resident in indigenous communities throughout generations. Taking steps towards a better understanding of indigenous cultural belief systems (a.k.a., worldview, cosmovision, indigenous knowledge) and how they apply to disaster risk reduction and resilience should be a first step, not an adjunct exercise, in a collective effort to reduce risk in indigenous communities.

Moving forward

As we move forward we must agree to avoid furthering indoctrination of the false dichotomy of the "scientific" vs. "indigenous" knowledge. They go hand-in-hand; empirical evidence is a central part of the scientific method and empirical evidence is at the core of indigenous knowledge. Respect must be given to indigenous knowledges and opportunity must be available to indigenous peoples to fully represent their knowledge.

First Nations knowledge keeper Henry Michel, in his introduction to the proceedings of the "Linking Indigenous Peoples' Knowledge and Western Science in Natural Resource Management Conference" (Mitchel & Gayton, 2001) explained it this way,

> *There are many misconceptions about IPK both in the general public and within the Aboriginal community itself. If non-indigenous participants are exposed to IPK as a system based on real concepts and practices, they can begin dismantling popular Western stereotypes of IPK as some elusive philosophy or superstition. Indigenous knowledge systems operate from the perspective of natural life systems. The natural laws of life – land, water, wind, the four cardinal directions, plants, animals, and humans – are the essential elements of those laws. The interrelationships that exist between these life elements are the basis of the natural laws. Indigenous knowledge systems and governance structures are modelled from these natural law principles. Western society has been so displaced from these natural world systems in which IPK is based that its value system has also become removed from nature. The incorporation of IPK systems with Western science will mean Western society must re-establish linkages based on natural systems thinking.*

An example of the kind of linkage Henry Michel speaks of may be the Inuit Traditional Knowledge for Adapting to the Health Effects of Climate Change project (IK-ADAPT). The project was a multi-year community-based initiative,

funded by the Institute for Circumpolar Health Research, that combined scientific research and Inuit traditional knowledges to develop an evidentiary base to inform policy and programming needed to assist Inuit communities in adapting to the health effects of climate change. Working in partnership with communities across Northern Canada, the program examined ways to preserve, promote, and disseminate traditional knowledges in order to prevent, prepare for, and manage the health impacts of climate change.

Heretofore, the terms "indigenous knowledge" and "traditional knowledge" have been used as placeholders – in meetings, conferences, needs assessments, policies, etc. – for a broader and deeper discussion that should and would happen at some time… but rarely seems to happen. It has been used to suggest that a deliberative body has given reasonable consideration to the necessity to respect indigenous peoples, their experience and their needs, without defining what that experience was, what those needs are or how, specifically, they would be met. And too frequently, when reports of meetings or findings of assessments were written, the words used were not the words of the indigenous delegates themselves; for, more often than not, there was neither a sufficient number of indigenous delegates assembled, nor was there enough time to discuss various indigenous perspectives (they are not homogenous), nor were sufficient interpretation and translation resources available, nor… ad infinitum, to accurately represent the many and varied needs of the communities about whom the meetings were convened and the assessments commissioned.

Will things change? Maybe this time. Because it's time.

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Abordagem Indígena sobre Manejo Integrado do Fogo em Terras Indígenas no Estado do Tocantins – Brasil

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RESUMO – O manejo integrado do fogo (MIF) pode ser uma abordagem nova para algumas pessoas e instituições públicas no Brasil, no entanto é prática comum nas comunidades das terras indígenas (TIs) Parque do Araguaia e Xerente, no estado do Tocantins. Estas manejam secularmente o fogo para reduzir o material combustível acumulado nas paisagens do Cerrado, garantir a frutificação das principais espécies nativas utilizadas em sua alimentação, caçar, confeccionar rota de fuga para os animais em caso de incêndios e para limpeza de roça e de áreas ao redor das aldeias. Unir esse conhecimento tradicional às diretrizes de atuação das instituições públicas representa um grande desafio no processo de construção do aprender a valorizar e respeitar o outro. Este seria o ponto de partida para construir estratégias que abarquem conhecimentos, técnicas e experiências almejando a harmonia entre os envolvidos, a preservação ambiental, a conservação dos patrimônios naturais e da biodiversidade existentes nas Terras Indígenas. O presente estudo traz a abordagem indígena sobre utilização do conhecimento tradicional sobre uso do fogo no âmbito do manejo integrado do fogo e do Programa de Brigadas Federais do Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Ibama), executado pelo Centro Nacional de Prevenção e Combate aos Incêndios Florestais (Prevfogo) nas TIs Parque do Araguaia e Xerente. O objetivo foi auxiliar a sociedade na compreensão do processo de integração entre instituição pública e comunidades indígenas na busca por melhorar a prevenção aos incêndios florestais e diminuir sua severidade nas terras indígenas.

Palavras-chave: Indígenas; manejo integrado do fogo; uso tradicional do fogo; Programa Brigadas Federais; terras indígenas.

Indigenous Approach to Integrated Fire Management in Indigenous Lands in the State of Tocantins – Brazil

ABSTRACT – Integrated Fire Management can represent a new approach for some people and public institutions in Brazil. However, it is a common practice for indigenous communities of the indigenous lands *Parque do Araguaia* and *Xerente*, in the state of Tocantins. The communities use fire traditionally to reduce accumulated combustible material in the landscapes of Cerrado; to ensure fruiting and hunting; to build escape routes for animals in case of wildfires; to promote slash-and-burn agriculture; and to clean the areas around the villages for protection. Bringing together traditional knowledge and institutional guidelines implies a challenge in the process of learning how to value and respect others. This is the milestone for developing strategies that encompass knowledge, techniques and experiences to achieve harmony among all stakeholders, and to promote conservation of natural heritage and biodiversity in indigenous lands. The present study addresses the indigenous approach of the use of fire according to the traditional knowledge within the scope of integrated fire management and the Federal Brigades Program of the Brazilian Institute for the Environment and Renewable Natural Resources (Ibama), carried out by the National Center for Prevention and Fighting Forest Fires (Prevfogo) in the indigenous lands Parque do Araguaia and Xerente. The objective was to assist society to understand the integration process between public institutions and indigenous communities in the search for improvements to prevent wildfires and to decrease their negative effects on indigenous lands.

Keywords: Indigenous peoples; integrated fire management; traditional use of fire; Federal Brigade Program.

Enfoque Indígena para el Manejo Integral del Fuego en Tierras Indígenas en el Estado de Tocantins – Brasil

RESUMEN – El manejo integral del fuego puede representar un nuevo enfoque para algunas personas e instituciones públicas en Brasil. Sin embargo, es una práctica común para las comunidades de las tierras indígenas Parque do Araguaia y Xerente, en el estado de Tocantins. Las comunidades utilizan tradicionalmente el fuego para reducir el material combustible acumulado en los paisajes del Cerrado; para asegurar la fructificación y la caza; construir rutas de escape para animales en caso de incendios forestales; promover la agricultura de roza y quema; y limpiar las áreas alrededor de las aldeas para su protección. Unir conocimientos tradicionales y lineamientos institucionales implica un desafío en el proceso de aprender a valorar y respetar a los demás. Este es el punto de partida para desarrollar estrategias que abarquen conocimientos, técnicas y experiencias, con el objetivo de lograr la armonía entre todos los actores, la preservación y conservación del patrimonio natural y de la biodiversidad en tierras indígenas. El presente estudio aborda el enfoque indígena sobre el uso del fuego según el conocimiento tradicional en el ámbito del manejo integral del fuego y el Programa de Brigadas Federales del Instituto Brasileño de Medio Ambiente y Recursos Naturales Renovables (Ibama), realizado por el Centro Nacional de Prevención y Combate de Incendios Forestales (Prevfogo) en las tierras indígenas Parque do Araguaia y Xerente. El objetivo fue ayudar a la sociedad a comprender el proceso de integración entre las instituciones públicas y las comunidades indígenas en la búsqueda de mejorar la prevención a los incendios forestales y sus efectos negativos en las tierras indígenas.

Palabras clave: Pueblos indígenas; manejo integral del fuego; uso tradicional del fuego; programa de brigadas federales; tierras indígenas.

Introdução

O estado do Tocantins fica localizado na região norte do Brasil, encravado no bioma Cerrado. Neste estado existem quatorze terras indígenas (TIs), sendo que nove destas encontram-se regularizadas (Funai, 2020).

As terras indígenas do estado do Tocantins, além da assistência da Fundação Nacional do Índio (Funai), a partir de 2013 começaram a ser atendidas pelo Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Ibama), com o Programa Brigadas Federais, executado pelo Centro Nacional de Prevenção e Combate aos Incêndios Florestais (Prevfogo), para apoio à preservação ambiental, prevenção, controle e combate aos incêndios florestais.

O fogo faz parte da cultura indígena desde seus ancestrais, sendo utilizado para cozimento dos alimentos, caça, limpeza de área para cultivo e proteção das moradias, entre outras utilidades. Ao longo do tempo as técnicas de uso do fogo foram sendo aprimoradas através das vivências e experiências empíricas e os indígenas aprenderam a manejar o fogo e a utilizá-lo também na prevenção aos incêndios florestais, a partir da redução do material combustível.

Com a implementação do Programa de Brigadas Federais do Prevfogo/Ibama nas terras indígenas do Tocantins surgiram divergências de opinião entre os técnicos do Prevfogo/Ibama e as lideranças indígenas. Houve defesa de posicionamentos de ambos os lados, tanto pelos servidores do Prevfogo/Ibama segundo sua doutrina de evitar o uso do fogo, quanto da Comunidade Indígena por ter a cultura em manejar com fogo a vegetação no período pós-chuva.

Depois das primeiras discussões, foi consenso a necessidade de reuniões para analisar a situação e a partir daí houve entendimento quanto ao uso do fogo para redução do combustível acumulado nas paisagens do Cerrado visando evitar a severidade dos incêndios na época crítica de sua ocorrência.

Nesse âmbito, o presente estudo teve como objetivo registrar a abordagem utilizada culturalmente para prevenção aos incêndios florestais realizada pelas comunidades indígenas nas TIs Parque do Araguaia e Xerente, no estado

do Tocantins, e a integração desse conhecimento em práticas incorporadas pelo Programa de Brigadas Federais do Prevfogo/Ibama.

Para a realização deste estudo foram acompanhados os trabalhos do Prevfogo/Ibama durante quatro anos nas TIs, sendo registradas as observações de campo, do dia a dia nas aldeias, e as discussões em reuniões para diagnóstico, planejamento e execução das práticas de manejo integrado do fogo (MIF) nas comunidades. Entende-se por MIF a integração da ciência e da sociedade com as tecnologias de manejo do fogo em múltiplos níveis. Pressupõe a compreensão da abordagem holística ou bem entrelaçada das questões do fogo, que leva em consideração as interações biológicas, ambientais, culturais, sociais, econômicas e políticas (Myers, 2006). Neste contexto a integração entre as técnicas de controle do fogo (prevenção, preparação, combate e uso do fogo) com os aspectos culturais, socioeconômicos e a ecologia do fogo tem como objetivo reduzir o número de incêndios (prevenção), aumentar a eficiência dos combates (preparação), melhorar o relacionamento entre os brigadistas e a comunidade (cultura do fogo) e garantir um regime de fogo adequado à preservação ambiental (ecologia do fogo). Uma vez que o fogo pode ser "bom" ou "mau", o fogo "bom" produz alimentos, ajuda na preservação da natureza e na proteção contra os incêndios florestais enquanto o fogo "mau" causa degradação ambiental e prejuízos às pessoas (Ibama, 2018).

Neste estudo foram definidas quatro perguntas norteadoras, de forma a construir sistematicamente a transcrição do olhar indígena sobre a utilização do conhecimento tradicional do uso do fogo e a discussão entre as comunidades indígenas e as instituições governamentais sobre o MIF.

Após quatro anos de acompanhamento da execução do Programa de Brigadas Federais e implementação do MIF nas TIs Parque do Araguaia e Xerente, por meio das observações, diálogos e registros feitos é possível afirmar que a integração entre instituição pública (Prevfogo/Ibama) e comunidades indígenas conduzida com humildade e respeito aos conhecimentos de cada envolvido nesta relação é benéfica para ambas as partes e para o meio ambiente, no que concerne à preservação ambiental com a prevenção aos incêndios florestais e diminuição das ocorrências de incêndios severos.

Material e Métodos

Área de abordagem

Este estudo foi realizado nas terras indígenas Parque do Araguaia, que possui 1.358.499,48ha e tradicionalmente é ocupada pelas etnias Tapirapé, Javaé, Karajá e Ava Canoeiro, e na Terra Indígena Xerente, que possui 167.542,10ha e é ocupada pela etnia Xerente. Ambas se encontram regularizadas e totalizam uma área de 1.526.041,58ha, representando mais de 5% do território do estado do Tocantins (Figura 1).

A cobertura vegetal, uso e ocupação do solo da Terra Indígena Parque do Araguaia é caracterizada por 57,74% de formação natural não florestal; 38,74% de floresta; 2,64% agropecuária; 0,86% de corpos d'água e 0,02% área não vegetada. Já na Terra Indígena Xerente 95,94% é floresta; 2,04% uso com agropecuária; 1,66% formação natural não florestal; 0,32% área não vegetada e 0,04% corpos d'água (MapBiomas, 2020).

As TIs Parque do Araguaia e Xerente possuem Brigadas Federais Indígenas do Prevfogo/Ibama, contratadas anualmente no período de junho a novembro no âmbito do Programa Brigadas Federais. Este Programa foi criado em 2013 com atuação nas terras indígenas por meio de Acordo de Cooperação Técnica celebrado entre Ibama e Funai, objetivando realizar ações de manejo integrado do fogo, que incluem a prevenção, monitoramento e combate aos incêndios florestais.

Por se tratar de brigadas federais em terras indígenas, estas são denominadas no Programa como "Brigadas Indígenas", e podem ser compostas exclusivamente por membros das comunidades indígenas ou complementadas com integrantes não indígenas, quando necessário (Ibama, 2018).

Coleta de dados

As informações foram coletadas a partir de observações de campo e conversas com brigadistas indígenas e anciões (indígenas mais velhos) de maio de 2015 a setembro de 2019. Nesse período participaram dos diálogos aproximadamente quarenta anciões e sessenta brigadistas indígenas.

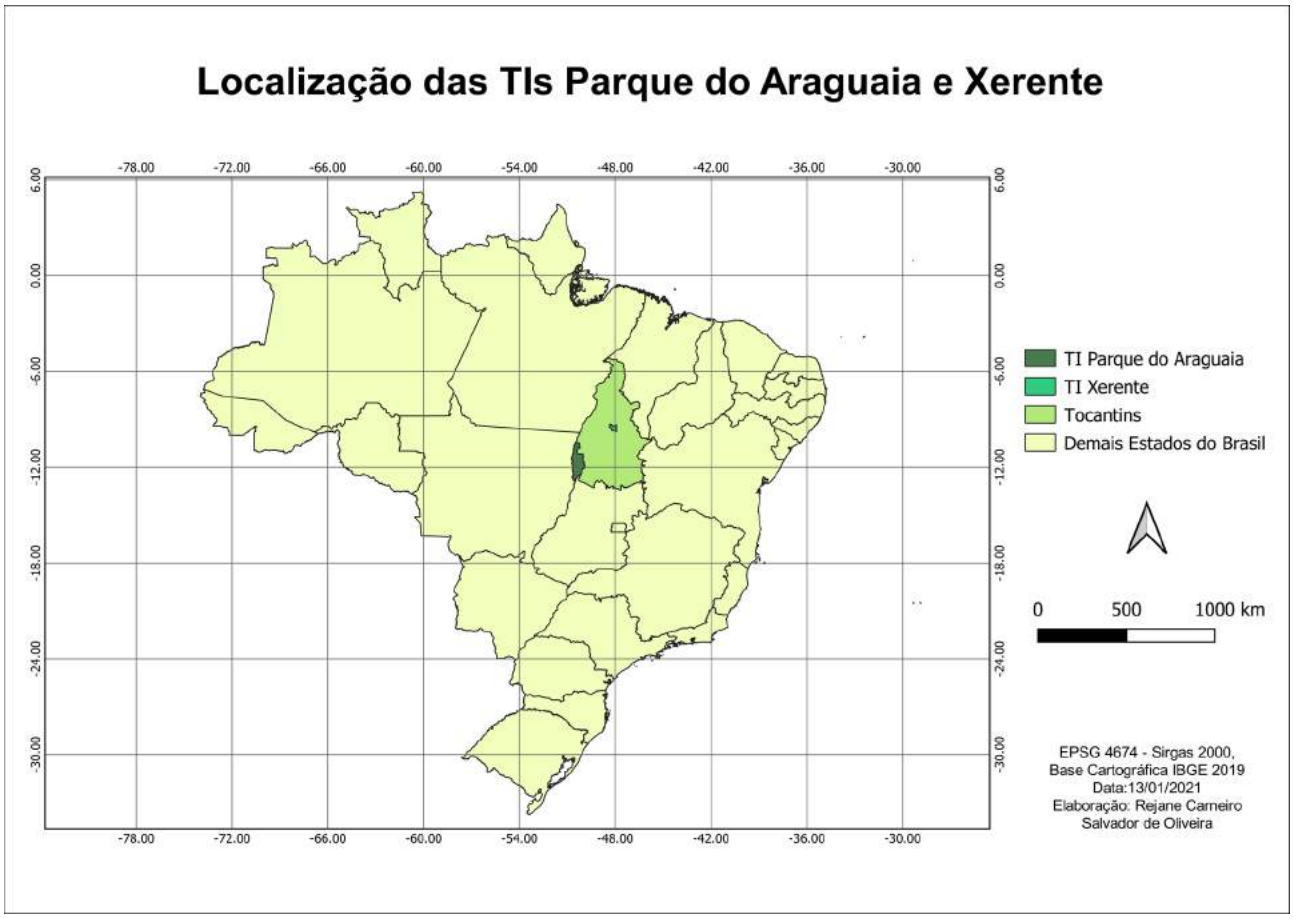

Figura 1 – Localização das TIs Parque do Araguaia e Xerente.

A coleta de dados foi feita de forma oral em rodas de conversa, seguindo ritual cultural indígena de transmissão de conhecimentos tradicionais. Este levantamento de informações foi facilitado pela participação de um indígena da TI Xerente, que participa das brigadas indígenas e possui boa articulação entre os povos Xerente, Ava-canoeiro, Javaé, Karajá e Tapirapé.

Objetivando transcrever o olhar indígena sobre a utilização do conhecimento tradicional do uso do fogo discutidos entre as comunidades indígenas e as instituições governamentais o presente estudo foi norteado pelas seguintes perguntas: Como as comunidades indígenas estão lidando com a abordagem do manejo integrado do fogo trazida pelo Prevfogo/Ibama? Como os indígenas veem a utilização, pelas instituições, da sabedoria indígena para desenvolver o trabalho de prevenção, controle e combate aos incêndios florestais? Como as comunidades indígenas veem o trabalho das Brigadas Federais do Prevfogo/Ibama? E como as comunidades indígenas veem a aplicação do seu conhecimento tradicional de uso do fogo frente às mudanças climáticas?

Resultados

1. Como as comunidades indígenas estão lidando com a abordagem do manejo integrado do fogo trazida pelo Prevfogo/Ibama?

Para os indígenas das etnias Xerente, Ava-canoeiro, Javaé, Karajá e Tapirapé essa abordagem do manejo do fogo não é nova, o que há é a retomada do que se fazia antigamente, ou seja, o resgate do uso tradicional do fogo.

No início da execução do Programa de Brigadas Federais, durante o curso de Formação de Brigada promovido pelo Prevfogo/Ibama, os brigadistas eram instruídos a não deixar queimar. Todo fogo detectado deveria ser extinto (política de fogo zero). Essa postura provocou choque entre a cultura indígena e a estratégia adotada pela brigada.

No entanto, esse conflito de posicionamentos foi conciliado através de reuniões entre servidores do Prevfogo/Ibama (técnicos e brigadistas) e anciões, (Figura 2), que passaram a orientar os brigadistas sobre a importância do uso do fogo na época pós-chuva e as técnicas utilizadas pelos seus ancestrais.

Por meio de diálogos e troca de experiências, os técnicos e brigadistas perceberam que a sabedoria tradicional de utilização do fogo no Bioma Cerrado traria bons resultados para a conservação ambiental e passaram a incorporar essa cultura nas suas práticas a partir do ano de 2015, criando um marco histórico de participação, zelo pelo uso do fogo, trocas de conhecimento e confiança entre as partes.

A partir desse momento percebeu-se uma satisfação dos indígenas em desenvolver o trabalho pensando na própria subsistência, pois a realização das queimas prescritas com a

Figura 2 – Reunião entre servidores do Prevfogo/Ibama e anciões indígenas. Fonte: Acervo da Coordenação Estadual do Prevfogo/Ibama/TO.

integração do conhecimento técnico e cultura local, aumenta a produção de frutas e mantém a população faunística, garantindo assim alimento para comunidade.

Observou-se pelas falas que o manejo do fogo proporciona uma cadeia de resultados positivos, assim como a felicidade das comunidades indígenas por fazerem o que sabem, usando as estratégias que sempre utilizaram para sobreviver e usufruir de maneira sustentável dos recursos naturais do Cerrado.

2. Como os indígenas veem a utilização, pelas instituições, da sabedoria indígena para desenvolver o trabalho de prevenção, controle e combate aos incêndios florestais?

A comunidade indígena vê com satisfação e gratidão a utilização da sabedoria dos seus ancestrais por uma autarquia federal da magnitude do Ibama. Este, ao perceber que estava usando estratégias equivocadas, deu oportunidade à

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comunidade indígena para construírem juntos estratégias de manejo integrado do fogo, tanto na aplicação da educação ambiental, formação dos brigadistas, controle e combate aos incêndios florestais, quanto nas queimas prescritas. Nesse momento foi instituído pelo Prevfogo/Ibama um processo de construção coletiva, seguindo as orientações dos anciões, trocando experiências, ampliando as técnicas de queima e dando autonomia às brigadas indígenas para executarem o trabalho de acordo com a realidade local.

3. Como as comunidades indígenas veem o trabalho das Brigadas Federais do Prevfogo/Ibama?

A comunidade indígena vê com orgulho, mas também muita preocupação, considerando o grau de periculosidade que envolve a atividade de brigadista.

A comunidade apoia os brigadistas, os quais além de combaterem os incêndios florestais e protegerem a biodiversidade das TIs, patrimônios natural e humano, desenvolvem também trabalho socioambiental, conseguem acessar todas as aldeias pela estrutura que o Prevfogo/Ibama oferece, orientam, plantam mudas de espécies frutíferas e arbóreas nativas, participam de eventos culturais, reuniões nas áreas de educação e de saúde. Enfim, a figura dos brigadistas na comunidade indígena é vista como elo entre os indígenas e o estado brasileiro.

4. Como as comunidades indígenas veem a aplicação do seu conhecimento tradicional de uso do fogo frente às mudanças climáticas?

Diante de um histórico de discriminação, preconceitos maldosos, difamações, perseguições entre outras situações difíceis, os indígenas se alegram por terem sido ouvidos e pelo uso tradicional do fogo estar trazendo benefícios ao meio ambiente.

O momento de aproximação, respeito e humildade em saber ouvir e aplicar os conhecimentos tradicionais demonstrado pelo Prevfogo/Ibama tem sido de muita alegria, não apenas pelo fato de serem reconhecidos ou respeitados, mas também por saberem que a Mãe Natureza terá dias melhores, que os guardiões estão contribuindo para que ela sofra menos e que a humanidade se beneficiará também.

Os indígenas sabem que ainda têm muito a contribuir para a conservação do meio ambiente, mas vivem, de certa forma, desprovidos de políticas públicas que garantam a todos os povos indígenas a permanência e proteção territorial. Enfrentam diariamente pressões no entorno de suas terras, pois estão vivendo em lugares ricos em épocas de crises financeiras. É notório que no Tocantins as terras indígenas figuram dentre os lugares mais preservados.

Ressaltam a importância do seu conhecimento tradicional para conservação ambiental, citam que não possuem certificados acadêmicos na área ambiental, mas possuem centenas de anos de experiências e práticas de como cuidar de quem os proporciona a vida. Vendo com muita gratidão a aplicação dos seus conhecimentos para reduzir as mudanças climáticas que a cada dia são mais severas.

Discussão

Em 2013, com o início do Programa Brigadas Federais a relação entre as comunidades indígenas e as instituições governamentais foi conflituosa, uma vez que as brigadas indígenas quando contratadas eram orientadas a apagar todo e qualquer fogo, "política de fogo zero", não considerando que os indígenas ao longo dos séculos sempre fizeram uso tradicional do fogo com objetivos determinados pela comunidade como caça, limpeza ao redor das aldeias, garantia da frutificação, rota de fuga para fauna e manejo da flora. Estas queimas tradicionais eram realizadas ao final do período chuvoso para aproveitar a alta umidade da vegetação e realizar queimas de baixa intensidade, com segurança e que se extinguisse naturalmente.

Para reduzir os conflitos e conciliar o entendimento, o Prevfogo/Ibama promoveu encontros entre anciões, lideranças indígenas, brigadistas indígenas e técnicos do órgão a fim de discutir o uso do fogo e definir estratégias que atendessem aos interesses de ambas as partes. Só após esses encontros houve entendimento pelos técnicos do Prevfogo/Ibama da necessidade do uso do fogo pelos indígenas e que o fogo logo após o período chuvoso seria de baixo impacto.

A partir deste entendimento os brigadistas contratados pelo Prevfogo/Ibama foram instruídos a acompanhar as queimas realizadas pelas comunidades com uso tradicional do fogo. A estas queimas as brigadas indígenas passaram a agregar conhecimentos técnicos como o uso de geoprocessamento e imagens de satélite na elaboração de mapas identificando os locais de acúmulo de biomassa.

Ao longo dos quatro anos de observações e conversas com os anciões e brigadistas verificou-se alguns pontos positivos em relação ao manejo integrado do fogo e da presença da Brigada Federal nas terras indígenas como o respeito pela pessoa índio e pelo conhecimento indígena, integração entre instituição pública e comunidades indígenas, aproximação do Estado com as comunidades indígenas, criação de laços, compreensão da cultura indígena, oportunidade dos indígenas cuidarem da terra de forma remunerada, empoderamento e inclusão social, e estabelecimento da brigada como elo entre comunidade e ações do Estado.

Na relação entre servidores do Prevfogo/Ibama e comunidade indígena todo o processo de diálogo almejava objetivos em comum, utilizar a experiência dos anciões integrada a novas técnicas para aplicar o fogo nas épocas e locais predeterminados, manejar o material combustível, favorecer a frutificação, impedir a formação de grandes frentes de fogo e facilitar as ações de combate.

Nesse sentido, o bom andamento das atividades envolvendo o Estado e a comunidade indígena está no desenvolvimento das ações de forma coletiva, dando aos envolvidos o direito e liberdade de expressão e respeitando acima de tudo o posicionamento de cada indivíduo. Assim, os erros foram reduzidos e os laços de confiança fortalecidos. Consolidado esse entendimento, concluiu-se que o segredo estava não apenas em quem sabia mais, e sim na humildade de atuar juntos em busca do mesmo objetivo. Nunca trabalhar de forma paralela, pois isto gera atritos e problemas no resultado da ação.

Conclusão

O Estado e a comunidade indígena, com o desenvolvimento de ações harmônicas e integradas, darão ao meio ambiente brasileiro mais proteção e segurança e, consequentemente as pessoas terão dias menos poluídos e mais gratificantes.

Os resultados positivos das ações desenvolvidas nas terras indígenas Parque do Araguaia e Xerente são visíveis. As comunidades indígenas estão sendo beneficiadas e tendo seus objetivos alcançados, a natureza está sendo preservada. Com as ações de manejo integrado do fogo as áreas manejadas estão produzindo mais frutos, fornecendo a matéria prima para os indígenas fazerem suas casas, tendo áreas incendiadas menores e menos impactos negativos na fauna e na flora. Como consequência, há melhora na qualidade de vida da comunidade indígena e fortalecimento das técnicas de gestão do uso do fogo nessas TIs.

Quanto aos pontos negativos em relação ao manejo integrado do fogo e à presença da Brigada Federal nas terras indígenas, identifica-se como ameaça a interrupção no processo de implementação do MIF, uma vez que as brigadas são contratadas anualmente apenas por seis meses, e nos outros seis meses do ano pode faltar estrutura (equipamentos e insumos) para as brigadas indígenas continuarem as práticas de manejo do fogo. Por fim, as mudanças de governo trazem insegurança e incerteza para continuidade do Programa de Brigadas Federais.

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Histórico, Avaliação, Oportunidades e Desafios do Manejo Integrado do Fogo nas Terras Indígenas Brasileiras

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RESUMO – As terras indígenas brasileiras formam o maior mosaico de áreas protegidas do país, sendo fundamentais para a conservação ambiental. Apesar disso, nem sempre foram alvo dos programas governamentais relacionados aos incêndios florestais. Quando atendidas, receberam ações isoladas e desarticuladas, que não foram avaliadas ou monitoradas adequadamente. Essa realidade mudou recentemente com a criação de um programa específico para as comunidades indígenas, baseado na valorização da mão de obra local e no conhecimento tradicional, por meio do manejo integrado do fogo. O objetivo desse artigo é apresentar um histórico das atividades de prevenção e combate aos incêndios florestais nas terras indígenas brasileiras e os principais resultados do Programa Brigadas Federais, implementado pela Fundação Nacional do Índio e pelo Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, por meio do Centro Nacional de Prevenção e Combate aos Incêndios Florestais (Prevfogo). Esses resultados demonstram a eficiência das brigadas indígenas e a relevância do conhecimento tradicional na implementação do manejo integrado do fogo, enfatizando a importância do aspecto sociocultural como fator de sucesso para a abordagem do tema. Além disso, o Programa Brigadas Federais desenvolveu procedimentos técnicos e administrativos que ordenaram as ações de proteção contra os incêndios florestais em territórios tradicionais, permitindo a expansão eficiente das áreas atendidas. Essa expansão é uma excelente oportunidade para apoiar políticas de conservação da biodiversidade ou de combate e mitigação das mudanças climáticas globais. Entretanto, proteger essas imensas áreas ainda é um desafio que exige ações de estruturação dos órgãos responsáveis, articulação interinstitucional, mudanças na legislação, consolidação da integração do aspecto sociocultural e pagamento pelos serviços ambientais prestados.

Palavras-chave: Índios; incêndios florestais; queimadas; Ibama; Prevfogo.

Background, Assessment, Opportunities and Challenges of Integrated Fire Management in Brazilian Indigenous Lands

ABSTRACT – The brazilian indigenous lands are fundamental for environmental conservation, shaping the largest mosaic of protected areas in the country. In spite of that, they were rarely targeted in governmental programs related to wildfires. Even when attended, they received isolated and disconnected actions with no proper evaluation nor monitoring. Recently there was a change by the creation of a specific program for indigenous communities, based on the empowerment of local labor force and traditional knowledge, through integrated fire management approach. This article aims to record an overview of the activities for preventing and fighting wildfires in indigenous lands and the main outcomes of the Federal Brigade Program, implemented by the National Indian Foundation and the Brazilian Institute for the Environment and Renewable Natural Resources, through the Specialized Center Prevfogo. The results highlight the importance and efficiency of traditional knowledge and indigenous brigades in the implementation of integrated fire management, pointing out the significance of the socio-cultural aspect as a successful element for addressing the fire issue. The Federal Brigade Program developed technical and administrative procedures that set up the protection actions against wildfires in traditional territories, allowing an efficient expansion of the areas assisted. This advance is an outstanding opportunity to support policies to preserve biodiversity and mitigate global climate change. However, to protect these immense areas is still a challenge that requires structuring actions

by the responsible agencies, interinstitutional articulation, changes in legislation, consolidation of the socio-cultural integration element and payment for environmental services provided.

Keywords: Indigenous people; wildfires; burning; Ibama; Prevfogo.

Histórico, Evaluación, Oportunidades y Desafíos del Manejo Integral del Fuego en Tierras Indígenas Brasileñas

RESUMEN – Las tierras indígenas brasileñas configuran el mayor mosaico de áreas protegidas del país y son fundamentales para la conservación del ambiente. A pesar de eso, no siempre fueron objeto de programas gubernamentales relacionados con los incendios forestales. Cuando asistidas, recibieron acciones aisladas y desarticuladas sin adecuada evaluación ni seguimiento. Hubo un cambio recién con la creación de programa específico para comunidades indígenas, basado en la valorización de la mano de obra local y el conocimiento tradicional, a través del manejo integral del fuego. Este artículo presenta las actividades de prevención y combate de incendios forestales en tierras indígenas y los principales resultados del Programa Brigadas Federales, implementado por la Fundación Nacional Indígena y el Instituto Brasileño de Medio Ambiente y Recursos Naturales Renovables, a través del Centro Especializado Prevfogo. Los resultados demuestran la relevancia y eficiencia del conocimiento tradicional y de las brigadas indígenas en la implementación del manejo integral del fuego, señalando la importancia del aspecto sociocultural como factor exitoso para abordar el tema del fuego. El Programa de Brigadas Federales desarrolló procedimientos técnicos y administrativos que ordenaron las acciones de protección contra incendios forestales en territorios tradicionales, permitiendo la expansión eficiente de las áreas atendidas. Estos avances son una excelente oportunidad para apoyar políticas para conservar la biodiversidad, combatir y mitigar el cambio climático global. Sin embargo, proteger estas inmensas áreas es un desafío que requiere acciones estructuradas y articuladas de los órganos responsables, cambios en la legislación, consolidación de la integración del aspecto sociocultural y pago por los servicios ambientales prestados.

Palabras clave: Comunidades indígenas; incendios forestales; quemas; Ibama; Prevfogo.

Introdução

As terras indígenas brasileiras (TIs) somam 1.170.674,1Km^2 preservados, correspondem a 13% do território nacional e apresentam excelentes indicadores ambientais, especialmente nos biomas Amazônia e Cerrado. Essas áreas são fundamentais para enfrentar os problemas ambientais, como a perda da biodiversidade e as mudanças climáticas globais, prestando diversos serviços ecossistêmicos (Crisostomo *et al.*, 2015; Ding *et al.*, 2016). Dentre as ameaças à manutenção dessas áreas, estão os incêndios florestais, que têm sido agravados por políticas de "fogo-zero" e pelas mudanças do clima (Nobre *et al.*, 2008; Moritz *et al.*, 2012; Durigan & Ratter, 2016; Fidelis *et al.*, 2018; Flannigan, 2019; Bilbao *et al.*, 2020).

Os ecossistemas podem apresentar diferentes respostas em relação aos efeitos do fogo. Existem ecossistemas sensíveis, que são prejudicados pelo fogo, pois evoluíram sem ele e não desenvolveram adaptações, como a maioria das florestas tropicais e subtropicais. Por outro lado, existem ecossistemas dependentes, que podem ser beneficiados pelo fogo, já que evoluíram na sua presença e desenvolveram adaptações específicas, como é o caso da maior parte das savanas tropicais (Bond *et al.*, 2005; Myers, 2006; Miranda *et al.*, 2010; Simon & Pennington, 2012). Os primeiros humanos que chegaram ao continente sul americano, há milhares de anos, devem ter compreendido essas diferenças e aprendido a utilizar o fogo para manejar os recursos naturais, acumulando um conhecimento empírico sobre os seus efeitos nos ecossistemas. Como exemplo, podemos observar que as comunidades que vivem nas florestas utilizam o fogo de forma mais restrita e cuidadosa, como na abertura de roças, limpeza de pátios e proteção das aldeias, resultando na detecção de menos focos de calor do que no entorno (Nepstad *et al.*, 2006). As comunidades que vivem nas savanas usam o fogo de forma muito mais ampla, inclusive em grandes queimadas para caça e no manejo da paisagem (Anderson & Posey, 1989; Mistry *et al.*, 2005; Melo & Saito, 2012; Welch *et al.*, 2013; Mistry *et al.*, 2016), resultando em uma detecção muito maior de focos de calor (Andrade *et al.*, 2013; Abreu & Souza, 2016). Este uso sistêmico do fogo nas savanas e o conhecimento escasso sobre a ecologia

do fogo nos ecossistemas brasileiros levaram, muitas vezes, a um entendimento equivocado das práticas de manejo da paisagem realizadas pelos povos indígenas (Leonel, 2000). A consequência dessa má interpretação foi a implementação de programas de governo focados em políticas de supressão total do fogo, ou políticas de "fogo-zero", que não consideravam a importância do uso do fogo (Brasil, 1989; Proarco, 1998; Mutch, 2001; Ibama, 2008).

Os programas de proteção contra os incêndios florestais no Brasil começaram a ser fortalecidos após o megaincêndio de Roraima (Kirchhoff, 1998), quando foram criadas estruturas especializadas em prevenção e combate, dentre elas o Centro Nacional de Prevenção e Combate aos Incêndios Florestai (Prevfogo), do Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Ibama) (Brasil, 1998). Algumas políticas públicas implementadas tiveram êxito e permanecem até hoje, a exemplo da contratação de mão de obra local como brigadistas e do uso do monitoramento via satélite (Morais, 2004). Outras iniciativas, como a formação de brigadas voluntárias e comunitárias, não apresentaram bons resultados e foram abandonadas (Proarco, 1998; Falleiro *et al*., 2011; Brasil, 2012). As primeiras ações realizadas pelo Prevfogo/Ibama dentro das TIs foram a formação de brigadas indígenas voluntárias e comunitárias, baseadas nas "políticas de fogo zero" e na realização de capacitação seguida da doação de equipamentos (Ibama, 2010). Posteriormente, alguns indígenas começaram a ser contratados para atuar nas brigadas formadas para proteger as unidades de conservação federais (UCs) ou no Programa de Brigadas nos Municípios Críticos (Brasil, 2007; Ibama, 2008, 2010a). A Tabela 1 apresenta uma compilação das informações sobre esse período, pesquisadas na Internet, nos arquivos do Prevfogo ou resgatadas junto aos servidores e colaboradores mais antigos.

A partir de 2007, no oeste do Mato Grosso, uma série de atividades conjuntas entre a Coordenação Estadual do Prevfogo/Ibama-Cuiabá e a Coordenação Regional da Fundação Nacional do Índio (Funai) de Tangará da Serra começaram a ser implementadas e registradas (Ibama, 2007; Ibama, 2008, 2008a, 2008b). Os documentos técnicos gerados passaram a incluir o uso do conhecimento tradicional indígena e do manejo com fogo nas estratégias de proteção do cerrado. Entretanto, essas atividades ainda eram baseadas exclusivamente no trabalho voluntário, uma vez que o Ibama só podia contratar brigadistas para atuar nas UCs. (Falleiro *et al*., 2011a).

A possibilidade de contratação de indígenas pelo Ibama começou a ser mais factível a partir de 2008, quando as brigadas das UCs começaram gradativamente a serem geridas pelo Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio) e o Prevfogo/Ibama passou a direcionar seus recursos para o Programa de Brigadas nos Municípios Críticos (Ibama, 2008). Muitas coordenações estaduais do Prevfogo/Ibama aproveitaram a oportunidade para contratar os brigadistas indígenas que já haviam sido capacitados como voluntários (Tabela 1), aumentando a eficiência de proteção das Terras Indígenas atendidas. As brigadas municipais de Brasnorte/MT, Tocantínia/TO e Pacaraima/RR, formadas predominantemente por indígenas, foram as pioneiras que abriram o caminho para uma integração cada vez maior entre o órgão ambiental federal e as comunidades indígenas.

A migração gradual das brigadas municipais para o interior das TIs, realizada pelas coordenações estaduais do Prevfogo/Ibama, coincidiu com o aumento das atividades de outras instituições, estaduais ou privadas, dentro dessas áreas. Paralelamente, iniciou a implementação da Política Nacional de Gestão Territorial e Ambiental de Terras Indígenas (PNGATI) (Brasil, 2012), que levou a Funai a implementar outras ações de prevenção e monitoramento nas TIs (Lacerda, 2013). Desta forma, os programas de proteção contra os incêndios florestais, realizados tanto pelos órgãos governamentais como por organizações não governamentais, começaram a se multiplicar. Essa proliferação de atividades, sem diretrizes claras ou autorizações formais, acabou resultando em conflitos entre instituições (Mongabay, 2010; CBM/MT, 2008, 2012) e descontrole sobre a gestão das TIs pelo órgão indigenista oficial. A Funai passa então a pressionar o órgão ambiental federal a assumir as suas atribuições (Ibama, 2010a; Funai, 2012; Funai, 2012a).

A criação de um programa específico para as terras indígenas, que integrasse as instituições e organizasse as ações implementadas, era urgente. A oportunidade surgiu com uma mudança na legislação, que obrigou o Prevfogo/Ibama a direcionar suas ações para a esfera de atuação federal (Brasil, 2011). Em 2013 o Programa de

Tabela 1 – Informações sobre brigadas indígenas não relacionadas diretamente ao Programa Brigadas Federais (BRIFs) do Prevfogo/Ibama.

Brigadas indígenas voluntárias ou comunitárias[1]				
Etnia	**Local**	**Ano**	**Órgão responsável**	**Fonte**
Pataxó	Parna Monte Pascoal/BA	1995-96	Ibama/Prevfogo	Paulo Cezar Mendes Ramos[11]
Pataxó	Parna Descobrimento/BA	1998	Ibama/Prevfogo	Paulo Cezar Mendes Ramos[11]
Macuxi	TI São Marcos/RR	1998	Ibama/Prevfogo/Proarco	Antonio Carlos M. Cattaneo[12]
Macuxi	TI São Marcos/RR	1999	Ibama/Prevfogo/Proarco	Antonio Carlos M. Cattaneo[12]
Diversas	Tis do lavrado/RR	2000-2003	Proarco[2]	Paulo Cezar Mendes Ramos[10]
Kadiwéu	TI Kadiwéu/MS	2001	Ibama/Prevfogo, CI[3] e CBM/MS[4]	Márcio Ferreira Yule[13]
Macuxi	TI Raposa Serra do Sol/RR	2002	Ibama/Prevfogo	Celso Luis Ambrósio[14]
Xavante	TI São Marcos/MT	2003	Ibama/Prevfogo	Rodrigo de Moraes Falleiro[15]
Kayapó	TI Capoto-Jarina e Xingu	2007	CBM/MT[5]	Mato Grosso, 2009
Macuxi e Taurepang	TI São Marcos	2008	Ibama/Prevfogo	Joaquim Pereira Parimé[16]
Nambikwara	TI Tirecatinga/MT	2008	Ibama/Prevfogo	Ibama, 2008a
Paresi	TI Paresi/MT	2008	Ibama/Prevfogo	Falleiro, 2011, 2011a
Manoki	TI Irantxe/MT	2008	Ibama/Prevfogo	Ibama, 2008b
Myky	TI Myky/MT	2008	Ibama/Prevfogo	Ibama, 2008c
Diversas	Bacia do Alto Xingu/MT	2008	CBM/MT[5]	Mato Grosso, 2009
Kayapó	TI Capoto-Jarina e Xingu	2008	CBM/MT[5]	CBM/MT, 2008.
Kawaieté	TI Xingu	2009	ISA[6] e Guarany	ISA, 2009
Paresi	Tangará da Serra/MT	2009-2010	Funai e Prefeitura	Maristella Aparecida Corrêa[17]
Diversas	Bacias do Xingu e Araguaia	2010	CBM/MT[5], AT[7] e US Forest Service[8]	Mongabay, 2010
Kayapó e Juruna	Ti Capoto-Jarina	2010	CBM/MT[5] e Guarany	Guarany Ind. Com. Ltda
Enawenê-Nawê	TI Enawenê-Nawê/MT	2011	ICMBio e OPAN[9]	ICMBio, 2011
Macuxi (Maturuca)	TI Raposa Serra do Sol/RR	2011	Ibama/Prevfogo e CIMI[10,9]	Joaquim Pereira Parimé[16]
Diversas	Tis do lavrado de Roraima	2011	Ibama/Prevfogo e CIMI[10,9]	Joaquim Pereira Parimé[16]
Krahô	TI Kraholândia/TO	2011	Funai	Funai, 2011
Brigadas contratadas formadas com indígenas nas unidades de conservação federais (Ibama 2001-2008) ou ICMBio (2009-2019) e nos municípios críticos: Ibama (2008-2012)				
Etnia	**Local**	**Ano**	**Órgão responsável**	**Fonte**
Kadiwéu	PARNA Serra da Bodoquena/MS	2002-2008	Ibama/Prevfogo	Márcio Ferreira Yule[13]
Manoki e Myky	Brasnorte/MT	2008-2012	Ibama/Prevfogo	Falleiro et al., 2011; 2016
Xerente	Tocantínia/TO	2008-2012	Ibama/Prevfogo	Vanderlei Gramma Pereira[18]
Taurepang e Macuxi	Pacaraima/RR	2008-2012	Ibama/Prevfogo	Joaquim Pereira Parimé[16]
Akrãtikatêjê	Bom Jesus do Tocantins/PA	2009-2010	Ibama/Prevfogo	Antônio Balderramas[19]
Pataxó	Porto Seguro/BA	2010	Ibama/Prevfogo	Ibama, 2010
Rikbaktsa	Juína/MT	2011	Ibama/Prevfogo	Cendi Ribas Berni[20]
Wapichana e Macuxi	Cantá/RR	2012	Ibama/Prevfogo	Joaquim Pereira Parimé[16]
Paresi	Tangará da Serra/MT	2011-2012	Ibama/Prevfogo	Maristella Aparecida Corrêa[17]
Suruí	São Geraldo do Araguaia/PA	2011-2012	Ibama/Prevfogo	Diego Gruimarães[21]
Karitana	Flona Bom Futuro/RO	2015	ICMBio	ICMBio, 2015

[1] Esses dados podem apresentar erros e omissões, uma vez que muitas pessoas não responderam aos e-mails solicitando informações. Além disso, muitos projetos, documentos, relatórios e resultados dessas atividades não foram encaminhados aos órgãos responsáveis, resultando na perda das informações e das experiências adquiridas.

[2] Programa de Prevenção e Controle às Queimadas e aos Incêndios Florestais no Arco do Desflorestamento; [3] ONG Conservação Internacional; [4,5] Corpo de Bombeiros Militar Estadual; [6] ONG Instituto Socioambiental; [7] ONG Aliança da Terra; [8] Serviço Florestal dos Estados Unidos; [9] ONG Operação Amazônia Nativa; [10] Conselho Indígena Missionário; [11] Ibama/Prevfogo Sede; [12] Ibama/Prevfogo RR; [13] Ibama/Prevfogo MS; [14] Ibama Prevfogo Sede, AP e SP; [15] Ibama/Prevfogo MT, SE e Sede; [16] Ibama/Prevfogo RR, [17] Funai MT/CR Tangará da Serra; [18] Ibama/Prevfogo TO; [19] Ibama/Prevfogo PA; [20] Ibama/Prevfogo MT e Sede e [21] Ibama/Prevfogo PA e GO.

Brigadas nos Municípios Críticos foi substituído pelo Programa Brigadas Federais, que dedicou grande parte dos recursos para a formação de brigadas indígenas (BRIFs-I), dentre outras categorias de brigadas (Ibama, 2013). A atuação do órgão dentro das TIs e o uso do conhecimento tradicional do fogo foram formalizados por meio de Acordos de Cooperação Técnica celebrados com a Funai (Brasil, 2013, 2019). Desde então, procedimentos administrativos e técnicos foram adaptados para esse novo público, por meio da elaboração de novos materiais didáticos (Ibama, 2017, 2017a) e da capacitação dos indígenas como brigadistas, chefes de esquadrão, chefes de brigadas, gerentes, instrutores de brigadas e especialistas em manejo integrado do fogo (Falleiro *et al.*, 2016).

Atualmente (2020) o programa protege 222.812,3km^2 e contrata indígenas de dezenas de grupos étnicos diferentes, responsáveis pela implementação das atividades de manejo do fogo, como prevenção, preparação, combate aos incêndios florestais e uso controlado do fogo. O conhecimento tradicional sobre o manejo do fogo foi resgatado e sistematizado (Falleiro, 2011a; Ibama, 2018), sendo utilizado nas estratégias de proteção que, aos poucos, estão substituindo as "políticas de fogo-zero". As queimas prescritas tradicionais estão sendo cada vez mais utilizadas na conservação das savanas brasileiras, sendo registradas por meio de planos de queima e avaliadas em campo. Parcerias com instituições científicas estão em andamento para ampliar essas pesquisas (CNPq, 2018), buscando gerar conhecimentos sobre e ecologia do fogo e aperfeiçoar cada vez mais o manejo dessas áreas.

O objetivo do presente trabalho é apresentar os principais resultados do Programa Brigadas Federais nas Terras Indígenas, por meio da compilação e análise de diversos documentos técnicos produzidos ao longo dos últimos anos. O artigo é uma complementação das apresentações realizadas na 7º Conferência Internacional de Incêndios Florestais, durante a Sessão Especial "Savanna Burning Challenges and Opportunities", bem como das apresentações orais do Subtema 1: Papel/Contribuição da Sociedade Civil no Manejo Integrado do Fogo (MIF) (Falleiro, 2020, 2020a). As experiências adquiridas durante a implementação desse programa podem auxiliar na proteção contra os incêndios florestais em outras áreas com aspectos sociais ou ecológicos semelhantes, de forma a garantir a proteção das florestas e savanas tropicais protegidas pelas comunidades autóctones.

Material e Métodos

Para elaborar o presente artigo foram analisados diversos documentos gerados durante a implementação e o monitoramento do Programa Brigadas Federais pelo Prevfogo/Ibama (Tabela 2). As informações coletadas foram sistematizadas e transformadas em gráficos e tabelas para subsidiar as discussões. Os resultados foram divididos em cinco subtópicos:

- Dados Gerais do Programa Brigadas Federais: foi realizada uma comparação entre o Programa Brigadas Federais como um todo e as brigadas indígenas. Foram analisadas as áreas protegidas, o número de brigadistas contratados, custos e algumas outras informações específicas sobre cada brigada indígena;
- Manejo Integrado do Fogo nas Terras Indígenas: foi realizada uma comparação entre o Programa Brigadas Federais como um todo e as brigadas indígenas. Foram analisadas a quantidade de atividades de prevenção, supressão de incêndios florestais, uso controlado do fogo, recuperação de áreas degradadas e de substituição do uso do fogo na agropecuária implementadas. Para o cálculo das áreas queimadas (queimas prescritas ou incêndios florestais), foram selecionadas 15 TIs, com extensão superior a 1.000km^2, para reduzir os erros acentuados de omissão devido à resolução de 500m e ao caráter generalista da metodologia utilizada (Chuvieco *et al.*, 2016; Padilla *et al.*, 2015). Essas TIs foram Araguaia, Xingu, Kraholândia, Tenharim-Marmelos, Raposa Serra do Sol, São Marcos, Araribóia, Apinajé, Xerente, Paresi, Utiariti, Uaçá, Baú, Mekragnoti e Kadiwéu;
- Uso do Conhecimento Tradicional no Manejo das Savanas com Fogo: foi apresentado um resumo dos principais resultados da aplicação dos regimes tradicionais de queima do cerrado. Os regimes de fogo e épocas de queima são melhor descritos no final deste tópico;

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- Principais Problemas Verificados no Programa: foram apresentados os principais problemas relacionados às condições de trabalho dos chefes das brigadas, infraestrutura das bases e condições gerais de trabalho, por meio de questionário dicotômico do tipo sim/não. Adicionalmente, foram analisados alguns problemas encaminhados à coordenação nacional do Programa Brigadas Federais de forma não sistematizada, mas que foram relatados pelos brigadistas;
- Desafios e Oportunidades: foram discutidas as oportunidades e desafios da proteção das terras indígenas contra os incêndios florestais.

Tabela 2 – Subtópicos, parâmetros avaliados, documentos utilizados e fontes de pesquisa.

Subtópico	Parâmetros	Documentos	Fonte
Dados gerais do Programa Brigadas Federais	Área protegida, quantidade de brigadistas, custos do programa e informações gerais sobre as brigadas indígenas.	Relatórios Anuais do NOC[1], sites da internet e planilhas internas de controle.	Ibama, 2016; 2017c; 2018a; 2019; Funai, 2020a e arquivo Prevfogo.
Manejo Integrado do Fogo nas Terras Indígenas	Quantidade de atividades de educação ambiental, aceiramento, queima prescrita, queima controlada, supressão de incêndios florestias, operações de combate ampliado, sistemas agrolorestais e recuperação de áreas degradadas. Áreas manejadas com queimas prescritas ou atingidas por incêndios florestais.	Relatórios Anuais do NOC[1], Relatórios Mensais das BRIFs, planilhas internas de controle e sites da internet. Planilha de áreas queimadas calculada pelo pelo produto MCD64 (Chuvieco, 2016).	Ibama, 2016; 2017c; 2018a; 2019; Arquivo Prevfogo e CIMAN[2], 2020.
Uso do conhecimento tradicional no manejo das savanas com fogo	Efeito de três regimes de fogo (exclusão do fogo, queimas prescritas e incêndios florestais) na mortalidade, severiddade, reprodução, perda de frutos e produção de frutos de árvores frutíferas nativas. Efeito na presença de fauna. Efeito de três épocas de queima prescrita (estação chuvosa, início da estação seca e metade da estação seca) na mortalidade, severidade, reprodução, perda de estruturas reprodutivas e produção de frutos de árvores frutíferas nativas.	Artigos em revistas especializadas, resumos em congressos ou conferências e documentos internos.	Ibama, 2018; Falleiro, 2011a; 2016; 2020, 2020a; Xerente, 2019 e Santana, 2019.
Principais problemas verificados no Programa Brigadas Federais.	Condições de trabalho dos chefes de brigada, estrutura das sases das brigadas e condições gerais de trabalho.	Relatórios Anuais do NOC[1], relatórios de supervisão das brigadas, sites da internet e planilhas internas de controle.	Ibama, 2016; 2017c; 2018a; 2019 e arquivo Prevfogo.
Oportunidades e desafios	Dimensão das Terras Indígenas brasileiras, das savanas tropicais e da área coberta pelo Programa Brigadas Federais.	Sites da internet.	Funai, 2020.

[1] NOC: Núcleo de Operações e Combate do Prevfogo/Ibama Sede.

[2] CIMAN: Centro Integrado Multiagências de Cooperação Operacional: http://queimadas.dgi.inpe.br/queimadas/ciman.

O subtópico "Uso do Conhecimento Tradicional no Manejo das Savanas com Fogo" utilizou uma metodologia mais complexa, que merece ser melhor descrita. Regimes de fogo e épocas de queima foram definidos por meio de um trabalho denominado "Resgate do Conhecimento Tradicional do Fogo" (Ibama, 2007a; Falleiro, 2011a; Ibama, 2018), representado, de forma resumida, na Figura 1. Segundo os indígenas, o cerrado necessita do fogo para se manter saudável,

o que é reforçado por diversos estudos do bioma (Pivelo, 2006; Oliveiras *et al.*, 2012; Schmidt, 2018). Entretanto, quando o fogo ocorre na época errada, a partir da metade da estação seca até a metade da estação chuvosa, os danos para as plantas e animais são muito altos (fogo ruim). Por outro lado, se o fogo ocorre na época certa, no final da estação chuvosa e início da estação seca, os danos são baixos e as plantas e animais são beneficiados (fogo bom). Essa dicotomia entre fogo bom e ruim tem sido uma abordagem comum na implementação do MIF no Brasil, abrangendo também outras atividades relacionadas ao uso do fogo (Berlinck & Batista, 2020).

Fogo bom: período ideal para a realização das queimadas prescritas.

Fogo ruim: período de ocorrência dos incêndios florestais.

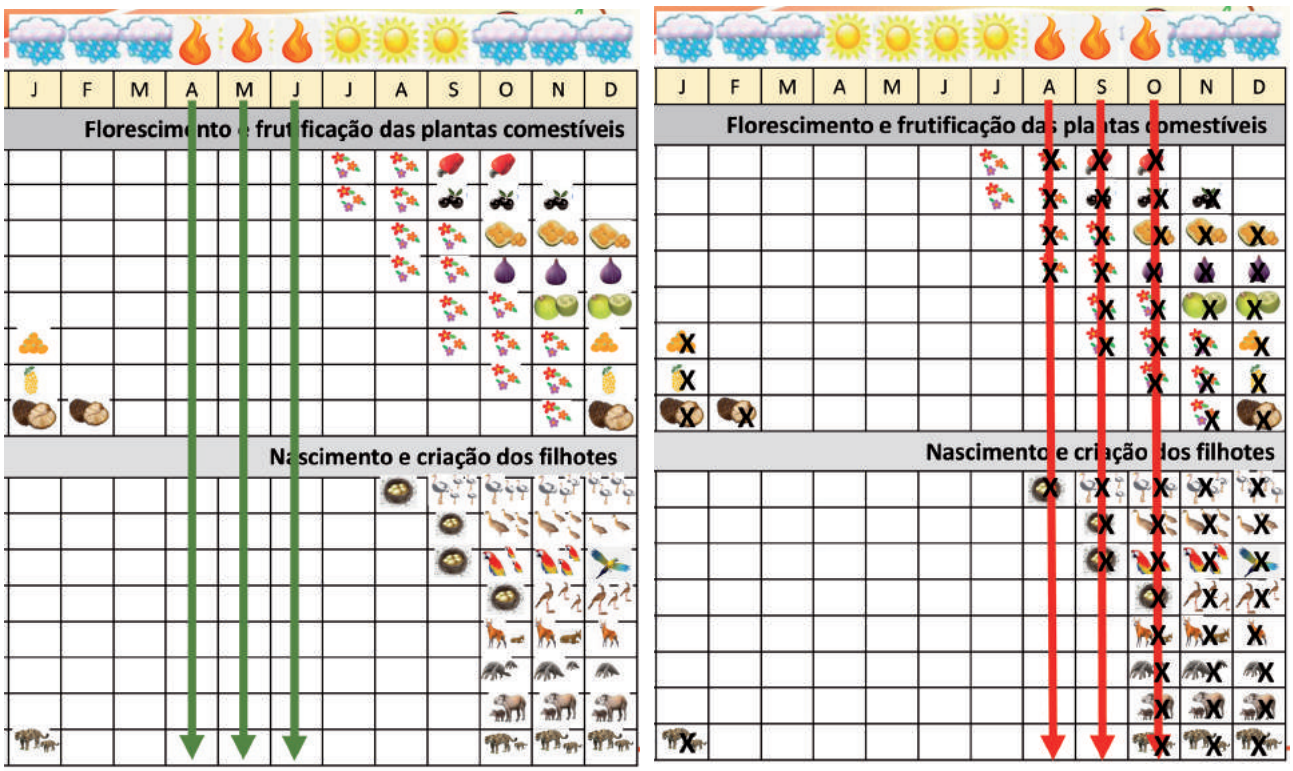

Figura 1 – Exemplo de representação gráfica do "fogo bom" e "fogo ruim" em relação ao ciclo anual das principais plantas e animais do cerrado, de acordo com etnia Xerente. Adaptado de Falleiro (2011).

O período do "fogo bom" para a realização das queimas prescritas pode variar dependendo da localização da TI e dos objetivos de manejo (Figura 2). As TIs localizadas mais ao sul do bioma cerrado apresentaram algumas diferenças em relação àquelas situadas mais ao norte, ou que são influenciadas pela inundação, como os Parques Indígenas do Xingu e Araguaia. Em relação aos objetivos de manejo, geralmente as comunidades utilizam o fogo durante um período amplo para manejar o combustível florestal ou aceirar aldeias e florestas. As queimadas realizadas com esses objetivos foram classificadas como queimas de proteção. Entretanto, algumas comunidades indicaram um período mais específico, situado entre abril e maio, onde as queimas resultam em uma alta produtividade de frutos comestíveis, sendo denominado de "queima de frutificação". Baseados nessas informações, foram definidos os regimes de fogo e épocas de queima descritos abaixo e representados na Figura 2.

Regimes de fogo

- Exclusão do fogo (EF): áreas com mais de 5 anos sem fogo;

- Incêndio florestal (IF): áreas atingidas pelo fogo durante o período considerado inadequado pelas comunidades (fogo ruim);
- Queimada prescrita (QP): áreas manejadas com fogo durante o período indicado pelas comunidades (fogo bom).

Épocas das queimas prescritas

- Queima prescrita na estação chuvosa: as primeiras queimas do ano, realizadas na estação chuvosa, muitas vezes coincidindo com períodos de interrupção das chuvas conhecidos como "veranicos" (Assad *et al.*, 1993).
- Queima prescrita no início da estação seca: as queimas realizadas durante o início da estação seca, com o objetivo de simular as "queimas de frutificação" (Ibama, 2018);
- Queimas prescritas na metade da estação seca: as últimas queimas aplicadas, que coincidem com a época mais utilizada no manejo e nas pesquisas (Gomes *et al.*, 2018).

Estações do ano[1] →	Chuvosa			Seca						Chuvosa		
	Metade	Final		Início		Metade		Final		Início		Metade
Meses do ano →	Jan.	Fev.	Mar.	Abr.	Mai	Jun.	Jul.	Ago.	Set.	Out	Nov.	Dez.
Épocas de queima →					Queima Precoce		Queima Modal		Queima Tardia			
citadas na bibliografia[2]												
Grupos étnicos ↓	Época e objetivo das queimas tradicionais nas áreas bem drenadas ou localizadas na região central e oeste do bioma ↓											
Bakairi/MT				Frutificação								
Xerente/TO				Frutificação		Proteção						
Krahô/TO				Frutificação		Proteção						
Paresi/MT		Proteção		Frutificação		Proteção						
Kalunga/GO	Proteção					Proteção						
Regime de Fogo das BRIFs[3] do Prevfogo →	Queimas Prescritas						Incêndios Florestais					
Época das queimas prescritas nas BRIFs[1] →	Estação Chuvosa			Início da Estação Seca		Metade da Estação Seca	Época em que o manejo com fogo não é recomendado					
Grupos étnicos ↓	Época e objetivo das queimas tradicionais nas áreas alagadas ou localizadas na região nordeste do bioma ↓											
Gavião/MA				Frutificação		Proteção						
Guajajara/MA				Frutificação			Proteção					
Krikati/MA				Proteção								
Kanela/MA				Proteção								
Alto Xingu/MT[4]				Proteção								
Araguaia/TO[5]				Proteção								
Regime de Fogo das BRIFs[3] do Prevfogo →	Queimas Prescritas						Incêndios Florestais					
Época das queimas prescritas nas BRIFs[1] →	Estação Chuvosa			Início da Estação Seca		Metade da Estação Seca	Época em que o manejo com fogo não é recomendado					

[1] Adaptado de Silva *et al*. 2008. [2] Baseado em Gomes 2018, Miranda 2010, Moura 2018, Rissi 2017, Sato 2003, Schmidt 2016 e Schmidt 2017BRIFs: Programa Brigadas Federais do Ibama/Prevfogo nas Terras Indígenas e Territórios Quilombolas (Falleiro 2016, 2021).[4] Inclui as etnias Mehinako, Kalapalo, Naruvôtu, Kuikuro, Yawalapiti, Aweti, Kamayurá, Matipú, Nafukuá, Trumai e Waurá das TIs Pequizal do Naruvôtu e Parque Indígena do Xingu (Ibama 2018).[5] Inclui as etnias Karajá, Javaé, Tapirapé e Avá-Canoeiro da TI Parque Indígena do Araguaia (Ibama 2018).

Figura 2 – Mês, época do ano e objetivo de manejo das queimas prescritas recomendadas em cada uma das terras indígenas e territórios quilombolas manejados.

Os regimes de fogo e as épocas de queima prescrita foram avaliados nas árvores frutíferas nativas importantes para as comunidades, por meio da análise da mortalidade de indivíduos adultos, severidade, taxa de reprodução, perda de estruturas reprodutivas e produção de frutos, além da frequência de vestígios de animais (fauna). Para coletar os dados em campo, foi desenvolvida uma metodologia específica para o programa, com base nos princípios da "Ciência Cidadã" (Bonney *et al.*, 2016; Dickinson *et al.*, 2012; Rotman *et al.*, 2012), que proporcionasse o envolvimento dos brigadistas no monitoramento e avaliação (Schmidt *et al.*, 2018; Falleiro *et al.*, 2021). Os dados coletados foram analisados estatisticamente com a utilização de modelos lineares de efeitos mistos (Zurr *et al.*, 2007) e comparados utilizando o teste de Tukey (p 0,05). No final do presente

artigo é apresentado um resumo dos resultados, que estão sendo detalhados em artigos específicos para cada espécie estudada.

Resultados e Discussão

Dados gerais do Programa Brigadas Federais

A Tabela 3 apresenta os dados gerais do Programa Brigadas Federais entre 2013 e 2019. Embora o Ibama contasse com permissão para contratar todos os anos até 2.520 brigadistas (Brasil, 2008), a quantidade anual variou entre 1.706 (2014) e 952 (2016), devido a limitações orçamentárias e contingenciamentos de recursos. A área total atendida pelo programa também teve variações ao longo dos anos, sendo a maior em 2018, com 234,6 mil km², e a menor em 2013, com 105,8 mil km². A proporção de brigadistas por km² variou entre 1/66,4 (2013) e 1/189,6 (2016).

Tabela 3 – Área protegida e número total de brigadistas do Programa Brigadas Federais[1] e das Brigadas Indígenas entre 2013 e 2019.

	Todas as Brigadas Federais						
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Área (Km²)	105.788,07	180.788,16	204.726,64	180.482,22	195.594,00	234.656,73	203.161,68
Brigadistas	1.593	1.706	1.413	952	1.079	1.525	1.459
	Brigadas Indígenas						
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Área (Km²)	64.252,59	145.080,28	171.402,65	170.309,52	185.795,18	225.301,69	172.772,69
Brigadistas	412	504	593	531	529	711	717

[1] Além das Brigadas Indígenas-BRIFs-I, o Programa Brigadas Federais contrata brigadas tipo BRIFs-A: projetos de assentamento da reforma agrária, BRIFs-Q: territórios quilombolas, BRIFs-E: especializadas por biomas e BRIFs-PE: pronto emprego para grandes operações de combate (Ibama, 2013).

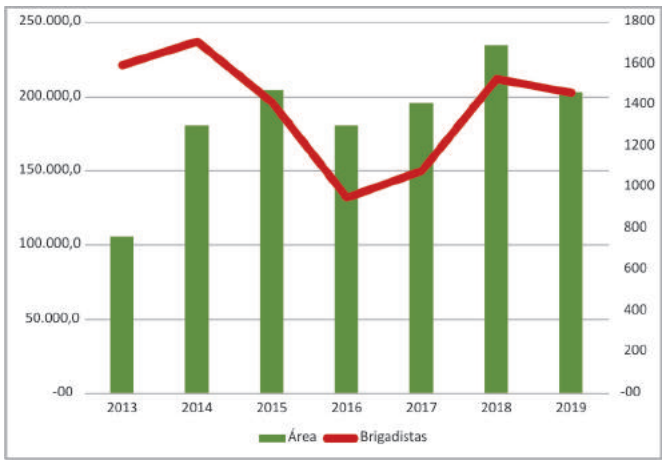

Figura 3 – Área total atendida pelo Programa BRIFs (Km²) e o número total de brigadistas entre 2013 e 2019.

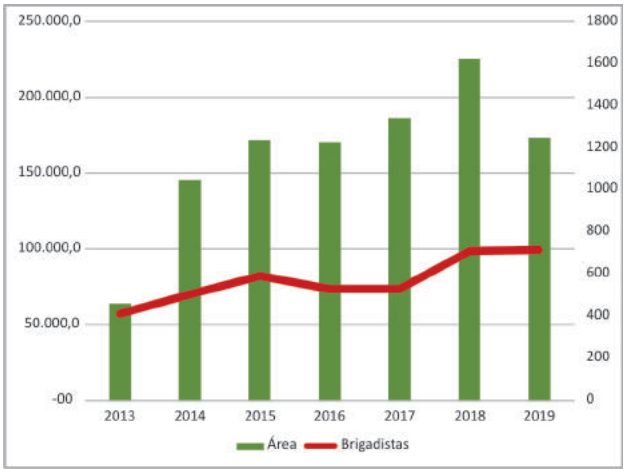

Figura 4 – Área das terras indígenas atendidas pelas BRIFs-I (Km²) e o número total de brigadistas indígenas entre 2013 e 2019.

A partir de 2016, o número de brigadistas indígenas passou a representar, aproximadamente, a metade do contingente total do programa, apesar das TIs representarem, em média, 86,9% das áreas atendidas (Tabela 3 e Figuras 3 e 4). A proporção de brigadistas indígenas por Km^2 variou entre 1/155,1 (2013) e 1/351,2 (2017). Embora esses números possam parecer desproporcionais, existem algumas particularidades na análise de brigadistas por área que devem ser consideradas. Por exemplo, proteger a TI Mekragnotire, com florestas preservadas e pouco povoadas, pode ser mais fácil do que proteger a TI Araribóia, com florestas degradadas e densamente povoadas, apesar da enorme diferença de tamanho entre elas. De forma geral, muitas áreas necessitam apenas de um aporte mínimo de brigadistas para implementar atividades de prevenção, extinguir pequenos incêndios e manter o monitoramento constante. Desde que, sempre que necessário, possam contar com ajuda imediata de brigadas de reforço especializadas. Em outras palavras, boa organização, monitoramento integrado e despacho rápido de recursos podem gerar melhores resultados quando comparados ao simples aumento do número de brigadistas por área. Dessa forma, a formação de brigadas de pronto emprego, preparadas para dar suporte em grandes operações de combate ou em atividades especializadas, deve ser vista como ação complementar às brigadas locais.

A Tabela 4 apresenta algumas informações sobre as TIs que receberam brigadas. Pode-se verificar que o programa atende principalmente as áreas localizadas nos biomas Cerrado e Amazônia. Isto se deve ao fato de que as TIs nesses biomas apresentam maior dimensão, áreas mais preservadas e muitos problemas causados pelos incêndios florestais. Além disso, a proporção de áreas de savana tropical é um fator importante para definir as estratégias de proteção, uma vez que podem ser manejadas por meio de queimas prescritas, conforme será discutido no final deste artigo.

A partir da atuação da primeira brigada contratada dentro de uma TI, a tendência é a ampliação do número de brigadistas nos anos seguintes. O Ibama/Prevfogo tem evitado ao máximo reduzir a quantidade de brigadistas ou interromper o programa nessas áreas, uma vez que já trabalha com recursos ínfimos em relação à área protegida. Entretanto, no decurso do programa, algumas brigadas apresentaram baixa eficiência, problemas disciplinares, grandes dificuldades logísticas ou baixo apoio das comunidades e das instituições parceiras. Nestes casos, foram canceladas e transferidas para outras áreas. Dessa forma, as brigadas das TIs Kanela, Bacurizinho, Limão Verde, Tapirapé-Karajá, Wawi, Alto Turiaçú e Kayapó foram canceladas e a TI Governador teve uma interrupção de 02 anos. As demais TIs com baixo número de brigadistas e de anos com brigadas foram incorporadas recentemente ao programa.

Cabe ressaltar que as brigadas indígenas, apesar de serem vinculadas a uma determinada área de atuação, também realizam atividades em outras áreas, denominadas áreas de apoio (Ibama, 2013; 2017). Desta forma, o Programa Brigadas Federais, por meio dos diversos tipos de brigadas (indígenas, assentamentos, quilombolas, especializadas e pronto emprego) apoiaram a proteção de 151.082,6Km^2 em 2016, 113.073,7Km^2 em 2017, 131.584,6Km^2 em 2018 e 216.709,1Km^2 em 2019; dentre unidades de conservação federais, estaduais, municipais e particulares (RPPNs), projetos de assentamento, territórios quilombolas e terras indígenas, que não foram contempladas diretamente com a implementação de uma brigada local (Ibama, 2016, 2017c, 2018a e 2019).

A Tabela 5 apresenta os custos do programa. O investimento médio por hectare é de R$ 1,5. Parte desses custos deveriam ser cobertos por projetos de pagamento pelos serviços ambientais prestados pelas comunidades, como sequestro de CO_2, proteção dos recursos hídricos e da sociobiodiversidade. Esse tema é retomado no final do artigo, durante as discussões sobre oportunidades e desafios.

Manejo integrado do fogo nas terras indígenas

O manejo integrado do fogo (Myers, 2006) pode ser entendido como a integração entre o manejo (prevenção, preparação, supressão e uso do fogo) com as necessidades sociais (econômicas e culturais) e a ecologia do fogo. A partir do ano de 2016, parte das atividades de manejo realizadas pelas BRIFs passaram a ser registradas por meio de relatórios mensais do Núcleo de Operação de Combate (Prevfogo/Ibama). Os principais resultados são apresentados nas Tabelas 6 a9.

Tabela 4 – Unidade Federativa (UF), nome, população local, número de etnias residentes, biomas, área total (km^2), área de savanas (%) e o número total de brigadistas contratados/número total de anos com brigadas entre 2013 e 2019 nas terras indígenas atendidas pelo Programa Brigadas Federais.

UF	Terras Indígenas	População	Etnias	Bioma	Área (ha)	% Savanas	Brigadistas/anos
TO	Araguaia	3.502	3	Cerrado	1.358.499,0	94,5	355/7
MT	Xingu	6.090	16	Amazônia	2.642.003,9	23,2	218/5
TO	Kraolândia	2.989	1	Cerrado	302.533,0	87,5	201/7
RR	Raposa Serra do Sol	23.119	6	Amazônia	1.747.465,0	72,4	190/7
AM	Tenharim-Marmelos	535	1	Amazônia	497.521,75	28,0	187/7
TO	Xerente/Funil	3.041	1	Cerrado	183.245,9	70,0	187/7
MS	Kadiwéu	1.697	4	Pantanal/Cerrado	538.535,8	71,6	163/7
MA	Araribóia	5.317	2	Amazônia/Cerrado	413.288,0	3,0	157/6
TO	Apinajé	2.342	1	Cerrado	141.904,0	75,5	147/6
MG	Xacriabá	7.999	1	Cerrado	46.415,9	44,1	143/7
MT	Paresi/Formoso	1.085	1	Cerrado	583.381,0	75,2	142/7
MT	Bakairi	734	1	Cerrado	61.405,5	70,0	131/7
RR	São Marcos	5.838	3	Amazônia	654.110,0	51,0	131/7
RR	Araçá	2.016	2	Amazônia	50.018,0	73,1	103/7
RR	Tabalascada/Canauanim/Malacacheta	527	3	Amazônia	52.827,8	21,4	103/7
BA	Coroa Vermelha	1.546	1	Mata Atlântica	1.495,0	0,0	101/7
GO	Avá-Canoeiro	7	1	Cerrado	38.000,0	39,1	101/7
MA	Bacurizinho	3.663	1	Cerrado	82.432,5	50,0	100/7
MS	Limão Verde	1.267	2	Cerrado	6.045,4	13,7	97/7
MA	Governador	655	3	Cerrado	41.643,0	21,6	89/5
MA	Porquinhos	667	1	Cerrado	79.520,0	69,8	88/6
MT	Utiariti	406	4	Cerrado	412.304,0	66,1	88/6
AP	Uaçá I e II	4.462	3	Amazônia	470.164,0	38,2	86/6
PA	Baú	188	1	Amazônia	1.540.000,0	0,0	86/6
PA	Mekragnotire	1.588	1	Amazônia	4.914.254,8	0,0	86/6
PA	Sororó	359	1	Amazônia	26.254,0	0,0	71/5
MA	Kanela	2.103	1	Cerrado	125.212,2	80,0	59/3
RR	Serra da Moça	697	1	Amazônia	11.626,0	92,7	58/4
MA	Carú	400	2	Amazônia	172.667,4	0,0	56/4
MS	Cachoeirinha	36.288	1	Cerrado/Pantanal	4.290,0	41,4	56/4
PA	Las Casas	409	1	Amazônia	21.344,7	57,2	41/3
PA	Kayapó	4.548	1	Amazônia	3.284.005,0	11,9	31/2
MS	Taunay-Ipegue	4.090	1	Cerrado/Pantanal	6.461,3	55,0	30/2
MT	Juininha	75	1	Cerrado	70.537,5	91,1	30/2
MT	Wawi	457	2	Amazônia	150.329,2	0,0	29/1
MT	Tapirapé/Karajá	512	2	Cerrado	66.166,0	43,5	28/2
MA	Krikati	1.016	1	Cerrado	145.000,0	91,6	15/1
MA	Alto Turiaçú	1.500	3	Amazônia	530.524,7	0,0	13/1

Tabela 5 – Custos em R$ do Programa Brigadas Federais nas Terras Indígenas entre 2016 e 2019.[1]

Ano	BRIFs-I	Salários	Queimas prescritas	Operações de Combate	Veículos	EPIs	Outros	Total
2016	531	4.619.700,0	15.910,9	5.684.978,2	2.880.000,0	531.000,0	11.716.339,4	25.447.928,5
2017	529	4.602.300,0	448.830,9	4.545.300,9	2.880.000,0	529.000,0	3.879.016,4	16.884.448,2
2018	711	6.185.700,0	1.270.477,1	1.919.335,2	2.880.000,0	711.000,0	23.733.487,7	36.700.000,0
2019	717	6.237.900,0	4.261.049,2	7.981.675,8	2.880.000,0	717.000,0	14.622.375,0	36.700.000,0

[1] Valores estimados em cálculos feitos pelo autor.

A Tabela 6 apresenta as atividades de prevenção dos riscos (educação ambiental) e da propagação do fogo (aceiramento) mais comuns. As atividades de educação ambiental englobaram palestras, oficinas e reuniões em escolas, feiras, associações e comunidades, além de visitas técnicas individuais. As brigadas indígenas executaram uma quantidade menor dessas atividades em relação as demais brigadas, atingindo um público médio também menor. Esses resultados já eram esperados, haja vista a dificuldade de deslocamento terrestre e aquático no interior das TIs. Como resultado, é comum encontrar membros das comunidades atendidas pelo Programa BRIFs que desconhecem o trabalho dos brigadistas locais, o que significa que há necessidade de maior investimento em atividades de divulgação, comunicação e orientação. Por outro lado, muitos brigadistas indígenas reclamaram da baixa disponibilidade de materiais de apoio e da linguagem complexa dos materiais didáticos disponibilizados.

A quantidade de aceiros construídos pelas brigadas indígenas também foi menor. De forma geral, a construção e manutenção de aceiros sempre foi baixa nas TIs, devido ao enorme custo e esforço exigidos, principalmente nas áreas de grande dimensão (Ibama, 2017, 2020). Aceiros manuais exigem muito esforço e há baixa disponibilidade de equipamentos motorizados, como tratores, para as brigadas. Embora esse tipo de atividade possa apresentar bons resultados em áreas de floresta, nas áreas de savana pode ser substituído pelo uso de queimas prescritas, com resultados muito melhores. A quantidade maior de aceiros reportados pelas demais brigadas são resultado do apoio a outras instituições, a exemplo da Brigada de Pronto Emprego (BRIF-PE) – "Tiro Quente/DF", que todos os anos se dedica à construção e manutenção de centenas de quilômetros de aceiros em unidades de conservação federais (Berlinck & Batista, 2020), principalmente no Distrito Federal.

Tabela 6 – Atividades de prevenção executadas pelas Brigadas Federais (BRIFs) e por todas as Brigadas Indígenas (BRIFs-I).

	Educação ambiental				Aceiros (Km)	
	Nº atividades		Nº participantes			
Ano	BRIFs	BRIFs-I	BRIFs	BRIFs-I	BRIFs	BRIFs-I
2016	1.859	367	33.836	6.960	1.221,8	196,0
2017	2.135	1.346	45.295	18.559	636,4	267,1
2018	3.135	884	72.557	19.122	1.079,3	338,0
2019	2.888	1.069	59.693	27.227	993,9	279,9

A Tabela 7 apresenta as atividades de uso controlado do fogo, o componente do manejo em que as brigadas indígenas se destacam. Um dos principais motivos é que o uso do fogo faz parte das práticas culturais indígenas. Como consequência, não há necessidade de autorização dos órgãos ambientais para a realização das queimadas dentro das TIs. Isso facilita o seu uso, tanto para produção agropecuária (queimada controlada) como para o manejo dos ecossistemas (queimada prescrita) (Ibama, 2017). O limite entre queima controlada e prescrita pode ser tênue, especialmente no caso do manejo de pastagens nativas para a criação de gado, fazendo com que muitas queimas controladas sejam registradas como prescritas, especialmente nas TIs localizadas na Ilha do Bananal e nos lavrados de Roraima.

Tabela 7 – Atividades de uso controlado do fogo executadas por todas as Brigadas Federais (BRIFs) e pelas Brigadas Indígenas (BRIFs-I).

	Queimadas controladas				Queimadas prescritas			
	Nº atividades		Área queimada (Km²)[1]		Nº atividades		Área queimada (Km²)[2]	
Ano	BRIFs	BRIFs-I	BRIFs	BRIFs-I	BRIFs	BRIFs-I	BRIFs	BRIFs-I
2016	754	303	70,2	23,3	84	60	3.395,7	3.384,8
2017	692	559	44,0	36,2	1.261	1.206	3.660,4	3.657,4
2018	1.109	735	14,9	96,9	2.538	2.511	2.876,0	2.873,0
2019	711	545	46,3	30,5	4.373	4.259	-	-

[1] Área calculada pelos relatórios Ibama, 2016, 2017, 2018 e 2019.

[2] Área calculada pelo produto MCD64, sem os dados relativos a 2019. Possui erros acentuados de omissão.

A queima controlada de roças é uma atividade extremamente importante dentro do programa. Essas queimas são realizadas na época mais seca do ano, envolvem combustível florestal pesado e podem gerar comportamentos do fogo difíceis de serem controlados. Embora algumas brigadas sejam especialistas nas queimas de roça, a atividade costuma resultar em grandes incêndios florestais no auge da estação seca (Ibama, 2020a). Modificar essa prática é uma tarefa difícil, uma vez que é parte integrante da cultura desses povos, sendo fundamental para a segurança alimentar das comunidades. Em alguns casos, como no Xingu, há relatos de conflitos entre anciãos e brigadistas devido às práticas ancestrais, que aumentam os riscos de a queima "escapar", isto é, gerar um incêndio. É um conflito de difícil resolução, uma vez que há limites para o programa interferir nas práticas tradicionais (Ibama, 2010; Lacerda, 2013). Como resultado, grandes esforços são empregados todos os anos para apoiar as queimas controladas de roças, inclusive durante as grandes operações de combate aos incêndios florestais, com o objetivo de evitar o surgimento de novas frentes de fogo.

As queimas prescritas são a atividade em que as brigadas indígenas se destacam, sendo os principais manejadores das savanas brasileiras, com áreas queimadas anualmente muito maiores do que as demais brigadas do Ibama ou do ICMBio (Berlinck & Batista, 2020). Os brigadistas indígenas são exímios manejadores do cerrado e do lavrado, o que pode ser verificado pelo número de queimas prescritas realizadas após a implementação do MIF (Tabela 7), reduzindo os incêndios florestais nesses ecossistemas e formando mosaicos de áreas manejadas. Embora a importância do uso do fogo nessas áreas seja um consenso entre os especialistas (Durigan & Ratter, 2016; Abreu *et al*., 2017; Eloy *et al*., 2018), ainda persistem dúvidas sobre os regimes de fogo ideais, como época, frequência, intensidade e tamanho das queimas. Nesse caso, o conhecimento indígena sobre os efeitos do fogo nos ecossistemas pode auxiliar na definição dos regimes de queima mais adequados para cada região (Hall, 1984; Butz, 2009; Garde *et al*., 2009; Mason *et al*., 2012; BIA, 2014; Moura *et al*., 2019). Por isso, o conhecimento tradicional sobre o uso do fogo no manejo e os regimes de fogo tradicionais foram avaliados durante o programa,

gerando diversos dados científicos que podem auxiliar a prescrição de queimas pelos gestores de outras categorias de áreas protegidas.

Algumas brigadas indígenas também implementaram atividades de alternativas ao uso do fogo na produção alimentar, como implantação de sistemas agroflorestais e de recuperação de áreas degradadas (Tabela 8). As alternativas ao uso do fogo, contudo, não são bem aceitas pelas comunidades, que preferem manter seu sistema tradicional de roças, fortemente relacionado com sua cultura alimentar e crenças espirituais (Ibama, 2010). Entretanto, algumas comunidades utilizam princípios relacionados aos sistemas agroflorestais, como os Kayapós das TIs Menkragnoti e Baú. A adoção de sistemas de produção sem fogo tende a se tornar mais importante nas TIs de menor área e maior densidade demográfica, onde a pressão para a abertura de roças vem prejudicando a preservação e regeneração das florestas.

Tabela 8 – Atividades alternativas ao uso do fogo e de recuperação de áreas degradadas implementadas pelas Brigadas Federais (BRIFs) e pelas Brigadas Indígenas (BRIFs-I).

	Sistemas Agroflorestais-SAFs				Projetos de Recuperação de Áreas-PRADs			
	Nº SAFs		Área SAFs (Km²)		Área PRADs (Km²)		Mudas nativas	
Ano	BRIFs	BRIFs-I	BRIFs	BRIFs-I	BRIFs	BRIFs-I	BRIFs	BRIFs-I
2016	34	5	0,255	0,100	1,665	0,730	69.660	24.477
2017	36	14	0,190	0,032	1,691	1,440	95.314	43.574
2018	41	3	0,267	0,040	2,247	0,620	183.902	71.603
2019	44	24	0,145	0,079	1,496	0,969	138.036	53.723

As atividades de recuperação de áreas degradadas também foram pouco implementadas, embora tenham sido realizadas pelas BRIFs Coroa Vermelha, Kadiwéu e Xerente. A maior parte dessas recuperações foram feitas em nascentes de riachos, mas há necessidade urgente de estudar e implementar atividades de recuperação das grandes áreas de florestas degradadas pelo fogo, que estão em um ciclo perigoso de aumento da intensidade e frequência dos incêndios florestais (Nepstadt *et al.*, 1999; Ibama, 2020; Bilbao, 2020). Esse tipo de atividade pode ser relativamente simples em relação aos projetos convencionais de recuperação de áreas degradadas-PRADs. Provavelmente, o simples enriquecimento do banco de sementes da área, por meio do lançamento manual ou aéreo de sementes (Ibama, 2016; ISA, 2020a), pode surtir bons efeitos e auxiliar na regeneração de algumas dessas áreas. O importante é que sejam tomadas medidas para acelerar esse processo, uma vez que a degradação florestal está se tornando o principal problema relacionado à segurança dos combatentes (Ibama, 2019, 2020, 2020a). Além disso, o investimento na recuperação dessas áreas pode ser uma excelente alternativa para os brigadistas durante o período do ano em que muitas vezes ficam desempregados, uma vez que o contrato do Prevfogo/Ibama abrange somente seis meses por ano.

A Tabela 9 apresenta as atividades de combate aos incêndios florestais. Embora nos últimos anos tenha sido relatado, pelos brigadistas e servidores do Prevfogo, uma redução de incêndios nas áreas de savana, devido à implementação das queimas prescritas, o mesmo não ocorreu nas áreas de floresta, que concentraram a maior parte das operações de combate Nível III, acompanhando o aumento da degradação florestal. Essa degradação corresponde à substituição da floresta primária por uma vegetação secundária baixa e adensada, conhecida pelos brigadistas como "carrasco", que apresenta grande dificuldade de abertura de linhas de defesa e de realização de queimas de expansão (Ibama, 2017). Além disso, essa vegetação está sujeita a comportamentos cada vez mais extremos do fogo, inclusive com a formação de nuvens pirocumulonimbus e risco de downburst (Werth *et al.*, 2011). Essas áreas perderam grande parte da biodiversidade original, produzem poucos recursos naturais para as comunidades e necessitam de um longo período para a recuperação. É o caso, por exemplo, das áreas degradadas da TI Araribóia (Ibama, 2016a), das ondas de severidade na TI

PI Xingu (Ibama, 2019a, 2020a) e do corredor de fogo Mucajaí-Apiaú na TI Yanomami (Ibama, 2020). Essas áreas são um prenúncio do que pode ocorrer em todo o restante da Amazônia, caso não sejam adotadas medidas para conter e reverter esse processo acelerado de degradação das florestas tropicais do bioma (Nobre, 2008; Silvério *et al.*, 2013, 2019).

Tabela 9 – Atividades de combate aos incêndios florestais executadas pelas Brigadas Federais (BRIFs) e pelas Brigadas Indígenas (BRIFs-I).

	Nº Combates Nível I[1]		Área queimada[2] TIs (km²)	Nº de Operações Nível III[1]	
Ano	**BRIFs**	**BRIFs-I**	**BRIFs-I**	**BRIFs[3]**	**BRIFs-I**
2016	3.388	1.009	13.230,1	8	4
2017	1.876	1.161	15.113,4	5	4
2018	1.738	616	6.035,5	7	2
2019	1.882	842	-	13	4

1 Nível I: combates locais. Nível II: operações a nível estadual. Nível III: operações a nível nacional. (Ibama 2017).

2 Calculado para um grupo restrito de 15 Tis com área superior a 100.000 ha.

3 As operações que não foram realizadas em Terras indígenas atenderam o ICMBio e os governos estaduais.

De forma geral, o Programa reduziu em 17% a área atingida pelos incêndios florestais, quando comparado ao período que antecede a sua implementação (Figura 5). Essa redução foi observada principalmente nas áreas de savana, uma vez que nas florestas tem sido verificado o aumento das áreas atingidas, devido aos problemas de degradação florestal e mudanças climáticas já discutidos no presente artigo. Cabe ressaltar que o programa ainda é recente e que séries de dados de longo prazo são mais adequadas para este tipo de avaliação (Lazzarini, 2016).

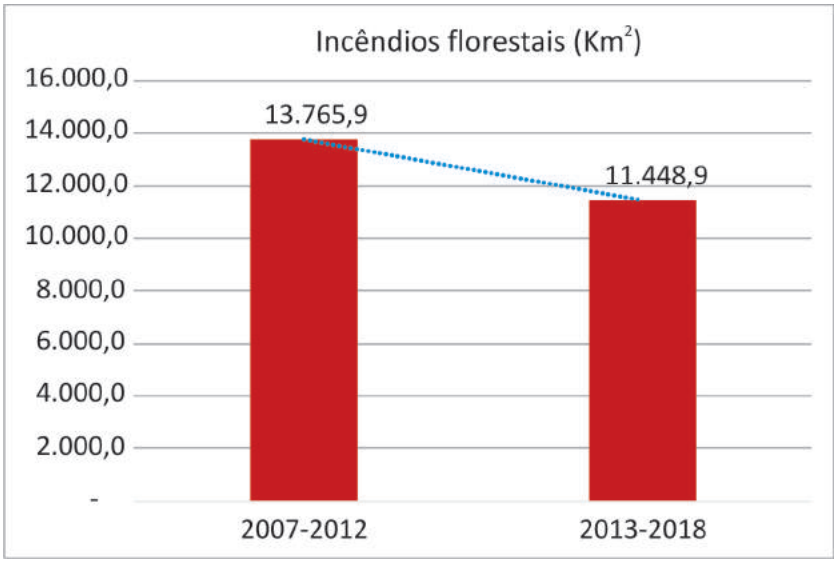

Figura 5 – Área atingida (Km²) por incêndios florestais nas terras indígenas atendidas pelo Programa Brigadas Federais antes (2007-2012) e depois (2013-2018) da sua implementação. Calculado para um grupo reduzido de 15 TIs, com extensão superior a 1.000km², para reduzir os erros acentuados de omissão devido ao caráter generalista da metodologia utilizada (Chuvieco *et al.*, 2016; Padilla *et al.*, 2015).

Uso do conhecimento tradicional no manejo das savanas com fogo

O Programa BRIFs nas Terras Indígenas foi baseado nos princípios do MIF e no respeito e valorização do conhecimento tradicional. Esse conhecimento foi importante especialmente na realização das queimas prescritas, indicando as áreas e as épocas mais propícias por meio do Resgate do Uso Tradicional do Fogo. Após as primeiras queimas, também foi feito um trabalho de monitoramento e coleta de dados, com o objetivo de avaliar cientificamente os efeitos do fogo nos ecossistemas e, principalmente, nas plantas e animais mais importantes para as comunidades.

Os regimes de fogo e as épocas de queima (Figura 2) foram considerados como tratamentos experi-mentais. No caso das espécies vegetais, foram avaliados a mortalidade após a passagem do fogo, severidade, fenologia, perda de estruturas reprodutivas devido ao fogo e a produtividade de frutos. As espécies vegetais avaliadas foram as árvores adultas de mangaba (*Hancornia speciosa*), pequi (*Caryocar brasiliense*), puçá (*Mouriri pusa*), cajuí (*Annacardium occidentale*), veadeira (*Pouteria ramiflora*), murici (*Byrsonima* spp.), cajuzinho (*Anacardium humile*), pitomba (*Talisia subalbens*) e a comunidade de árvores frutíferas em geral.

No caso das espécies animais, as comparações foram feitas somente entre a frequência de vestígios nos diferentes regimes de fogo. As espécies avaliadas foram o tamanduá bandeira (*Myrmecophaga tridactyla*), anta (*Tapirus terrestres*), seriema (*Cariama cristata*), ema (*Rhea americana*), além das famílias Tinamidae (*Rhynchotus rufescens* e *Nothura maculosa*), Dasypodidae (*Priodontes maximus, Euphractus sexcinctus, Dasypus novemcinticus* ou indeterminados), Canideae (*Chrysocyon brachyurus, Cerdocyon thous* e *Lycalopex vetulus*) e Cervideae (*Ozotocerus bezoarticus, Mazama gouazoubira* e *Mazama americana*).

Os resultados indicam que a maior parte das espécies frutíferas apresentam menos danos e maior produção de frutas quando manejadas com queimas prescritas. Os incêndios florestais apresentaram as maiores taxas de mortalidade, de severidade e de perda das estruturas reprodutivas devido ao fogo. A exclusão do fogo apresentou resultados intermediários.

Em relação a época de realização, as queimas no início da estação seca apresentaram as maiores proporções de árvores no estádio reprodutivo e maior produção de frutos por planta, confirmando essa época como ideal para as "queimas de frutificação". As queimas na estação chuvosa apresentaram as maiores taxas de severidade, as menores proporções de indivíduos no estádio reprodutivo e a menor produção de frutos. As queimas tardias apresentaram resultados intermediários. As queimas na metade da estação seca apresentaram resultados intermediários. Em relação a fauna, o *M. tridactyla* e as aves da família Tinamideae apresentaram maior frequência nas áreas sob exclusão do fogo. A *R. amerciana* e as famílias Canideae, Dasypodideae e Cervideae apresentaram maior frequência nas áreas manejadas com queimas prescritas. Todas as espécies e famílias apresentaram menor frequencia nas áreas atingidas pelos incêndios florestais, exceto *T. terrestres* e *C. cristata*, que não apresentaram nenhuma diferença significativa entre os tratamentos (Xerente & Falleiro, 2019; Santana & Falleiro, 2019 e Falleiro *et al.*, 2020).

Os resultados corroboraram o conhecimento tradicional e proveram informações importantes para compreender os efeitos da exclusão do fogo, dos incêndios florestais e das queimas prescritas, além de indicar a melhor época para manejar as espécies frutíferas mais valorizadas pelas comunidades. Os resultados parciais dos efeitos ecológicos do manejo tradicional no cerrado já haviam sido apresentados em Congressos e Conferências (Xerente & Falleiro, 2019; Santana & Falleiro, 2019 e Falleiro *et al*., 2020), inclusive aqueles relativos à savana amazônica denominada lavrado (Falleiro *et al*., 2020a). Os resultados definitivos estão sendo preparados para serem publicados em revistas científicas especializadas e na elaboração de planos de manejo integrado do fogo específicos para cada terra indígena.

Principais problemas verificados nas brigadas

A Tabela 10 apresenta as condições gerais de trabalho das BRIFs-I. De modo geral, os chefes de brigadas têm baixo acesso a tecnologias como computador, internet e telefone. Algumas bases de brigada apresentam problemas de infraestrutura e acesso a serviços essenciais, como energia elétrica, água e esgoto. Também

faltam alguns equipamentos de proteção individual (EPIs) específicos, equipamentos de combate e veículos adaptados. Além disso, muitas vezes, os equipamentos, materiais e estruturas mencionados, são disponibilizados muito tarde, além de serem precários ou inadequados. Dessa forma, ainda são necessários grandes investimentos na melhoria de condição de trabalho desses brigadistas, que está muito distante daquela verificada em programas semelhantes desenvolvidos em outros países (BIA, 2020; WoF, 2020).

Tabela 10 – Quantidade (%) de Brigadas Indígenas-BRIFs-I que apresentam os indicadores avaliados.

Condições gerais de trabalho do chefes de brigada (%)				
Computador	Internet	Telefone	Ar condicionado	
27,5	37,0	7,5	12,8	
Estrutura das bases das brigadas (%)				
Energia elétrica	Água potável	Esgoto	Almoxarifado	Garagem
85,3	84,3	63,0	83,0	45,8
Condições gerais de trabalho (%)				
EPI completo	Equipamentos de combate	Equipamentos de manutenção	Veículos	Apoio das comunidades
82,5	86,3	65,5	84,0	92,5

Os brigadistas indígenas também precisam ter mais acesso às oportunidades de capacitação. Mesmo dentro do Programa, muitas vezes foram preteridos nos cursos mais especializados. Como resultado, existem apenas dois instrutores de brigadas indígenas no programa e nenhum perito.

Os materiais didáticos são outro problema recorrente. É necessário adaptar vários materiais de comunicação e educação ambiental para a realidade indígena, explicando a importância do trabalho das brigadas para a comunidade. Embora o material de capacitação das brigadas tenha sido adaptado recentemente (Ibama, 2017, 2017a), ainda há muitos ajustes a serem realizados.

Desafios e oportunidades

O Brasil se encontra em um processo de mudança de paradigma, de uma política de fogo zero para o manejo integrado do fogo, no qual há o entendimento de que o fogo desempenha um papel ecológico importante em alguns ecossistemas (Steil, 2015). Um dos aspectos de elevada importância na abordagem MIF é a inclusão da participação social (Myers, 2006; Steil *et al.*, 2019; Bilbao *et al.*, 2020), sem a qual os esforços para a construção de políticas públicas podem falhar e reconduzir para políticas de supressão, impedindo a adaptação às futuras ameaças de incêndios (IUFRO, 2018). Dessa forma, a participação das comunidades que têm conhecimento e prática no uso do fogo é fundamental, uma vez que concentram informação crucial, além de serem as principais partes interessadas, dado que são as vítimas de primeiro grau dos incêndios (Fonseca-Morello *et al.*, 2017).

A implementação do Programa Brigadas Federais tem sido um instrumento importante para a implementação do MIF no Brasil, apresentando resultados como redução dos incêndios florestais, proteção da biodiversidade, geração de renda e segurança alimentar em algumas das áreas de maior diversidade socioambiental do planeta. Entretanto, o Programa ainda apresenta diversos problemas que precisam ser resolvidos.

Os recursos disponíveis são limitados, o que impede a sua expansão para outras áreas que também necessitam de ações de proteção contra os incêndios florestais (Tabela 11). Além disso, a maior parte dos recursos humanos é fornecida por

meio da contratação temporária dos brigadistas (seis meses por ano), o que significa que precisa ser implementado e encerrado todos os anos. Isso resulta em elevado custo com atividades de seleção, contratação, mobilização e desmobilização, além da inevitável alta rotatividade dos brigadistas, que muitas vezes conseguem empregos fixos em outras áreas. Além disso, as bases das brigadas são precárias e isoladas em relação às demais instituições que trabalham na região. Nas áreas indígenas, esses problemas são ainda mais graves, pois a presença do estado é fraca, há imensas dificuldades logísticas, as comunidades são pobres e as diferenças culturais dificultam a padronização dos procedimentos.

Tabela 11 – Área total dos biomas brasileiros, área das terras indígenas e área atendida pelas Brigadas Indígenas-BRIFs-I (Km^2).

	Área total	Terras indígenas	BRIFs-I
Bioma Amazônia	4.196.943,0	1.153.444,5	132.783,2
Bioma Cerrado	2.036.448,0	89.797,1	42.180,7
Bioma Mata Atlântica	1.110.182,0	7.337,3	15,0
Bioma Caatinga	844.453,0	2.089,3	965,7
Bioma Pampa	176.496,0	20,0	0,0
Bioma Pantanal	150.355,0	2.555,3	1.762,1

O aperfeiçoamento e expansão do Programa são fundamentais para enfrentar o problema do agravamento dos incêndios florestais no Brasil. Entretanto, investimentos financeiros sem o devido acompanhamento de estruturação física e técnica das instituições tendem a apresentar resultados pífios a médio e longo prazo. Além disso, a atuação dos diversos órgãos, níveis de governo e da sociedade civil, embora seja fundamental para a proteção ambiental, precisa ser feita de forma organizada e integrada, para evitar a proliferação de iniciativas pontuais e conflitos de atribuições, como aqueles que foram observados antes da implementação do Programa.

A legislação atual determina a atuação articulada entre as instituições (Brasil, 1998, 2016) e existem novas iniciativas importantes, mas que precisam do apoio do Congresso Nacional, como a discussão do Projeto de Lei que dispõe sobre a Política Nacional de Manejo Integrado do Fogo (Brasil, 2018), que permanece sem novos andamentos desde dezembro de 2018, quando foi submetida à apreciação da casa. Por outro lado, esse projeto ainda não resolve os problemas relativos à criação da profissão de brigadista florestal, com cargos, salários e planos de carreira que garantam a ascensão profissional dos trabalhadores mais dedicados e qualificados.

Por fim, o pagamento pelos serviços ambientais prestados pelas comunidades, semelhante ao que ocorre na Austrália (Whitehead *et al.*, 2009), é um elemento fundamental para irradiar o sentimento de comprometimento com a proteção ambiental, presente nos brigadistas, para o restante da comunidade.

Conclusão

O Programa Brigadas Federais do Prevfogo/Ibama conseguiu organizar, unificar e padronizar as ações de manejo integrado do fogo nas terras indígenas brasileiras.

As brigadas indígenas apresentaram produtividade semelhante às demais categorias de brigadas, se destacando principalmente nas atividades de uso controlado do fogo.

O conhecimento tradicional indígena sobre o manejo das savanas com fogo foi corroborado por meio de uma avaliação científica e pode auxiliar na determinação dos regimes de fogo mais adequados para os ecossistemas brasileiros.

As instituições responsáveis precisam de maior aporte de recursos humanos, financeiros e tecnológicos para ampliar e aperfeiçoar o Programa Brigadas Federais.

O alinhamento dos programas implementados pelo governo, iniciativa privada, sociedade e comunidades é fundamental na implementação das políticas de proteção contra os incêndios florestais, devendo ser reforçado por meio do cumprimento da legislação em vigor e aperfeiçoado por meio da tramitação da Política Nacional de Manejo Integrado do Fogo.

A regulamentação da profissão de brigadista florestal deve ser incorporada à Política Nacional de Manejo Integrado do Fogo.

O pagamento pelos serviços ambientais prestados pelas comunidades indígenas é fundamental para a manutenção do Programa Brigadas Federais a longo prazo.

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To Burn or not to Burn? The History behind the Construction of a New Paradigm of Fire Management in Venezuela through Interculturality: Local Actions of National and Regional Impact

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"… 'Look, son, do not go ahead of me.' Why did the old wise man say that?

Because if on the journey one goes ahead, you are more likely to trip up. There could be an animal, there could be a snake or a spider that bites you. But don't go behind me either. If you do, you won't be able to see what I am seeing, as I am in front of you. So, one has to be very careful. That is why our grandparents said that we must walk together hand in hand. In that way we both can see what is ahead and we won't trip up. This is my advice to the institutions, academy and government - let's all hold on to grab each other to walk together, so no-one trips up…"

Sr. Valeriano Contasti, President of Elders Council of Kavanayén Indigenous Community, and natural leader of the community for more than 30 years, during the closure speech of the workshop: "Design of action plans on climate change: Integrating perspectives from the local Indigenous with academy and institutions in Canaima National Park" Venezuelan Institute of Scientific Research, Altos de Pipe, Gran Caracas, Venezuela January 23 to 25, 2017

ABSTRACT – The presence of a savanna-forest vegetation mosaic in the Gran Sabana, Canaima National Park (CNP), has been more than an academic controversy since the 1980s through to the 2010s in Venezuela. Scientists, Park administrators and officials from institutions devoted to protect the Caroní river basin within the limits of the Park, argued that the presence of savannas under a tropical rainfall regime that could support humid forests was due to the fire practices used by the local Pemón Indigenous communities. This misconception justified applying fire suppression policies, aimed at putting out all types of fires in CNP, especially the "compulsive burning" (thus so called by some scientists) by Pemón people in forest areas. This paper describes the initiatives, pursued for more than 20 years, to consolidate intercultural and participatory fire management in the CNP, Gran Sabana, which evolved as result of several participatory action-research projects coordinated by academics, and supported by national and regional public development institutions. The inclusion of Pemón Indigenous communities, firefighters, public officials, and academics in field research and joint experimentation, as well as in debates and dialogues on socio-ecological issues relevant to CNP, allowed the development of articulated knowledge and actions that were the foundations of a new paradigm of fire management and strategies for climate change mitigation and adaptation. Since

2015, these actions have been further extended to neighbouring countries of the Guiana Shield in the Northern Amazonia and other regions of Latin-America, with the collaboration and support of Venezuelan, British and other European institutions.

Keywords: Indigenous fire knowledge; integration of scientific, indigenous, and technical knowledge; integrated fire management; Canaima National Park; Northern Amazonia.

Queimar ou não Queimar?
A História da Construção de um Novo Paradigma de Manejo do Fogo na Venezuela por meio da Interculturalidade: Ações Locais de Impacto Nacional e Regional

RESUMO – A existência do mosaico de vegetação savana-floresta na Gran Sabana, Parque Nacional Canaima (PNC), representou mais do que uma polêmica na academia da Venezuela, no período de 1980-2010. Pesquisadores, administradores do Parque e funcionários de outras instituições encarregadas de proteger a bacia do rio Caroní, dentro do Parque, argumentaram que a presença de savanas em regime de chuva tropical típico de florestas úmidas era uma decorrência das práticas de uso do fogo utilizadas pelas comunidades indígenas Pemón. Essa falsa premissa justificou a aplicação de políticas de supressão, destinadas a apagar todo tipo de fogo no PNC, especialmente as "queimadas compulsivas" (assim chamadas por alguns pesquisadores) em áreas florestais, realizadas pelo povo Pemón. Este artigo descreve as iniciativas realizadas ao longo de mais de 20 anos para consolidar o manejo intercultural e participativo do fogo no PNC que evoluíram a partir de diversos projetos de pesquisa-ação participativa coordenados por acadêmicos e apoiados por instituições públicas nacionais e regionais. A inclusão de comunidades indígenas Pemón, bombeiros e funcionários públicos durante a execução de experimentos de campo, bem como em debates e diálogos sobre questões socioecológicas, permitiu o desenvolvimento de conhecimentos e ações articuladas que foram, posteriormente, os alicerces de um novo paradigma do manejo do fogo e de estratégias de mitigação e adaptação às mudanças climáticas no PNC. Desde 2015, essas ações foram estendidas aos países vizinhos do Escudo das Guianas, ao norte da Amazônia, e a outras regiões da América Latina, com o apoio de instituições venezuelanas, britânicas e outras instituições europeias.

Palavras-chave: Conhecimento indígena sobre fogo; integração de conhecimento científico, indígena e técnico; manejo integrado do fogo; Parque Nacional Canaima; Amazônia Norte.

¿Quemar o no Quemar?
La Historia detrás de la Construcción de un Nuevo Paradigma de Manejo del Fuego en Venezuela a través de la Interculturalidad: Acciones Locales de Impacto Nacional y Regional

RESUMEN – La existencia del mosaico de vegetación sabana-bosque en la Gran Sabana, Parque Nacional Canaima (PNC), ha representado más que una controversia académica en Venezuela, en el período 1980-2010. Científicos, administradores del Parque y funcionarios de otras instituciones encargados de proteger la cuenca del río Caroní, dentro del Parque, argumentaban que la presencia de sabanas bajo un régimen pluvioso tropical típico de bosques húmedos, se debía a las prácticas de fuego utilizadas por las comunidades indígenas Pemón. Esta falsa premisa justificaba la aplicación de políticas de supresión, destinadas a apagar todo tipo de fuegos en el PNC, especialmente las "quemas compulsivas" (así denominadas por algunos científicos) en zonas forestales, por parte del pueblo Pemón. Este artículo describe las iniciativas realizadas durante más de 20 años, para consolidar el manejo intercultural y participativo del fuego en el PNC que evolucionaron como resultado de varios proyectos participativos de investigación-acción coordinados por académicos y apoyados por instituciones públicas nacionales y regionales. La inclusión de las comunidades indígenas Pemón, los bomberos y los funcionarios públicos durante la ejecución de experimentos en campo, así como en debates y diálogos sobre temas socio-ecológicos, permitió desarrollar conocimientos y acciones articuladas que fueron luego los cimientos de un nuevo paradigma de manejo del fuego y de estrategias de mitigación y adaptación al cambio climático en el PNC. Desde 2015, estas acciones se han extendido a países vecinos del Escudo Guayanés, al norte del Amazonas, y otras regiones de América Latina, con el apoyo de instituciones venezolanas, británicas y otras europeas.

Palabras clave: Conocimiento indígena del fuego; integración de conocimientos científicos, indígenas y técnicos; manejo integral del fuego; Parque Nacional Canaima; Amazonia norte.

Introduction

Fire is a natural phenomenon of terrestrial ecosystems, occurring on all continents of our planet (Bowman *et al*., 2009; Bilbao *et al*., 2020; FIRMS, 2021). It is associated with human evolution, from prehistoric times to agricultural activities and the formation of cultural landscapes (Mouillot & Field, 2005; Pausas & Keeley, 2009; GFMC, 2013; Bowman *et al*., 2011). The area affected by fires annually ranges between 300 and 400Mha (GFMC, 2013; GFMC, 2019; IUFRO, 2018) with an average of 341Mha (1997-2011), or 2.6% of the entire global land area (Chatenoux & Peduzzi, 2013; van Lierop *et al*., 2015; Giglio *et al*., 2018).

Fires have a significant impact on the production of carbon dioxide and other greenhouse gases (CH_4 and N_2O) that contribute to climate change (Randerson *et al*., 2012). From 1997 to 2016, biomass burning from different ecosystems produced CO_2 emissions (2.2 10^{15} g C yr^{-1}), equivalent to 23% of global fossil-fuel CO_2 emissions in 2014 (Le Queré *et al*., 2015; Boden *et al*., 2015; Van der Werf *et al*., 2017). Approximately 84% of global carbon emissions originate in the tropics. Sixty two percent is from tropical savannas, underlining the importance of fire as a driver of biogeochemical cycles and ecosystem processes in tropical ecosystems, particularly in savanna areas (Van der Werf *et al*., 2017). Savannas were the ecosystems, at the global level, with higher mean values of fire attributes (ignitions, size, duration, expansion and speed) relative to the other fire types (boreal forest, temperate forest, deforestation, agriculture) during 2003-2016 (Andela *et al*., 2019).

However, not all fires are the same. Millions of people across the world use fire in managed or controlled ways. This could be for social, cultural and economic reasons, linked to livelihoods including swidden cultivation or rotational farming, hunting, gathering of materials and food collection (Mistry *et al*., 2005; Bilbao *et al*., 2010; Ziegler *et al*., 2011; Huffman, 2013; Welch, 2014; Archivald, 2016; Eloy *et al*., 2018; Nikolakis & Roberts, 2020). A wildfire, on the other hand, is any uncontrolled fire in combustible vegetation that occurs in the countryside or wilderness area. Wildfires usually differ from other fires by their extensive size, the speed at which they can spread out from source, potential to change direction unexpectedly, and their ability to jump gaps such as roads, rivers and fire breaks (Bowman *et al*., 2009; GFMC, 2013; GFMC, 2019). In some countries, large wildfires are becoming the most common expression of wildland fires at present. For example, in the United States, it is estimated that 3% of fires are responsible for 95% of the area burned (Short, 2014).

The main global drivers of wildfires today are increases in the length of the fire weather season and drought duration and intensity due to climate change, demographic and land use change, and policies that are not consistent with the socio-environmental realities of the territories and entrenched in a history of fire suppression. This has led to a new dynamic of fires: an increasing frequency of wildfires of high intensity that fall into the category of "mega-fires" that exceed the containment and fighting capacity of fire-fighting services, retreating only when the weather or fuel conditions change (Tedim *et al*., 2018; Bilbao *et al*., 2020). Mega-fires differ from the large wildfire; they transform ecosystems and habitats, have severe socio-economic impacts, and generate substantial costs in human lives and fire suppression efforts, reaching regional disaster level (Fidelis *et al*., 2018; Moreno *et al*., 2020a; Bilbao *et al*., 2020). Recent examples of mega-fires are in the Pantanal (Brazil, 2020, 3.2Mha, 22% of the territory; Mega, 2020), Delta del Paraná (Argentina, Jan-Sept 2020, 330000ha, 14% of the territory; MAyDS, 2020), and California, Oregon and Washington (the USA, 2.5MHa, Bloch *et al*., 2020). In general, fires in South America have peaked from February to June and from August to October 2020, with these nine months having the highest numbers of fires since 2011. During March, April and May 2020 respectively, fire hot pixels were 20%, 49% and 10% higher than previously registered highs since 1998 (Anderson *et al*., 2020).

In the past decades, most Latin American countries adopted 'zero-fire' policies to avoid and control virtually any fire type. These policies focus on fire-fighting techniques such as fire brigades, technical support (e.g., helicopters and trucks), predictive fire risk modelling, and environmental education programs, to dissuade Indigenous and, in general, rural peoples from burning (Eloy *et al*., 2019; Mistry *et al*., 2019; Ponce *et al*., 2020). However, the region's fire exclusion and fire-fighting policies have frequently failed in operational, ecological, and socio-environmental terms, especially in fire-dependent areas, such

as grasslands and savannas. The main criticisms made of fire suppression policies are that they do not take into account the ecological and cultural role of fire in many ecosystems of the world, and to date, have been ineffective at reducing the area burnt (Eloy *et al.*, 2019; Mistry *et al.*, 2019; Ponce *et al.*, 2020; Bilbao *et al.*, 2020; Durigan, 2020).

What can the alternative be? Is it possible to avoid catastrophic wild to fires (wildfires) fires under conditions where fire-dependent and fire-sensitive ecosystems coexist? Can fire be managed in coexistence with local populations who rely on it for subsistence practices?

New paradigms of fire management have emerged both in South America and in other regions of the world, which show themselves to be more effective in socio-environmental and economic terms than suppression policies, especially under conditions of extreme climatic events. This new approach to fire is based on the recognition of the diversity of knowledge, expectations, interests and needs (biological, social/cultural and economic), emphasizing the importance of intercultural dialogues and healthy governance systems to sustain decisions on the use or not of fire (and define where, when and what to burn) (Myers, 2006; Bilbao *et al.*, 2010; Durigan & Ratter, 2016; Falleiro *et al.*, 2016; Bilbao *et al.*, 2019; Mistry *et al.*, 2019; Barradas *et al.*, in press; Bilbao *et al.*, 2020).

This article tells the story of the collective construction of a new fire management paradigm in Venezuela, starting from suppression policies to adopting a participatory and intercultural approach to fire management. This process initiated in Canaima National Park (CNP), a protected area of 30,000km^2 that lies at the centre of the geologically ancient Guiana Shield of Venezuela in the northern Amazonia basin of South America. The CNP is comprised of a vegetation mosaic of dense evergreen submontane and montane forests and savannas, and high tepui (tabletop) meadows and shrublands, and constitutes a globally strategic area for ecosystem conservation due to its high biodiversity richness and the presence of globally threatened endemic species (766 species, IUCN Red List Ecosystem). Because of its geological and physiographical singularity, in addition to its biological and cultural value, CNP was declared a UNESCO World Heritage Site in 1994. This strategic area protects part of the Caroní Basin's headwaters, influencing the hydrological stability of the Guri Reservoir which generates 80% of the country's hydroelectric power. The CNP is also home to the Pemón Indigenous people. They inhabit and manage the extensive territory of the Park, particularly the sizeable eastern savanna region called the 'Gran Sabana'. Forest is also an essential ecosystem for the Pemón culture due to its high provision of resources (fruits, firewood, crafts, construction material, medicines), water and soil organic matter for shifting cultivation practices.

Conservation policies undertaken in past decades in CNP have dismissed traditional fire management by the Pemón Indigenous peoples, leading to the dangerous build-up of fuel that promotes catastrophic wildfires. Together with global climate, socio-cultural and demographic changes in the Park, the impacts on the unique biocultural landscape of CNP are potentially devastating. Therefore, a coherent fire management plan is crucial for conserving this threatened landscape and the Indigenous communities that depend on it for their survival.

Description of the area

The Canaima National Park (CNP, 5°20'0"LN, 61°30'0"LW), located to the southeast of the Orinoco River in the border with Brazil, is the second largest park of Venezuela (3MHa). The CNP forms part of the Guayana Massif, which is one of the most ancient geological formations on Earth (3000 million years) and extends over a large area of the northern Amazonia Basin (Figure 1). The Park, created in 1962, sits on the ancestral territory of the Indigenous Pemón, who have occupied the region since prehispanic times (Perera, 2000; Gassón, 2002). According to the national census (INE, 2011), this Indigenous group's total population was estimated at 30,148 people, of which more than three quarters live within the Park's perimeter-making it the fourth largest Indigenous group numerically in the country. CNP is also the National Park with the largest number of inhabitants in the country.

The frequent occurrence of fires is of great concern in CNP, where large treeless savannas occur despite the fact that forest is the predominant vegetation type in the park (Delgado *et al.*, 2009). The actual vegetation cover is considered by some authors to be a transitional stage in a long-term process of degradation, originally caused by fires, and conditioned by high vulnerability of forests,

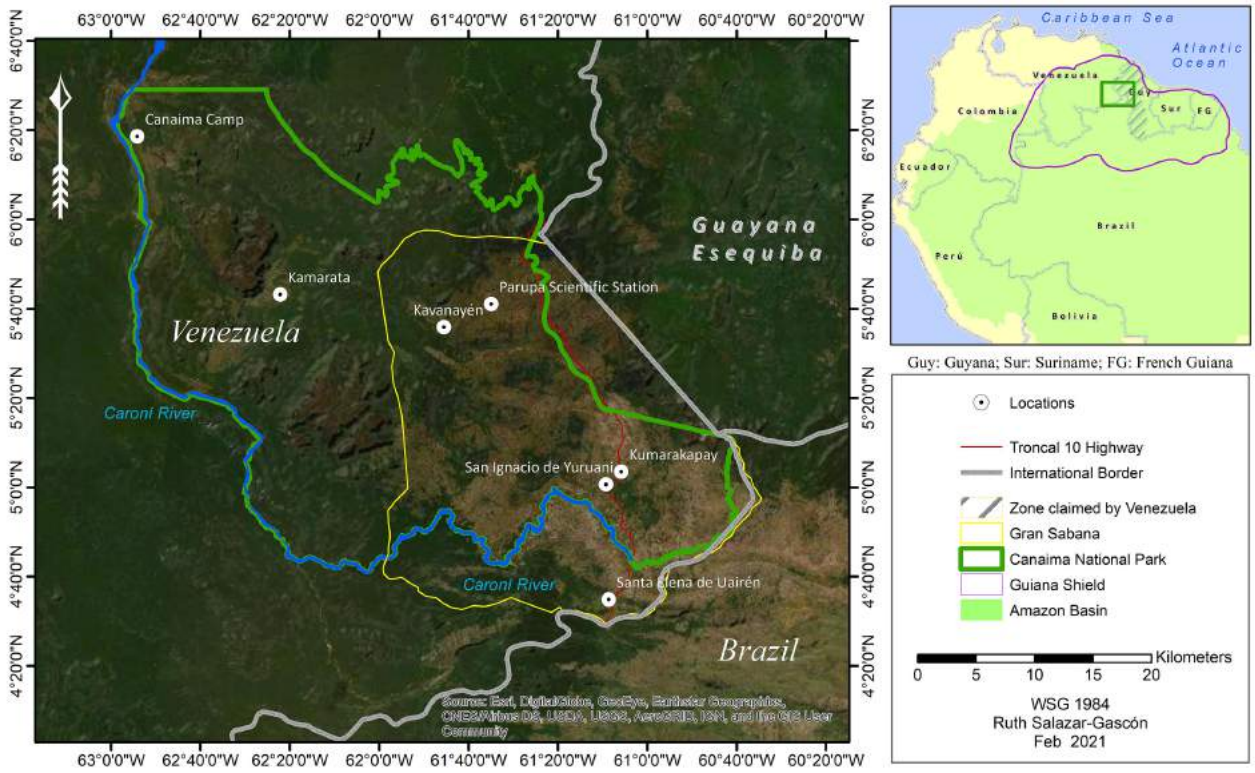

Figure 1 – Location of Canaima National Park. Dark green areas indicate woodland ecosystems and beige one's savannas. Data base: Red Amazónica de Información Socioambiental (RAISG, 2020: https://www.amazoniasocioambiental.org/), ECOSIG y EDELCA.

soils and episodic drought stress (Hernández, 1999; Fölster *et al*., 2001; Dezzeo & Chacón, 2005; Hernández & Castellanos, 2006; Rull, 2009; Hernández *et al*., 2012). On the other hand, the local population, the Pemón community, depend on fire for their livelihood and sustain that fire use is a cultural right (FIEB, 2007).

The 'Gran Sabana' plateau, excluding the tepui tops, shows an altitudinal N-S gradient from 1,500 m.a.s.l. in Sierra de Lema to 800 m.a.s.l. in Santa Elena de Uairén, on the Brazilian border. The climate can be considered tropical humid to very humid and submesothermic for the whole region, with annual precipitation between 1,500 and 4,000mm and average annual temperatures between 17°C and 22°C. The rain pattern is seasonal in the Gran Sabana, with a wet season from May to December and a drier period from January to April (Hernández, 1994; Huber & Febres, 2000).

The vegetation is dominated by "Terra firme" and riparian forest, representing 60% of the total vegetation cover (Delgado *et al*., 2009). Both types of forests are evergreen with a mountain type and submesothermic (800-1,500 m.a.s.l.), and constitute the region's most used ecosystems by the local Indigenous population. This latter issue contributes to increasing the already high spatial heterogeneity of these forests, which results in clusters of forests with different heights, levels of structural complexity and associations with secondary forests, scrub or savannas, not always related to changes in landforms or soil texture (Dezzeo, 1994; Hernández, 1994; Bilbao *et al*., 2011a; Figure 1).

On average, 70% of wildfires originate in the Gran Sabana's savanna areas (Gómez *et al*., 2000; Bilbao *et al*., 2010). In consequence, savannas and ecotonal savanna-forest zones represent the most exposed areas to the action and degradation of wildfires. The ecotonal savanna-forest areas are also very vulnerable due to the presence of a diversity of forest tree seedlings (Bilbao *et al*., 2011a).

Fire suppression policies in Canaima National Park, Venezuela

In 1980 the national hydroelectric company CORPOELEC (formerly EDELCA) and CVG (acronym in Spanish for Venezuelan Guayana Corporation) created a program for fire suppression and combat, framed within a policy of fire exclusion in the region to protect and conserve the vegetation of the Caroní basin, including CNP. The program was born as a response to the impact of a long history of wildfires in the region, especially during the intense dry seasons of 1979 and 1980, which affected extensive areas of forests, shrublands and savannas, shocking public opinion and the media. Park administrators and the hydroelectric company's perception and major concerns were that forest cover loss was associated with big wildfires, their potential effect on hydrological soil erosion and the increase of the amount of sediments that could be deposited downstream in water bodies and dams. Thus, in 1981, with the approval of the formally competent institutions, a PCIV (acronym in Spanish for Vegetation Fire Control Program) was created, with CORPOELEC in charge of the prevention, detection, combat and investigation of wildfires in the region. Additionally, an Intensive Protection Area (API, acronym in Spanish) was established (21,100km^2) according to the priorities of CORPOELEC (Hernández, 1984). The API included the drainage network of the Caroní river, integrated by the sub-basins of the Karuay, Aponwao, Yuruaní, Kukenan, Arabopo and Ikabarú rivers (Gómez *et al.*, 2000; Millán, 2015).

Since its creation, the main objective of the PCIV has been to reduce the impact of fire on vegetation (mostly the forest), regulate the transport of sediments to avoid erosion, and "minimize burning and ensure adequate fire management" by the Pemón Indigenous communities (Galán, 1984; Gómez *et al.*, 2000; Rodríguez, 2004). For this purpose, the PCIV has been training its staff in technical aspects of prevention, detection, firefighting, and the PCIV Information System (Todd, 1985; Figure 2a and 2b). The PCIV Brigade, also called the 'Carlos Todd' Initial Attack Brigade, were named in honor of Ing. Carlos Todd, a pioneer member of PCIV Brigade, who promoted research and the use of to combat wildfires in the region. The Brigade focus on early interventions against wildfires; most of their members are Pemón Indigenous members, many of whom have been in service since its creation, for more than 30 years. This characteristic has been of great importance for the good performance of the program since its members have an in-depth knowledge of the territory and the motivations, location and periodicity of the cultural practices of fire use carried out by the Pemón. However, Indigenous Pemón PCIV members can only reach the rank of Chief of Brigades or Coordinator, with higher positions going to non-Indigenous people based outside the Park. Therefore, fire policy is defined at higher hierarchical levels, sometimes outside the Gran Sabana, at the company headquarters.

Despite the enormous organisational efforts, high professionalism and commitment by all the staff of Carlos Todd Initial Attack Brigade and the significant investment made by the regional government during the last thirty years in the development of infrastructure, and the provision of equipment and personnel for the program of fire control in the Park, on average only 13% of the 1000 to 3000 fires reported per year can be effectively fought (Gómez *et al.*, 2000; EDELCA-CORPOELEC, 2008).

This program has also had social costs, stemming from the historical conflict over fire with the Pemón Indigenous communities. The institutional narrative elaborated by CORPOELEC during these years led to a public image of the Pemón people as being responsible for the wildfires, and stigmatizing the traditional practice of burning as the source of the "fire problem". Both assumptions are summarized in the qualifying adjective of "quemones" (from "quemar": to burn, it stands colloquially for "burners", "those who burn", a pejorative term (Rodríguez *et al.*, 2013; Bilbao *et al.*, 2017) or "compulsive burners" (Rull, 2009), which were popularly applied to the Pemón.

On the other hand, Pemón people, independent of their age, perceived that the conservation and preservation policies and programs advanced by the different public agencies, placed them at a crossroad: "If we cannot make the burnings, nor work in the conucos (small Indigenous cultivation area inside the forests), how shall we eat?" Additionally, they wondered why was it that now fire turned out to be wrong while they had been using it in the same manner for thousands of years (Bilbao *et al.*, 2019). However, some of them, especially the younger ones, admitted the loss of the elders' traditional knowledge of fire use and the sense of the burnings. Thus, they posed

Figure 2 – a) Forest firefighters from the Carlos Todd Initial Attack Brigade creating a firebreak to control a wildfire in the western sector of the PNC. b) Fighting a vegetation wildfire in the vicinity of the Roraima Tepuy in 2007 (Photographs a and b by PCIV). c) Pemón Indigenous, from Para-biologist program, registering air and soil temperatures after fire spread through an experimental fire plot. d) Some Indigenous participants from the Para-biologist course, firefighters from the Vegetation Fire Control Program of the hydro-electrical Company (CORPOELEC-EDELCA) and the research team from the Simón Bolívar University (USB) in charge of the IAB (Interactions Atmosphere – Biosphere) project (Photographs c and d by USB team).

the need of recovering traditional knowledge as a form of "not losing the credibility of the Pemón nation as the guardian of the savanna".

Building a new fire management paradigm

In Venezuela, since 1999, initiatives for the consolidation of intercultural and participatory fire management in the Gran Sabana, Canaima National Park (CNP), evolved as a result of a series of participatory action-research projects coordinated by the Simón Bolívar University, financed by the Ministry of Science and Technology and supported by national and regional public development institutions. The inclusion of Pemón Indigenous communities, firefighters, government institutional actors and academics in field research and joint experimentation on fire behaviour, as well as the debate and dialogue on socio-ecological issues of the CNP, led to the development of articulated knowledge and actions resulting in the foundation of a new paradigm of fire management and strategies for climate change mitigation and adaptation. Since 2015 these actions have been further extended

to neighbouring regions of the Guiana Shield of Brazil and Guyana with the collaboration and support of Venezuelan, British and other European institutions. In the same year, the Intercultural and Participatory Fire Management Network (or Parupa Network) was founded to strengthen and enhance the above-mentioned initiatives and to learn among the different stakeholders (local communities, scientists, government).

In the following sections, we summarise the main developments to date.

4.a. The first steps. Long-term fire experiment on the savanna-forest gradient in Gran Sabana. For the first time, the academy becomes an ally of Indigenous peoples in the topic of fire

- **IAB Project:** *Interactions Atmosphere – Biosphere of the 'Gran Sabana', Bolívar State, Venezuela (Figure 3).*

Various impacts of extreme severity have been attributed to fire, for example, intense processes of degradation of the vegetation, loss of buffer capacity to resist extreme climatic phenomena, soil degradation, changes in the water balance, tourism-related degradation, sediment increase in water courses, alteration of biogeochemical cycles and biodiversity loss. Due to the strategic importance of this region, both political and economic, these types of threats constituted a deep concern for local, regional, national or international institutions dedicated to conservation. Thus, one of the motivations to perform experimental studies on fire and its impacts on ecosystems was the lack of evidence of the real impact of fire on plant and soil components, the relevance of climatic variables and combustible material on the behaviour of fire as well as their historic effect on ecosystems.

To understand the actual dynamics of fire in the region, a long-term fire experiment was initiated in 1999, as part of the IAB multidisciplinary project, funded by the Ministry of Science and Technology (Bilbao *et al.*, 2009; Bilbao *et al.*, 2010; Millán *et al.*, 2013; Bilbao *et al.*, 2017). The experiments allowed an evaluation of the behaviour of fire and its effects under different treatments of frequency and period of burning during the dry season; they were conducted by simulating Indigenous burning practices on a savanna-forest gradient (where 70% of all fires start) in conjunction with members of the Indigenous community and CORPOELEC's fire brigades (Figure 4 a).

The long-term fire experiment was carried out using permanent plots (5°41'08.8"N - 61°31'39.9"O) in the north of the 'Gran Sabana' (one of the areas with higher fire incidence), in a savanna-gallery forest gradient characteristic of the region (Figure 4b). The experiment compared the behaviour of fire and its effects on vegetation and soil in 31 burns carried out in 21 plots of 0.5ha distributed according to a randomized block design with three replicates according to the burning treatments: a) different periods during dry season; b) different annual fire frequencies; c) control areas without burning (with fire exclusion from 1 to more than 12 years).

All the decisions regarding time of the day, meteorological condition adjustments, ignition onset and fire extinction were carried out according to the technical knowledge of the PCIV brigades, and traditional knowledge from Pemón people from different communities. The long-term biomass recovery and the effect on soils after the burns were carried out by periodic biomass and soil collections throughout the study period (Bilbao *et al.*, 2009; Bilbao *et al.*, 2010).

The results of the fire experiment (Bilbao *et al.*, 2009; Bilbao *et al.*, 2010; Bilbao *et al.*, 2011a) evidenced the following aspects:

1. Fire can occur in a broad range of climatic conditions and of combustible material characteristics.
2. Contrary to widespread belief, the burns are highly variable regarding intensity and behaviour and, in general, show low combustion efficiency. None of the 31 experimental burns was the same, breaking the myth that fire, when it occurs, is calamitous, contesting the belief that fire absence is always a good thing.
3. The wind velocity, accumulation of dead material, and leaf and stem biomass of the herbaceous layer constitute the main factors that contribute to fire behaviour increasing fire line intensities, burn efficiencies and fire propagation.
4. Due to the low recovery of biomass after a fire, the combustible material does not sustain annual burns, which are only possible every 3 to 4 years and, rarely, every two years.

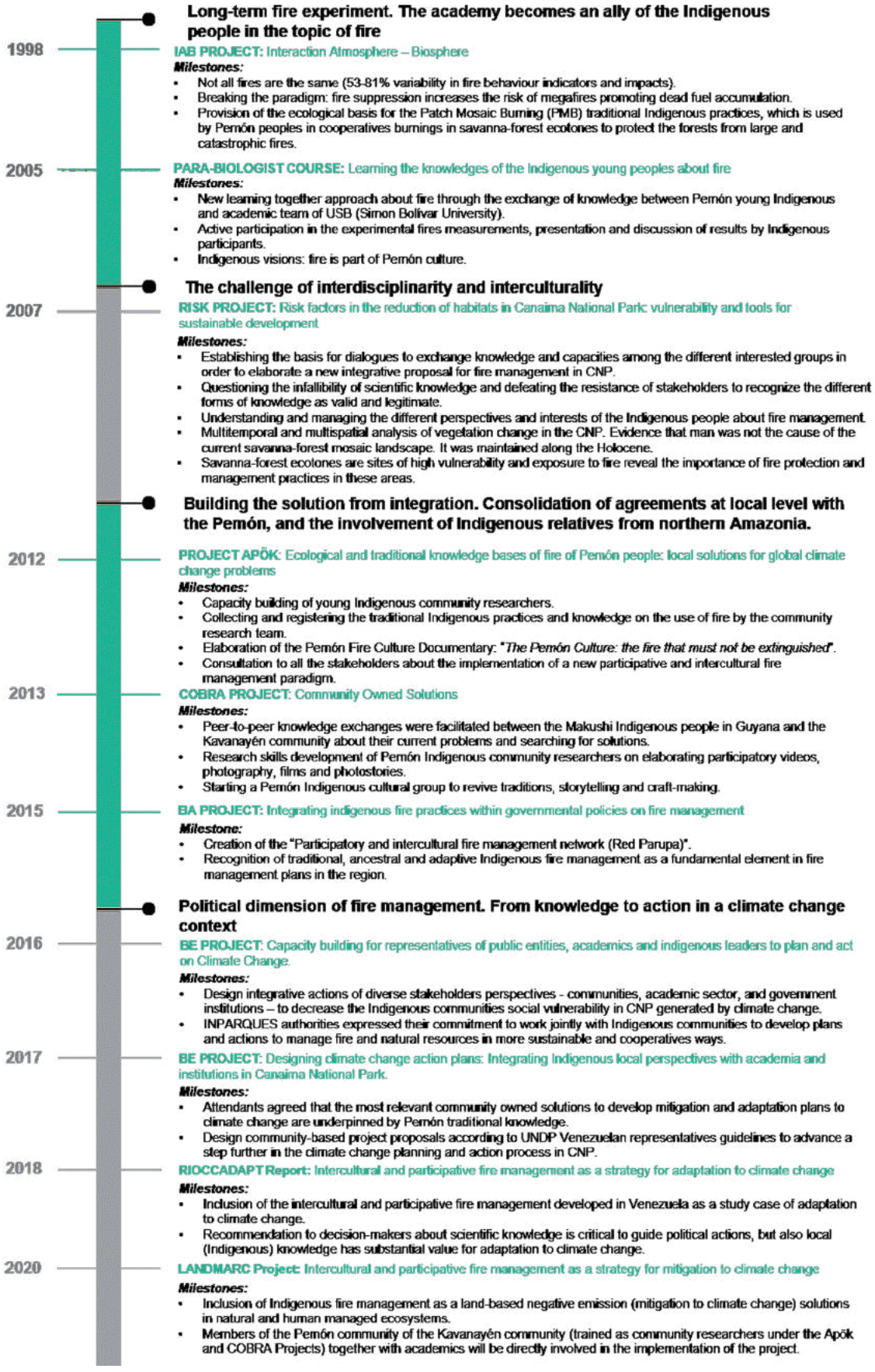

Figure 3 – Timeline and milestones building a new fire management paradigm along the last two decades in Venezuela (1998-2020).

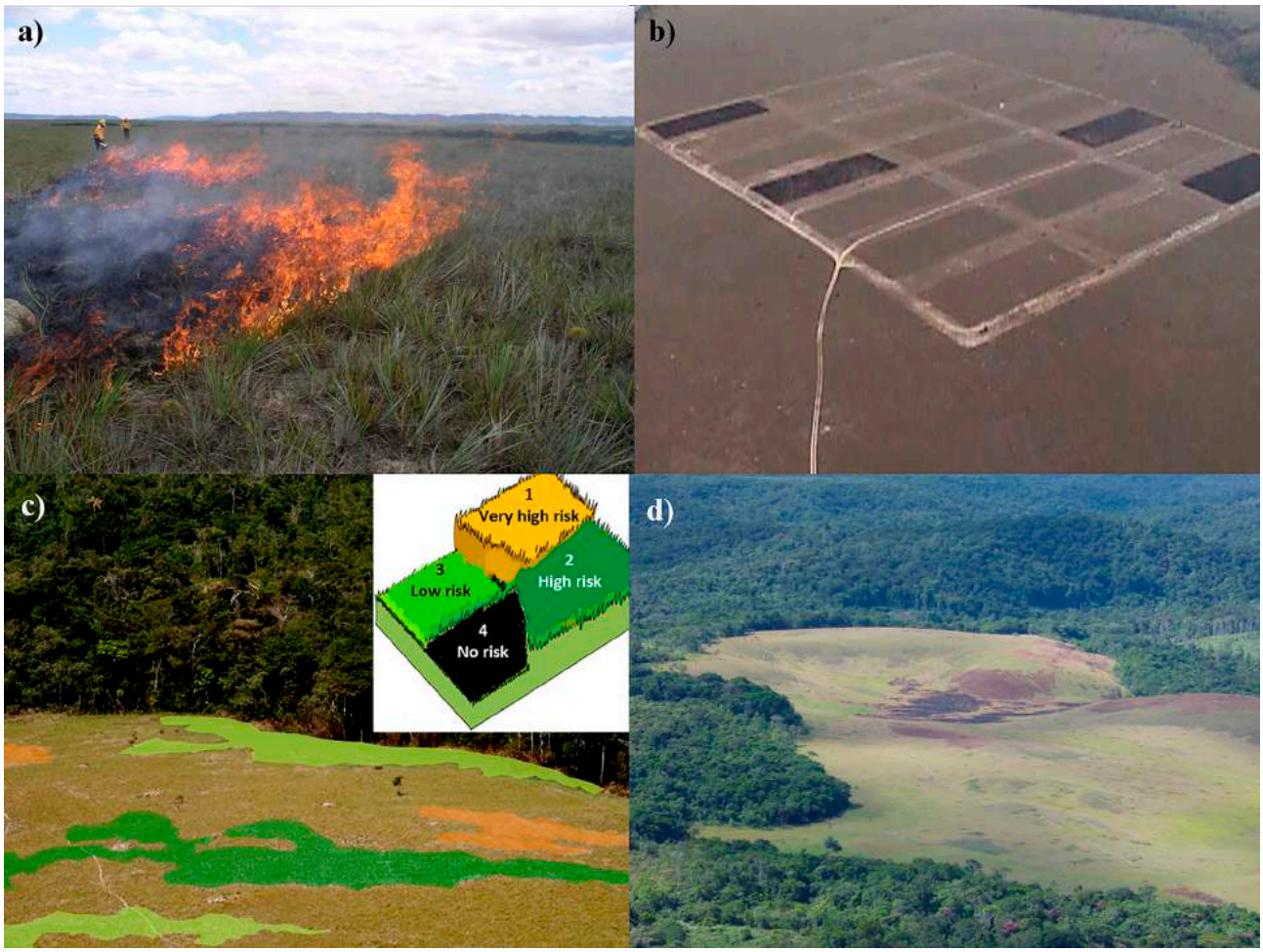

Figure 4 – Experimental burns initiated by Indigenous Pemón firefighters (Photography by Bibiana Bilbao); b) Aerial view of the long-term fire collaborative IAB experiment plots (Photography by Rafael Salas); c) and d) Different views of Indigenous Patch mosaic burnings (PMB) (Photography by Ruth Salazar-Gascón).

5. When savannas are left undisturbed for more than four years since the last burn and reach biomass >600 g m^{-2} and a green/dry ratio >1, they are more vulnerable and exposed to a greater risk of wildfire occurrence and spread.

These results suggested that the savanna vegetation in CNP allows the creation of a mosaic of patches with different fire histories; at the same time, these patches can be used as firebreaks to reduce the risk of larger fires, especially in the most vulnerable areas and those with high diversity, such as the savanna-forest ecotones, which, in turn, are the entry routes of fire into the forest. This technique is referred to as patch mosaic burning (PMB; Parr & Brocket, 1999; Bilbao *et al.*, 2009, 2010; Figure 4 c and d).

The discovery and characterisation of the ecological basis of the PMB technique was one of the most significant results of the study. This technique used by the Pemón for millennia produces a savanna landscape in different stages of succession, which acts as natural firebreaks when a wildfire reaches the border of a previous burned patch. This strategy avoids catastrophic wildfires in the most vulnerable areas of ecotones (Bilbao *et al.*, 2009; Bilbao *et al.*, 2010; Bilbao *et al.*, 2011a; Figure 4 c and d).

Many paradigms were broken by these experiences, the most important being that the Pemón Indigenous peoples were the incendiaries; by contrast, we showed that they were in fact the "masters of fire". In conclusion, the academic knowledge together with the traditional Pemón

knowledge opened the possibilities of a new fire management scheme in Canaima National Park, under the ancestral Pemón system of 'fire controls fire'. This strategy contradicted those adopted by governmental agencies of the Park that used fire exclusion leading to the risky accumulation of dead combustible material that can promote the occurrence of wildfires of considerable magnitude and extension.

However, it was also clear that besides to suppression policies, the Indigenous acculturation processes had become another threat to traditional practices in the use of fire by Indigenous communities. This was promoted initially by religious missions and later by formal school education, as well as changes in the socio-economic patterns of Pemón communities. The acculturation process's main consequences were revealed by the use of fire by some young members of Pemón communities, who did not follow the underlying knowledge of the grandparents about how, where, and what for it should be used (Bilbao *et al*., 2010; Rodríguez *et al*., 2013; Bilbao *et al*., 2017; Bilbao *et al*., 2019).

Thus, from this analysis we understood the importance not only of the ecology but also of the human dimensions as part of the conflict regarding the use of fire in the region. Likewise, the low effectiveness in the management of fire was revealed in the lack of connections among state institutions in CNP, Pemón Indigenous communities and information generated in academic institutions, as well as the articulation of knowledge.

The publication of the results (discussed in this section) from the article by Bilbao *et al*. (2010), earned the authors the National Award 2013 for Best Scientific Work and Innovation in Venezuela.

- **Course for Para-biologists,** *learning the knowledge of the Indigenous young people about fire (Figure 3).*

In February 2005, the leading author of this paper was invited to participate as a speaker in the "Para-biologist Training Program for the Pemón People", organised by "The Nature Conservancy-Venezuela", together with the Universidad Experimental de Guyana (UNEG) and Fundacite Guayana, at the Parupa Scientific Station, Gran Sabana Authority of the CVG. This Program consisted of the training of fifteen young Pemón, from different regions of their territory and ethnic groups: Arekuna, Taurepán and Kamaracoto. Selection criteria for the Indigenous participants was based on having had some form of educational training. The topic of the course was "Non-forest ecosystems and the management of savannas"; to define the concept of savannas and describe the environmental and biological parameters that determine the existence of savannas and other non-forest ecosystems.

It is crucial to mention that fire related issues were not included in the course. Fire was still a taboo subject to deal with, both for the communities that felt historically stigmatised and "blamed" for the use of fire in the Park, and for the Park authorities, which did not want to re-start the "fire conflict" with the Pemón communities in the Park. However, on a personal level, Bibiana Bilbao considered it impossible to talk about the ecology of the Gran Sabana, particularly in savanna ecosystems, without including fire. So, she considered to add to the aims of the course: *"the importance and use of fire in savanna management and other ecosystems"*.

This activity represented an enormous challenge. Despite having taught at the University (to undergraduate and graduate students) and having been a primary and secondary school teacher, Bibiana Bilbao felt that it was not fair to assume the role of teacher on this occasion. How was she going to teach the Pemón people about savannas and fire? Perhaps they were the ones that should teach her. Hence, she decided then to implement a knowledge exchange dynamic, sharing her knowledge with them, and they agreed to share their knowledge with their colleagues and with her. At that time Bibiana Bilbao and her team were engaging in the long-term fire experiment on the permanent plots of the savanna-forest gradient near Parupa Station. She invited the course participants to accompany the 2005 experimental burns and the corresponding measurements of fire behaviour (rate of propagation, flame height, fire temperature profiles, intensity, burning coefficients, among others), meteorological variables (air and soil humidity and temperature, solar radiation, wind speed and direction) and combustible material (species composition, accumulated biomass, green to dry ratio, and moisture content). She and her team also gave the participants initial training on the use of the equipment and methodology for

measuring different variables, as well as the use of computers for data analysis and results presentation (Figure 2 c and d).

After the participation in the experimental burns and the visit to different plant communities of grasslands, ferns, forests and savannas in the area, a discussion about the role of fire in the dynamics of ecosystems was organised. The participants of Para-biologist course presented the results obtained during the experimental burns and participated actively in the discussion and debates. Some relevant conclusions related to fire during the discussions were:

1- At no time was fire mentioned as a disturbing element in the savanna, despite repeated questions regarding the determining drivers of savanna dynamics. For them, fire is part of the savannas, like plants and soil.

2- Fire is an important management tool in the establishment of conucos (itinerant agriculture) and hunting practices in forest and savanna-forests ecotones. Fire is an essential part of their culture.

3- Several participants stated that various traditional practices in these activities are being lost within the Pemón communities, making it more difficult to control fire and its effects, especially under recent climate changes and weather variability.

4- The use of fire in different practices has increased, due to the increase of food demand, contributing to a greater fire frequency and area of impact.

5- They mentioned the expansion of the savannas and a marked reduction in the forest area due to a more intensive agriculture and hunting practice.

Bibiana Bilbao noticed the exchange of knowledge that took place was one of the most fascinating experiences of her entire career as a researcher and teacher. It was also very stimulating and enriching to see the interaction between Indigenous participants, and students and technical staff of the laboratory from USB. The firemen of the CORPOELEC Program also participated in this activity and taught them many practices and knowledge about how to control and avoid the spread of fires. For the first time in the Park, they all had the opportunity to learn from each other.

These experiences were the seeds that showed the need for the next project to be not only interdisciplinary (a step beyond the multidisciplinary nature achieved in the IAB project), but also intercultural, with the active participation of Indigenous people, Park administrators, firemen and in general all stakeholders in the Park. In addition to these two challenges, a third requisite that became evident was the need to carry out action-research. How could one move from knowledge to action? Trying to answer this question, the "Risk project" was born.

4.b. The challenge of interdisciplinarity and interculturality. Building the bridge between Indigenous and ecological knowledge, as well as of institutions around the fire theme

- **Risk Project:** *Risk factors in the reduction of habitats in Canaima National Park: vulnerability and tools for sustainable development (Figure 3).*

The Risk Project aimed at establishing the basis for dialogues to exchange knowledge and capacities among the different interested groups in order to elaborate an integrative proposal for fire management in CNP. The notion of risk was strategically used in the heading of the project proposal to call the attention of our prospective funder, the National Science Council, about the importance, novelty, and opportunity of the project. We wished to emphasize the increasing vulnerability with regard to interconnected technological, social and natural risks of catastrophic potential, the uncertainty with respect to the patterns and frequency of natural disasters due to environmental change, and the growing importance of the symbolic connotations of risk. We wanted to explore an increasingly significant approach brought to us by one of our co-authors (Hebe Vessuri), who had previously been related to the Millenium Ecosystem Assessment, and was a member of the scientific boards of the International Risk Governance Council (IRGC), the International Science Council (ICSU)´s Committee on Scientific Planning and Review, and the International Human Development Program on Global Change (IHDP). She brought to us examples showing a valuable mindset change with regard to science and scientific authority. Scientific knowledge

in modern history had been almost universally considered an undisputed public good. Now, it was also perceived as potentially producing risks and dangers so far unthinkable. Technological development was already incorporating notions of uncertainty, ambiguity and complexity (Renn, 2008).

Placing the issue of governance within a broader agenda that contemplated the cultural strengthening of Pemón Indigenous communities through their active participation in knowledge exchange and sharing, changed our research perspective. It gave a clearer focus on the need to develop capacities and strategies that went beyond a simple discourse about the practice of multidisciplinarity and presented challenges such as (a) understanding and managing the different perspectives and interests of the people involved relative to problems at different scales and their impacts in the management and governance of conflicts; (b) defeating the resistance of stakeholders to recognize the different forms of knowledge as valid and legitimate; (c) reconciling the different social and political contexts involved in these processes; and (d) developing a research approach based on deepening a critical learning focused on the construction of communication bridges indispensable for a permanent "translation" process between disciplines, knowledge fields, communities and management and decision-making institutions.

To meet these challenges, we developed a series of actions, mainly within the framework of the Risk Project and in cooperation with other initiatives.

1) The promotion of safe meeting spaces to enable the construction of a knowledge dialogue among Indigenous communities and institutions about fire management in CNP (Figure 5). The first achievement of the project was the implementation of a symposium entitled "Institutional, ecological and sociocultural perspectives on the fires of Canaima National Park" and the workshop "Bringing together perspectives for the creation of a legitimate and effective environmental policy for the management of fire in Canaima National Park". Both were carried out in the VII Venezuelan Congress of Ecology in Ciudad Guyana November 5-9, 2007 (García & Bilbao, 2007; FIEB, 2007). In the symposium, representatives of the Pemón people participated for the first time as stakeholders, and eight chiefs from different communities joined the event. This first workshop aimed at analysing the scientific (academic) knowledge, Indigenous wisdom and different perception of fire and its effects in the region and constituted the first meeting of this type in the country, especially because of the participation of Indigenous people.

   Among the main conclusions of the workshops was the need to acquire knowledge about fire and its effects in CNP and develop tools for an effective management and use in the region.

2) To complete this last objective, a risk analysis approach was followed (considering the vulnerability, exposure and risk of ecosystems). In this sense, to better understand the role of fire in ecosystems, studies were carried out in the short, medium and long term and at different spatial scales. The process of building this new knowledge was carried out with the support and participation of the Indigenous communities.

   Here is a summary of the main results and conclusions of the studies carried out in this sector:

   2a- Studies in different locations in Canaima National Park, both in the eastern part – Gran Sabana – and in the western region, revealed oligotrophic, highly acidic soils, generally sandy in texture, and very low organic matter content, even in forested areas (Pedraza *et al.*, 2009; Salazar-Gascón *et al.*, 2012; Bilbao *et al.*, 2013). Despite these nutrient limitations, Indigenous soil management techniques seemed very useful for agricultural activities, especially when considering that Indigenous people settled in the area millennia ago. Studies of the effect of fire on savannas' and forests' soil component revealed a soil nutrient availability increase and a marked decrease in the toxic aluminium acidity (Salazar-Gascón *et al.*, 2012; Bilbao *et al.*, 2012; Lares, 2015). The use of fire by Indigenous people in shifting cultivation practices, throughout the tropical region, is a practice known for the efficiency of transferring nutrients from plant biomass

Figure 5 – a) Meeting between the Indigenous community members of Kavanayén, Canaima National Park, and representatives of the Risk project. b,c) Working group made up of elders and youth from the Pemón indigenous communities (Photographs a, b and c by Diego Bilbao). d) Pemón Indigenous grandfathers and e) Pemón Indigenous participants in one of the assemblies with the Kavanayén community (Photographs d and e by Adriana Millán). f) Risk Project working group (Photography by Diego Bilbao).

(the main component that stores nutrients) for the fertilization of soils.

2b- Since forests are the primary source of ecosystem services (such as climate and hydrological cycle regulators, soil conservation, etc.) and natural resources for the Pemón people, we evaluated if these ecosystems were at risk, including their vulnerability and degradation levels. Likewise, if this is happening, what are the degradation rates and at what time scale are they occurring? And finally, what is the role of fire in these processes?

To answer these questions, we studied the history of vegetation changes at different time scales: millennial-scale (paleoecological studies), decadal-scale (through remote sensing studies) and in periods of a decade or less (through remote sensing and the aforementioned long term fire experiments) corresponding to several locations

in the western sector (Gran Sabana) and eastern CNP (Canaima).

Paleoecological Studies:

Palaeoecological reconstructions based on the analysis of pollen, spores and microcarbons were obtained from five sedimentary records located in the N-S altitudinal gradient of the Gran Sabana, in shallow lagoons, riparian forest and fern systems. The radiocarbon ages of the records ranged between 7500- and 1200-years BP (Leal, 2010; Leal & Bilbao, 2011; Bilbao *et al*., 2011b).

High levels of Poaceae pollen (grasses, the dominant herbaceous component of the savannas) were present along all the paleorecords in the Gran Sabana sites. This indicates that large areas of savanna, comparable to the actual ones, have existed in this region since the Early-Middle Holocene (around 7500 BP-before present). The only exception in this regard was the record located on the Gran Sabana's border, which has remained forested during millennia. Furthermore, the peat bog from "Parupa" showed that woody elements' density was higher in a drier period under more frequent/intense local fire regimes than the actual precipitation and fire conditions. In "El Oso" locality, savannas were more extended in the past than in the present, reaching up to 60% of total counts of pollen during 3,400 to 1,900 years BP, after forest species pollen types started to increase slowly.

Our results suggested that extensive treeless savannas comparable to the current ones have occurred in the region for long periods. This means that the current proportion of forests and savannas present in the Gran Sabana have varied very little in the past 10,000 years (Leal, 2010; Leal & Bilbao, 2011; Bilbao *et al*., 2011b; Leal *et al*., 2013; Leal *et al*., 2016).

Decade scale studies:

Vegetation coverage and land use maps of CNP Eastern sector (Gran Sabana) were obtained for the 1987-2007 period using Landsat Thematic Mapper TM / ETM + images with 30m resolution. Based on these maps analyses of vegetation change trajectories were performed through time (woody versus non-woody or herbaceous vegetation; Delgado-Cartay *et al*., 2007; Higgins *et al*., 2010).

Results revealed that secondary forests were the most dynamic ecosystems in the eastern sector of CNP and showed the most significant number of trajectories: 1) towards the formation of new conucos areas (agricultural areas), 2) remaining as secondary forests, 3) degrading towards mixed communities or savannas, and 4) recovering towards a state similar to primary or mature forest. Despite all these changes, the total area occupied by the different land-cover classes remained stable and the Gran-Sabana land-cover in 2007 is remarkably similar to what it was in 1987.

Considering the historical debate that has been associated to the human fire uses as the origin of the Gran Sabana landscape, composed by a mosaic of forests and savannas, we did not expect the land-cover distribution to remain constant. Likewise, this contrasts with dramatic shifts in landcover observed in other tropic forest regions over comparable periods of time and even at present (Nepstad *et al*., 2001; Achard *et al*., 2014; Barni *et al*., 2015; Clerici *et al*., 2020).

Another study based on the analysis of satellite images, in the western sector of CNP, indicated for a similar period of time, 1986 and 2006, an average rate of 0.064% forest cover loss within CNP limits (Flantua, 2008; Flantua *et al*., 2013). For the same period in the external buffer zone (about 10km away from CNP borders) the mean observed loss of forest was 0.18% of the original wooded cover. This was almost three times higher than the loss rate registered within the Park. Similar annual rates of 0.16% in forest cover reduction were also recorded in the north western limits of the CNP where deforestation is probably caused by the illegal extraction of wood for commercial uses. This last figure contributed significantly to increasing the average value of forest loss for the entire CNP, which would have been even lower than the 0.064% registered (Flantua & Bilbao, 2007; Flantua, 2008; Flantua *et al*., 2013).

These findings do not support the allegedly called "recent sabanization" process in the Gran Sabana due to Indigenous traditional activities, especially when considering that vegetation changes have occurred throughout the Holocene probably under changing climate conditions.

This leads to the conclusion that although it is possible that human beings have not played any determining role in the origin of the savannas of

Gran Sabana in CNP, they may have contributed to their maintenance through the use of fire, especially during humid periods when forest expansion processes in the region could have been favoured (Mendez, 1999; Leal *et al*., 2016).

This last conclusion has profound implications in the current scenario of Global Environmental Change. Fire needs to be managed to avoid large fires in CNP that affect vulnerable plant communities such as riparian forests which provide vital environmental services in the area. The development of fire management plans in CNP must give priority to the contact zones between riparian forests and savannas since these systems have a more significant recurrence of fire and constitute principal sites of natural forest restauration (Bilbao *et al*., 2010; Bilbao *et al*., 2011a; Bilbao *et al*., 2017).

The Risk project ("Risk factors in the reduction of habitats in Canaima National Park, Venezuela: vulnerability and tools for sustainable development") received, in October 2010, the Europe Award for Innovation for Sustainable development in Venezuela (awarded by the Goethe Institute, the Spanish embassy in Venezuela, the French embassy in Venezuela, the British Council, the Delegation of the European Union in Venezuela and the Academy of Physical, Mathematical and Natural Sciences).

4.c. Building the solution from integration. Consolidation of agreements at the local level with the Pemón, and the involvement of Indigenous relatives from Northern Amazonia

- **Apök project** (fire in Pemón Language): *Ecological and traditional knowledge bases of fire of Pemón people: local solutions for global climate change problems (Figure 3)*.

This project was part of a national portfolio of strategic research projects on climate change, promoted by the Ministry of Science and Technology of Venezuela. Apök project attended various interests and motivations expressed previously within the framework of Risk project either by the Indigenous community or the officials from national conservation institutions. Thus, the leaders and the council of elders of the Pemón Arekuna community, expressed publicly their concerns as demographic, sociocultural and educational transformations have affected the traditional ways in which grandparents share their knowledge to new generations (Bilbao *et al*., 2014; Bilbao *et al*., 2019). As in many Indigenous cultures around the world, the system of knowledge transmission in Pemón culture is based on oral communication. Therefore, they identified the need to record in written or audiovisual manner their traditional practices about fire and in general their natural resources management. Likewise, the Risk Project identified the importance of promoting traditional practices of Indigenous fire, as a conservation tool for CNP laying the groundwork to build a new paradigm of fire management in the Park.

Considering the processes of ancestral knowledge loss faced by Pemón people, Apök project implemented several activities focused on the Arekuna community of Kavanayén in CNP:

1- The project started by setting a team of young community researchers, who were in charge of carrying out the process of gathering Indigenous ancestral knowledge and practices in relation to the use of fire, itinerant agriculture and hunting. The focus was to interview the community elders or grandparents, who are considered a living heritage of knowledge and traditions of the Pemón people. The Indigenous community researchers received training on the techniques for conducting interviews and on the collection and documentation of the information obtained. The decisions in relation to the grandparents to be interviewed and the questions being asked were jointly discussed with project researchers. The community researchers conducted all the interviews in Pemón language, and the information obtained was transcribed and validated afterwards with the interviewees (Figure 6a, 6b and 6c). During this process, several assemblies were carried out in the community to inquire further into relevant issues regarding the use of fire brought up in the interviews, as well as to present the advances of the project.

2- Following the request made by the Pemón community, a video documentary: *"Pemón Culture: The fire that must not be extinguished"* was done in the framework of the Apök project (Bilbao *et al*., 2014). The production team submitted the video's

Figure 6 – a) Community researchers and teachers of Kavanayén Agricultural Technical School (ETAK) carrying out soil and ash sampling tasks in the community school conuco in Kavanayén Indigenous community (photography by Dimana Shiskova); b) Worktables where grandfathers of the Pemón community validated the information collected by community researchers; c) Presentation of the worktable results about Indigenous traditional fire management (photographs b and c by Maiquel Torcatt); d) Community researchers conducting interviews for participatory videos (photography by Cobra team).

content to the approval of a community assembly. The documentary included interviews with youngsters, adults and elders revealing the importance of Pemón traditional knowledge about fire, as well as the threats and concerns resulting from interrupting these Pemón's practices in CNP's ecosystems (Figure 7). In November 2013, the video was completed and shown for the first time in the community, who was grateful and satisfied with its content. The video was also shown in the film forum: "To burn or not to burn: breaking the paradigms of the use of fire in the conservation of tropical ecosystems", organised by Apök Project, at the X Venezuelan Congress of Ecology, celebrated in Mérida. This event allowed a valuable live communication exchange between Indigenous members of the community who attended the forum and academics.

3- In the framework of Apök, we also started to conceptualize collectively a new fire management paradigm for CNP. The proposal included the ancestral knowledge and practices of the Pemón about the use of fire, the development of scientific knowledge concerning the ecology of fire developed previously in the IAB and Risk projects, as well as the technical capabilities of the PCIV and entities in charge of fire control in the CNP.

Figure 7 – a) Indigenous community researcher interviewing one of the grandfathers during the filming of the documentary "Pemón Culture: the fire that must not be extinguished" (https://youtu.be/ePc3UB98lE4), (photograph by Adriana Millán). b) Indigenous community researchers in the process of collecting ancestral knowledge related to the use and management of fire (photograph by Sofía Marín).

The participative process was based on: 21 interviews (with PCIV brigade members and workers from the CORPOELEC Environmental Management Unit, Bolívar region), as well as four workshops (with members of the Pemón community of Kavanayén and Pemón brigade members of the PCIV. These activities showed how both Pemón community members and the institutions were willing to work together to design a management strategy that respects and considers Pemón traditions and knowledge. Participants agreed and highlighted the use of fire as a conservation strategy based on the implementation of prescribed burns, application of ancestral Pemón fire management practices, and support of academics. The use of participatory and adaptive approaches and the development of research programs accordingly, are fundamental to the new fire management approach (Millán *et al.*, 2013; Millán, 2015).

- **COBRA Project.** *Community owned solutions.*

During the APOK project, another project to promote traditional knowledge was initiated. Project COBRA, funded by the European Commission, aimed to enable and disseminate grassroots solutions to complex environmental management and governance problems in the Guiana Shield, South America using an action research approach. As part of the project, peer-to-peer knowledge exchanges were facilitated; in this case between the Makushi in Guyana and the community of Kavanayén. More specifically, through participatory video and photography, films and photostories were screened and discussed, and this led to Kavanayén starting a cultural group to revive traditions, storytelling and craft-making (Tschirhart *et al.*, 2016). In addition, the project helped to build capacity in Kavanayén on the use of participatory video, thus adding to the growing suite of research skills developed by previous projects in CNP.

- **British Academy Project.** *'Integrating Indigenous fire practices within governmental policies on fire management' (Figure 3).*

The results of the compendium of sustained actions described above set the stage for the First Regional Meeting of Intercultural Management for the Participatory Management of Fire, celebrated between July 8 and 11 of 2015. The meeting took place at the Parupa Scientific Station in the 'Gran Sabana of CNP, where Pemón and Yekuana communities met and exchanged with Makushi,

Wapishana and Kayapo Indigenous peoples from Brazil and Guyana (Figure 8 a and b; Bilbao & Mistry, 2015; Bilbao *et al*., 2019). These groups face similar fire issues, and the meeting helped them to recognize the necessary steps to promote their ancestral knowledge. In addition, researchers and representatives of institutions from Venezuela, Brazil and the United Kingdom participated in the meeting. Furthermore, this meeting resulted in agreements for the design of a plan of fire management based on the autochthonous knowledge of the Pemón people and the rescue of their ancestral traditions (INPARQUES Oficial, 2015; Más VERDE DIGITAL, 2015; Notiambiente, 2015; Bilbao & Mistry, 2015; Bilbao *et al*., 2019; Bilbao *et al*., 2020).

This initiative was developed in the framework of the project 'Integrating Indigenous fire practices within governmental policies on fire management' funded by the British Academy, a research funder from the United Kingdom. The aim of the project was to develop a 'case' for integrating

Figure 8 – a) Presentation of methodological aspects of the workshop held at the Parupa Scientific Station in July 2015 for the creation of Intercultural and Participatory Fire Management Network b) INPARQUES (Acronym in Spanish of National Parks Institute) forest firefighter presenting the results of the working group on current fire management in Canaima National Park (photography by Cobra Collective Indigenous researchers). c) Member of Indigenous Pemón community presenting the results of fire management working group at the British Embassy workshop (1) held at the Venezuelan Institute of Science and Technology (IVIC), (photography by Maiquel Torcatt). d) Park ranger (and member of the Indigenous Pemón community) and INPARQUES forest firefighter, presenting the results of fire management working group at the British Embassy workshop (2) held at the headquarters of the INPARQUES forest-firefighter department, (photograph by Ruth Salazar-Gascón).

Indigenous fire practices within government fire management policy by combining existing data from experimental burns and participatory research on Indigenous land practice knowledges, and collecting new data on fire impact inside and outside Indigenous lands, and stakeholder perspectives. The 'Intercultural and Participatory Network of Fire Management', or 'Red Parupa' was one output from this collaboration between Royal Holloway University of London and the Universidad Simón Bolívar (Bilbao & Mistry, 2015; Bilbao *et al.*, 2019).

4.d. Political dimension of fire management. From knowledge to action: plans and networks in a climate change and regional context

- **British Embassy Projects:** *"Promoting the design and implementation of a national Climate Change plan in Venezuela",* and *"Capacity building for Venezuelan civil servants, academics and Indigenous leaders to plan and act upon Climate Change" (Figure 3).*

Several studies and evidence show how Indigenous land use practices, including fire use, conserve carbon and maintain biodiversity (Trauernicht *et al.*, 2015; Mistry *et al.*, 2016; Roos *et al.*, 2016; Russell-Smith *et al.*, 2017; Bilbao *et al.*, 2020). Controlled and appropriate use of fire can contribute to soil fertilization and vigour of vegetation recovery and net productivity (Bilbao *et al.*, 2017). Knowledge about the Indigenous uses and management of fire are critical to inform the design of climate change mitigation and adaptation strategies.

Thus, to promote participatory and sustainable fire management within climate change policies in Venezuela, funded by The British Embassy (BE) in Caracas and supported by the Instituto Venezolano de Investigaciones Científicas (IVIC) and INPARQUES National Parks authorities Firefighters Body, two workshops were held during the 2016-2017 and 2017-2018 periods.

The participative methodology used in these two workshops aimed to facilitate knowledge and experience exchange among participants and included: expert presentations, video exhibits, proposed questions and exercises addressed by small discussion groups, participatory audiovisual techniques (i.e. drawings, storyboard design, dramatizations, short video recordings) as well as plenary discussions. Five different discussion groups composed of Indigenous participants, researchers and public servants were organised according to the following thematic areas: 1) Food sovereignty; 2) Management and conservation of water resources; 3) Fire management; 4) Biodiversity, and 5) Social vulnerability and socio-productive activities.

The activities of both workshops are described below:

BE Workshop 1: *"Climate change action plans design: Integrating local Indigenous, academic and institutional perspectives in Canaima National Park, Venezuela" (Figure 8A)*

The aim of the first workshop was to design a Climate Change action plan to integrate local solutions and scientific research into public policies for long-term intercultural sustainable management in Canaima National Park. Eighty participants belonging to six Indigenous, fifteen academic, nine government, and two NGO organizations attended the first training workshop.

This first workshop helped academics and managers approach and understand the world-views, beliefs and values of Pemón Indigenous culture and acknowledge Indigenous ancestral fire and natural resources management in public policy instruments to manage CNP. Similarly, this workshop provided strength to Indigenous participants to safeguard their ancestral knowledge since this is a crucial factor to resist adverse situations that currently affect them. Academics and public managers expressed great interest in the mechanisms used to articulate diverse knowledge and capacities in the process of building up an interdisciplinary and intercultural model of knowledge and research on climate change. They also showed interest in designing integrative actions of diverse stakeholders' perspectives – communities, academic sector, and government institutions – to decrease the Indigenous communities' social vulnerability in Canaima National Park generated by climate change.

Particularly, INPARQUES authorities expressed their commitment to work jointly with Indigenous communities to develop plans and actions to manage fire and natural resources in more sustainable ways.

BE Workshop 2: *"Development of intercultural and participatory tools for the implementation of mitigation and adaptation plans to climate change in Canaima National Park." (Figure 8B)*

This second workshop was a follow-up activity derived from the agreements reached in the previous one. This project offered a set of training activities organised in an intensive workshop to increase the stakeholders' capacities to implement action plans based on adopting local solutions to mitigate and adapt to climate change in CNP. The workshop allowed scientists, government authorities, and Pemón Indigenous leaders to understand basic climate science, build maps of institutional climate change networks, and design local climate change solutions, exploring some international bilateral and multilateral financial cooperation opportunities. Fifty-three participants belonging to twenty-six different Indigenous, academic and government organisations as well as from two British academic organisations attended and actively participated in this training workshop.

During the workshops, especially designed group activities reinforced some key concepts about climate change (i.e., mitigation, adaptation, resilience, greenhouse gas emissions impacts, among others), as well as planning and project design on local climate change adaptation (i.e., identification and characterisation of local and national stakeholder networks, local socio-environmental problem identification, community owned solutions, project design).

Attendants agreed that the most relevant community owned solutions to develop mitigation and adaptation plans to climate change are underpinned by Pemón traditional knowledge. The traditional agricultural practices and fire management, and the respect and preservation of forest vegetation of CNP, among others, are deeply rooted positive cultural aspects in the Pemón people, which are compatible with natural resources conservation and CO_2 emissions reduction.

The workshops dynamics allowed a thorough mapping of all stakeholders involved in fire management and conservation in CNP. This helped clarify the responsibilities and strategic relevance and put into context the role each agency and the community itself has or may have to address local problems. As a result, participants agreed that past and current individual stakeholders' interventions were ineffective and caused conflict; instead, coherent and integration action policies need active cooperation networks of institutions and communities supported on knowledge exchange. Therefore, communication, organisation and cooperation are necessary to generate collectively responses that are both adaptive and flexible to problems related to climate change.

The workshops promoted an increasing willingness and disposition from representatives of Indigenous communities, scientists and government institutions to work cooperatively with each other, to comply with policies, programs and projects to mitigate and adapt to Climate Change in Canaima National Park. The attendance of high government authorities from INPARQUES, the Environment and Risk Management Ministries, and the British Embassy demonstrated respect and expectation.

National authorities who participated in the workshops acknowledged the need to devise a new institutional framework to guide government authorities in meeting commitments in designing policies and strategies to deal with the complexities and challenges climate change demands.

The results of these Workshops also provided relevant information to feed the next Venezuelan Communication on Climate Change. However, the most significant advance was the proposal of Indigenous communities' active participation in developing the Third National Communication on Climate Change supported by IPCC Venezuelan representatives.

One of the workshop's significant achievements was that participants had the opportunity to design community-based project proposals according to UNDP Venezuelan representatives' guidelines to advance a step further in the climate change planning and action process in CNP.

The intercultural knowledge exchange experience around fire management in CNP shows that the inclusion of communities and relevant stakeholders nurtures and speeds up viable policy design and implementation, setting up the lead for a new socio-environmental governance process to address climate change challenges in Venezuela.

4.e. Expanding our frontiers. The impact at the regional level. Venezuela as a case study

Along the implementation of the mentioned projects, the interaction with Indigenous leaders, students, researchers, and public institutions in national and international meetings as well as the formal publication of the projects findings allowed to recognize that beyond Venezuela's borders similar problems derived from fire suppression policies occurred. This has inspired some initiatives promoted by different communities and institutions in Venezuela and neighbouring countries in support of changing fire suppression policies and laws. The drafting of two new bills in South American countries in 2019 (one submitted to the Brazilian National Congress, and another to the Colombian National Congress), are examples of these efforts aiming to enact new national policies based on integrated fire management to replace the "zero fire" provisions still in force today in both countries (Mistry *et al.*, 2019; Bilbao *et al.*, 2019; Bilbao *et al.*, 2020; Pardo & Bilbao, 2020). In Venezuela, the Firefighters Body from INPARQUES has reoriented its philosophical doctrine in order to adopt integrated intercultural fire management practices devised jointly in the participative workshops promoted along recent years.

- **RIOCCADAPT report.** *Adaptation to Climate Change Risks in Ibero-American Countries (Figure 3)*

Another significant achievement is the inclusion of the case study of Venezuela in the RIOCCADAPT report (http://rioccadapt.com/, Moreno *et al.*, 2020b) in the chapter dedicated to Wildfires (Bilbao *et al.*, 2020). The purpose of the RIOCCADAPT report was to assess the climate change adaptation actions being carried out in the member countries of the Red Iberoamericana de Oficinas de Cambio Climático (Ibero-American Network of Climate Change Offices or RIOCC), i.e., Spanish- and Portuguese-speaking countries in the Americas, the Caribbean, and the Iberian Peninsula. The Network gathers the national climate change offices of the Environment Ministries of the Ibero-American countries. RIOCC is a collaborating partner of the Nairobi Work Program from the United Nations Framework Convention on Climate Change. Its goal is to assist Parties, particularly developing countries, and facilitate informed decision-making by governments on practical adaptation measures to respond to climate change adequately.

The experiences acquired in Canaima National Park in the construction of an intercultural and participative fire management as a strategy for adaptation to climate change were included in the RIOCCADAPT report as one of the successful case studies related to fire management and climate change adaptation in the Ibero-American region. This exercise implied contextualizing adaptation actions in terms of vulnerabilities, exposure of socio-ecosystems and risks and impacts of climate change, including recommendations about most effective measures to help governments anticipate its effects, and be prepared to protect the most vulnerable aspects and build more resilient societies (Moreno *et al.*, 2020a; Bilbao *et al.*, 2020). CNP case study was included in this report as an example of good practice on how to build socio-environmental policies starting from a bottom-up process. For the first time in the Ibero-American region, a recommendation was made to take into account and learn from local knowledge and practices (Indigenous and rural) to develop climate change adaptation strategies about the problem of fires, which is severely affecting the entire region. A key recommendation to decision-makers derived from this experience is that scientific knowledge is critical to guide political actions, but also local (Indigenous) knowledge has substantial value for adaptation to climate change. CNP case showed also that regional cooperation, dialogue and exchange of information and experiences among countries is also crucial to face these global and complex crises.

- **LANDMARC Project.** *LAND-use based Mitigation for Resilient Climate pathways (Figure 3)*

To be able to fulfil the Paris Agreement and meet the world's climate goals research, policy and markets are increasingly looking at land-based negative emission solutions. Funded by the European Commission, the nineteen LANDMARC consortium partners, across 14 countries and 5 continents, will spend the next four years (2020-2024) working to enhance understanding in the area by providing better estimates of the realistic potential of land-based negative emission

solutions in agriculture, forestry, and other land-use sectors. This project includes 16 specific LMT case studies in four continents.

In order to explore the potentialities of Indigenous fire management as a land management technology (LMT), the Cobra Collective and Simón Bolívar University will lead a case study in Venezuela building on previous CNP experiences, seeking to open up discussions and share lessons to provide the basis for developing continental narratives and scenarios in the Americas. This is the only case study included in the LANDMARC project in which the management of Indigenous fire for agricultural purposes and forest protection was proposed to be considered an LMT. Since fire has been historically viewed as an element of deforestation and emitter of greenhouse gases, Canaima National Park's experiences represent an unusual and innovative alternative for fire management to mitigate climate change. Members of the Pemón community of the Kavanayén community (trained as community researchers under the Apök and COBRA Projects) together with academics will be directly involved in the implementation of the project. From our perspective, this is a well-deserved and earned acknowledgement of their valuable knowledge and protection of their Indigenous ancestral practices.

In our opinion, these unique characteristics represent significant achievements derived from a long trajectory of joint efforts around the socio-environmental role of fire in CNP.

Conclusions

Numerous empirical studies in different contexts have shown the negative effects in the long term of the command-and-control management approach. These works demonstrate that the elimination of perturbations and variability of ecosystems end up eroding their resilience and regeneration capacity (Folke *et al.*, 2002). The practice of fire suppression as a control mechanism (especially in ecosystems that have evolved with fire) not only has favored the occurrence of more damaging wildfires, but also land management agencies are devoting ever greater resources to suppressing fires leading to what Gunderson and Holling (2002, cit. Butler & Goldstein, 2010) call a "rigidity trap" of pathological resistance to novelty and innovation. This practice has dominated the wildland fire management strategies in the United States for nearly 100 years, although in the last decade fire scientists have called for an end to the war against fire on the wildlands (Butler & Goldstein, 2010).

The combination of scientific and traditional Indigenous knowledge constitutes a promising strategy to develop environmental policies for an efficient management of fire and the restoration of degraded areas. Likewise, this strategy might be successful for the conservation of forests as well as for the mitigation and adaptation to climate change and the conservation of the cultural integrity of the Pemón people. Integrating scientific and Indigenous knowledge was one of the main challenges addressed by the Risk, Apök and more recent projects, whose goals were to define long-term actions required for the sustainable use of resources, respecting the laws and legal framework of Canaima National Park as well as the sovereignty and rights of the Pemón Indigenous communities.

There has been a paradigm change in the approaches to fire management and the practices of some environmental managers in several South American countries, including Venezuela and Brazil. Thus, from the suppression and combating of fire as the predominant management policy, important advances have been made towards a recognition of the social and cultural uses of fire by Indigenous and local communities, and the understanding of ecological phenomena, as a basis for the design of new management instruments. The next challenge is to strengthen and promote intercultural and participatory processes through the development of intercultural platforms that allow dialogue and exchange of knowledge and skills between all stakeholders involved. This should involve a management instrument that ensures equitable conditions of participation and implementation of all stakeholders, in their various fields of action (from the planning of prescribed fires to their implementation and monitoring) and the exchange of experiences and consolidation of cross-border fire management Programs.

We consider that this approach will allow us to address new challenges and the search for solutions in several areas: a) from the environmental point of view: climate change and land-use change are generating transformations in the patterns of fire regime and behaviour producing mega-fires that cannot be addressed through isolated initiatives. It is necessary to develop a framework for local, national

and regional consultation; b) from the cultural point of view: Indigenous and local rural communities are suffering from processes of acculturation accelerated by external pressures related to the denial of their traditional practices, loss of territory, migrations, incorporation into productive systems foreign to their own ways of life, among others. A new intercultural and participatory governance must focus on the legitimization of Indigenous knowledge of traditional fire use and its active incorporation in the design and implementation of fire and natural resource management policies in their territories, as well as the promotion of the process of rescuing their traditional practices and knowledge and the strengthening of forms of knowledge transfer between generations; c) from the institutional point of view: the customary implementation of institutional policies designed top-down, with good purposes, but often with a lack of knowledge of the socio-environmental realities of territories, have historically failed in the application of inclusive and effective programs in fire management and control. Despite the important changes of paradigms addressed by several institutions in Venezuela, it is necessary to reinforce and extend these experiences to a greater number of institutions and to promote, from the legal and practical point of view, inclusive fire management policies; d) from the methodological point of view: achieve the effective participation of actors with different perspectives on the use and management of fire through intercultural interfaces that generate bridges of understanding and cooperation. This would be an excellent opportunity to generate effective cross-border concerted actions in fire management, strengthening institutions and increasing technological and cultural exchange.

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

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

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

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

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

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

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

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

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

Historical and legal context

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

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

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

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

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

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

Integrated Fire Management in Federal Protected Areas

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

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

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

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

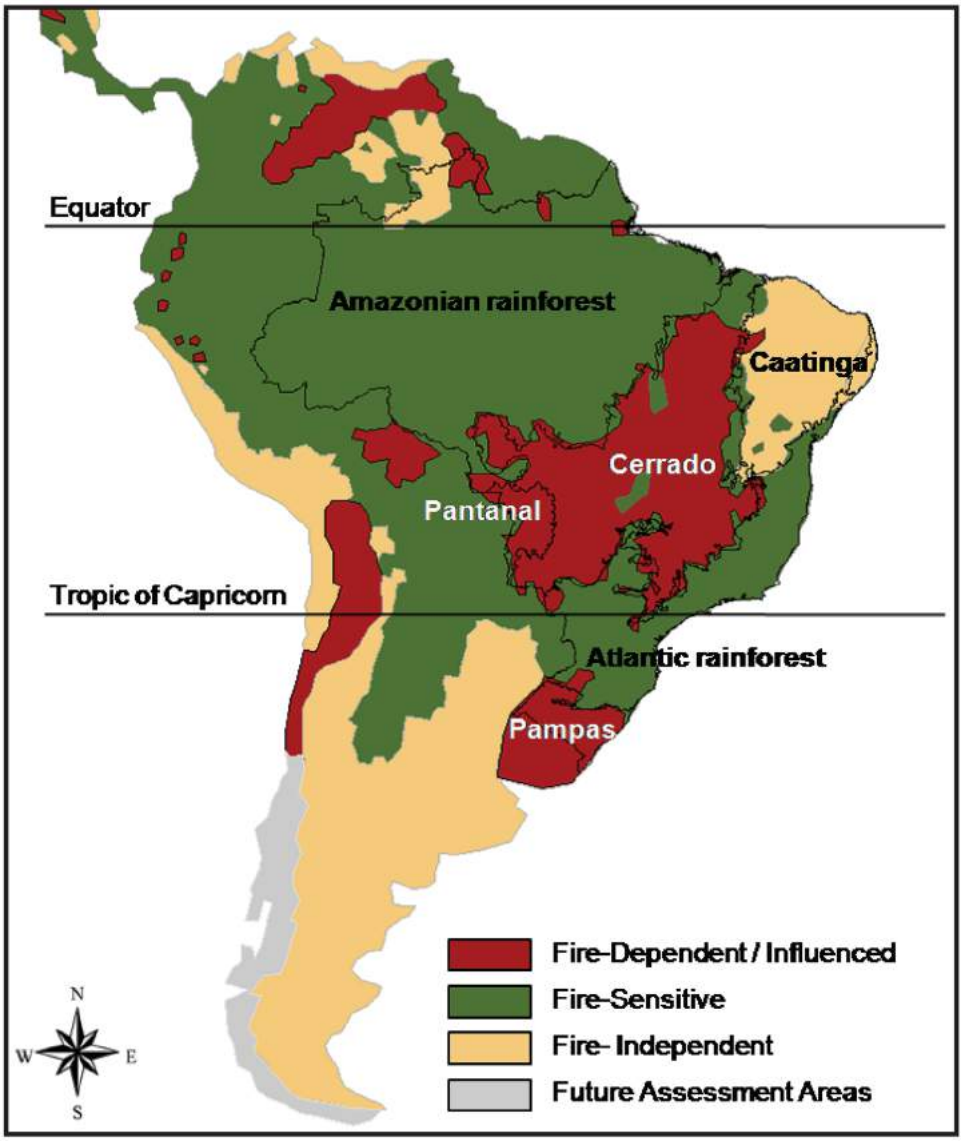

Figure 1 – Brazilian biomes and their relationship with fire (Hardesty *et al*., 2005).

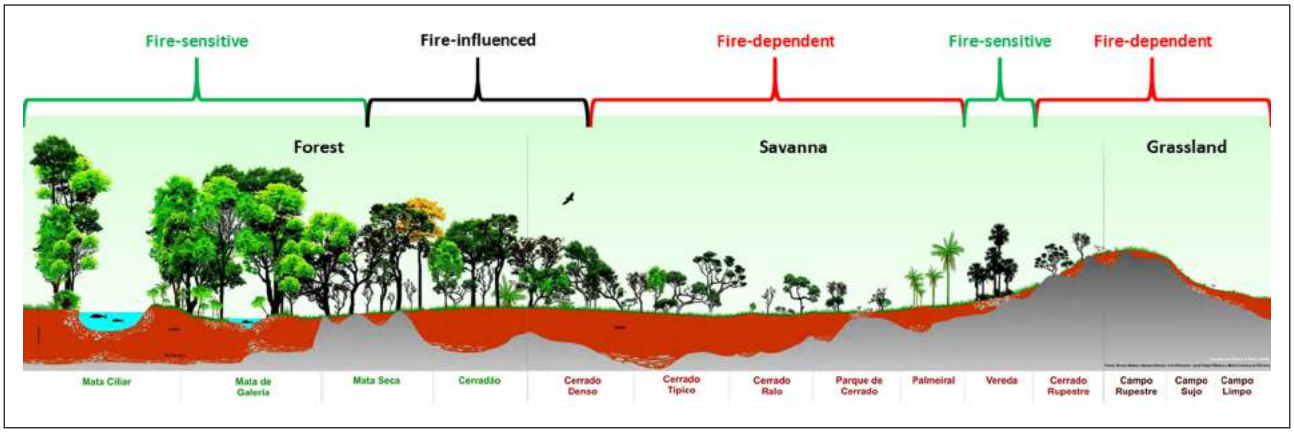

Figure 2 – Phytophysiognomies of the Cerrado biome divided into Fire-sensitive, fire-dependent and fire-influenced (adapted from Ribeiro & Walter, 2008; and Walter & Ribeiro, 2010).

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

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

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

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

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

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

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

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

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

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

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

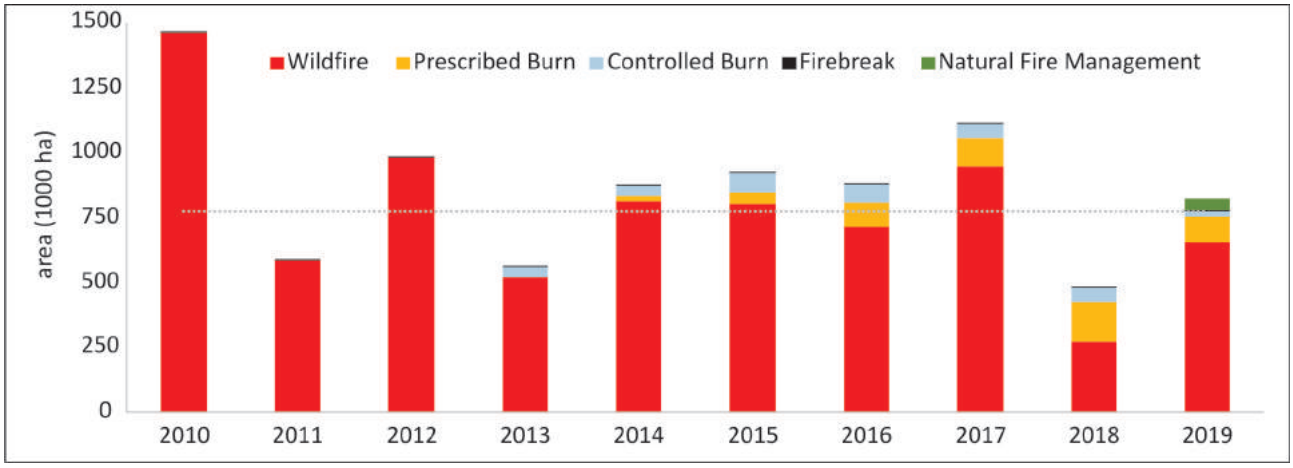

Figure 3 – Area affected by fire in the Cerrado between 2010 and 2019 divided in five categories. The line is the average of the wildfire area in the same period (Berlinck & Batista 2020).

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

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

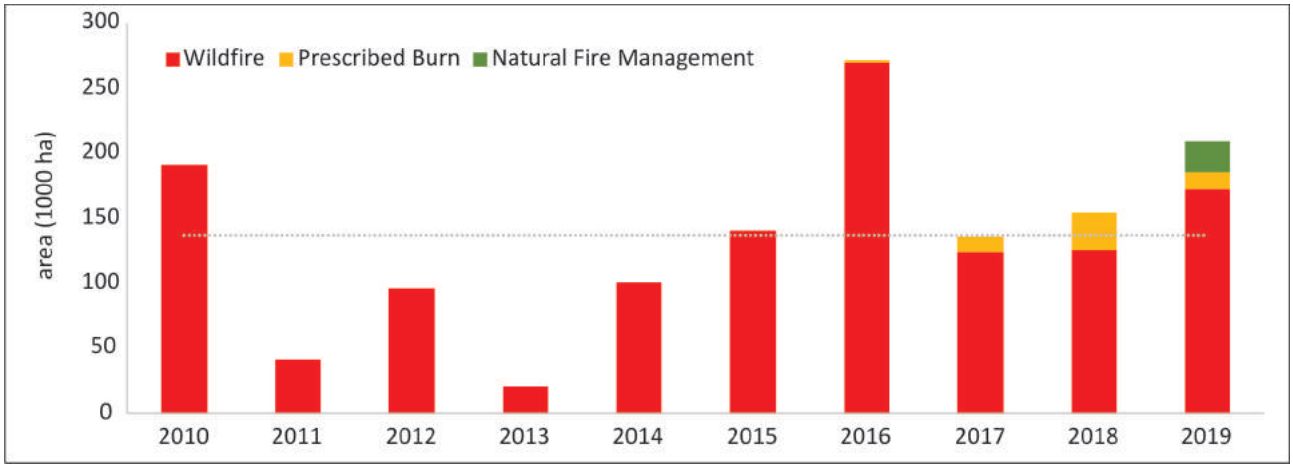

Figure 4 – Area affected by fire in the Amazon Biome between 2010 and 2019 divided in categories. The line is the average of the wildfire area in the same period (Source: ICMBio).

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

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

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

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

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

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

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

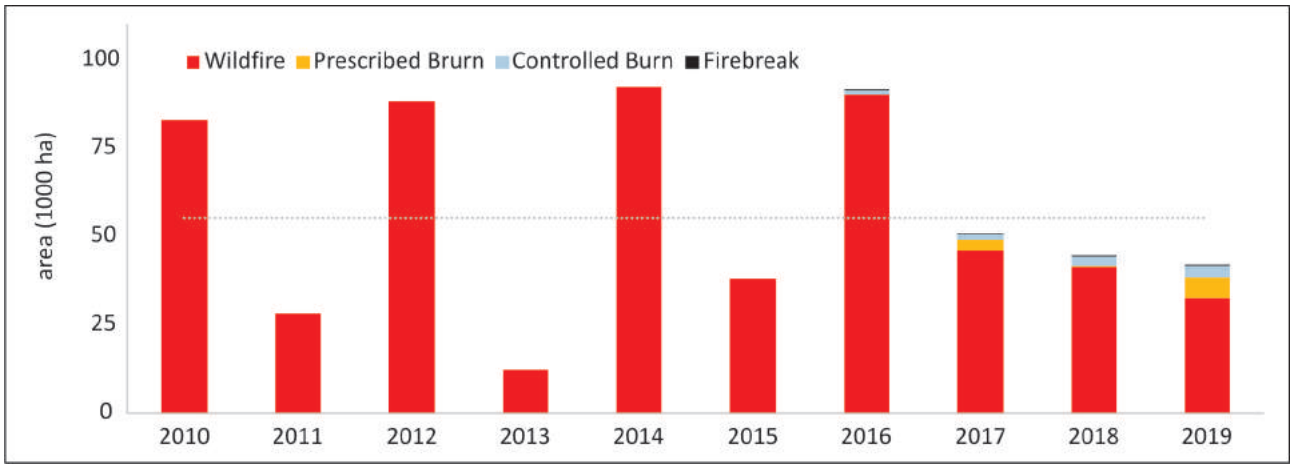

Figure 5 – Area affected by fire in the Serra da Canastra National Park between 2010 and 2019 divided in categories. The line is the average of the widfire area in the same period (Source: ICMBio).

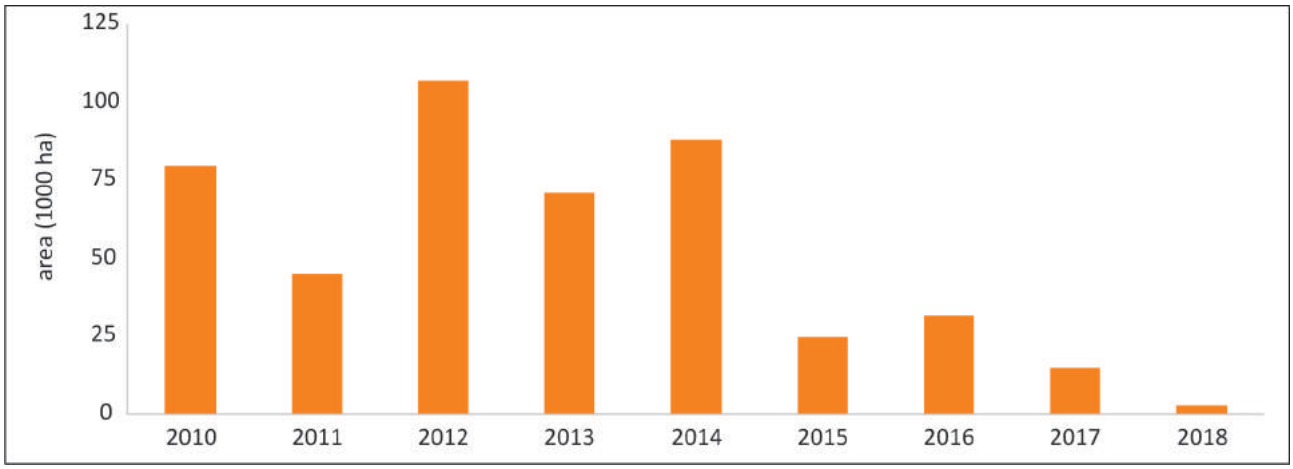

Figure 6 – Comparison of the size of the biggest wildfires in Serra Geral do Tocantins Ecological Station between 2010 and 2018 (Source: ICMBio).

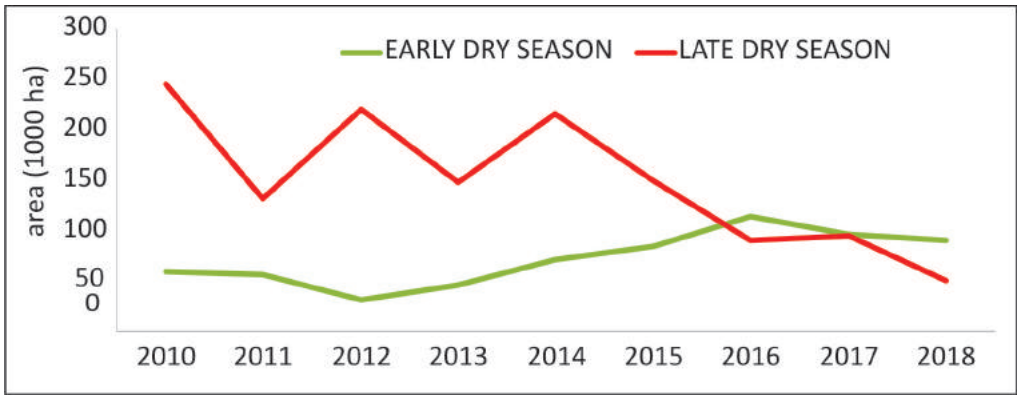

Figure 7 – Comparison of the area burned at the beginning and end of the dry season at Serra Geral do Tocantins Ecological Station (Source: ICMBio).

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

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

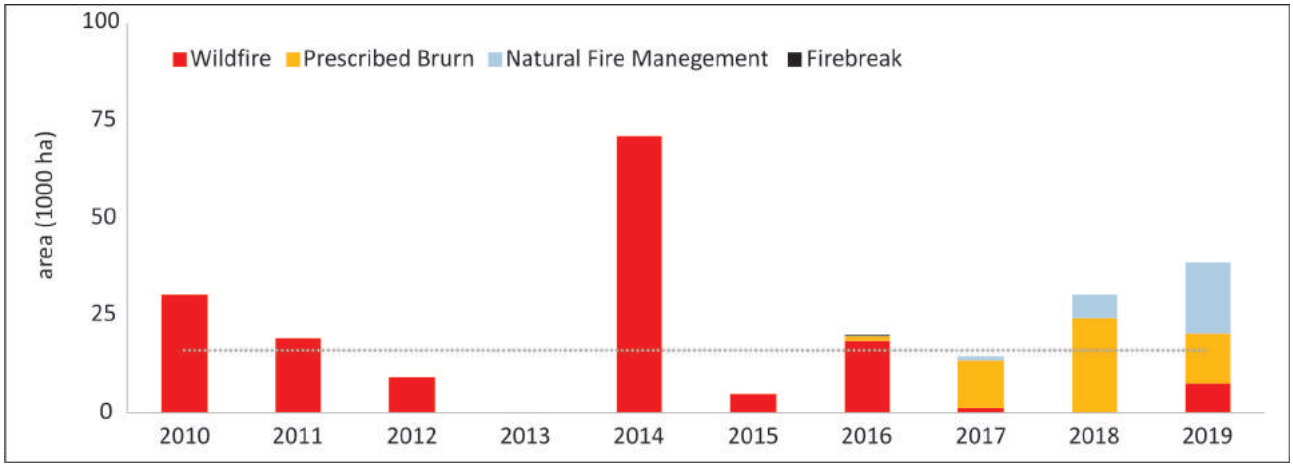

Figure 8 – Area affected by fire in the Campos Amazonicos National Park between 2010 and 2019 divided in categories. The line is the average of the wildfire area in the same period (Source: ICMBio).

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

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

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

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

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

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

Conclusion and Future Perspectives

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

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

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

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

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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 7000km^2, 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 – movilizando 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 Wagtendonk, 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 & Pennington, 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 (~7.000km^2) 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

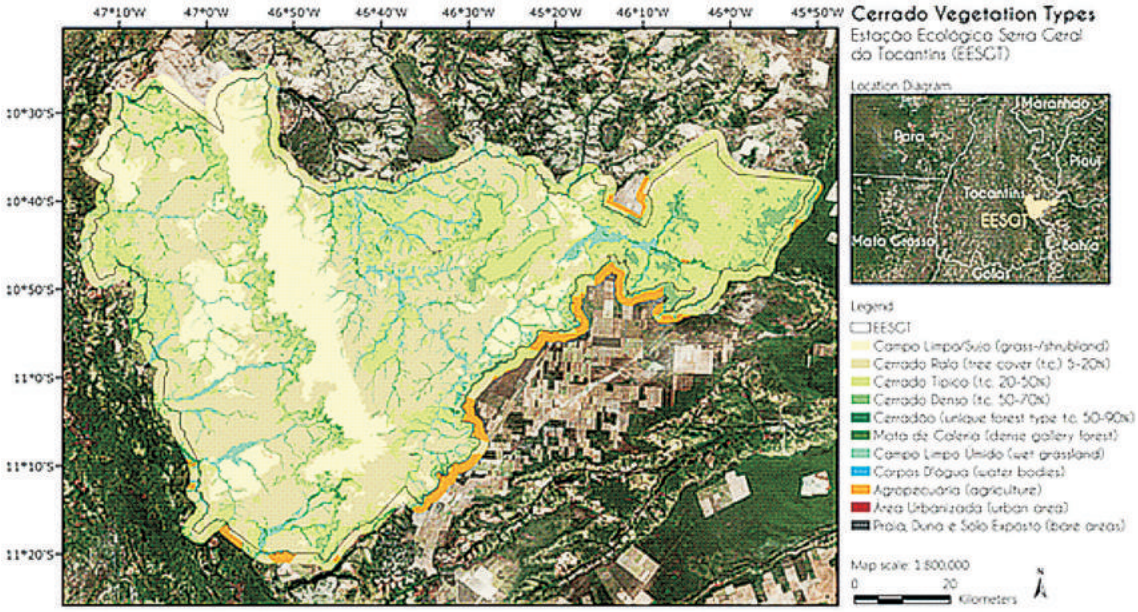

Figure 1 – Serra Geral do Tocantins Ecological Station: location and Cerrado vegetation types. Source: Franke *et al*. (2018).

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 Japalão 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

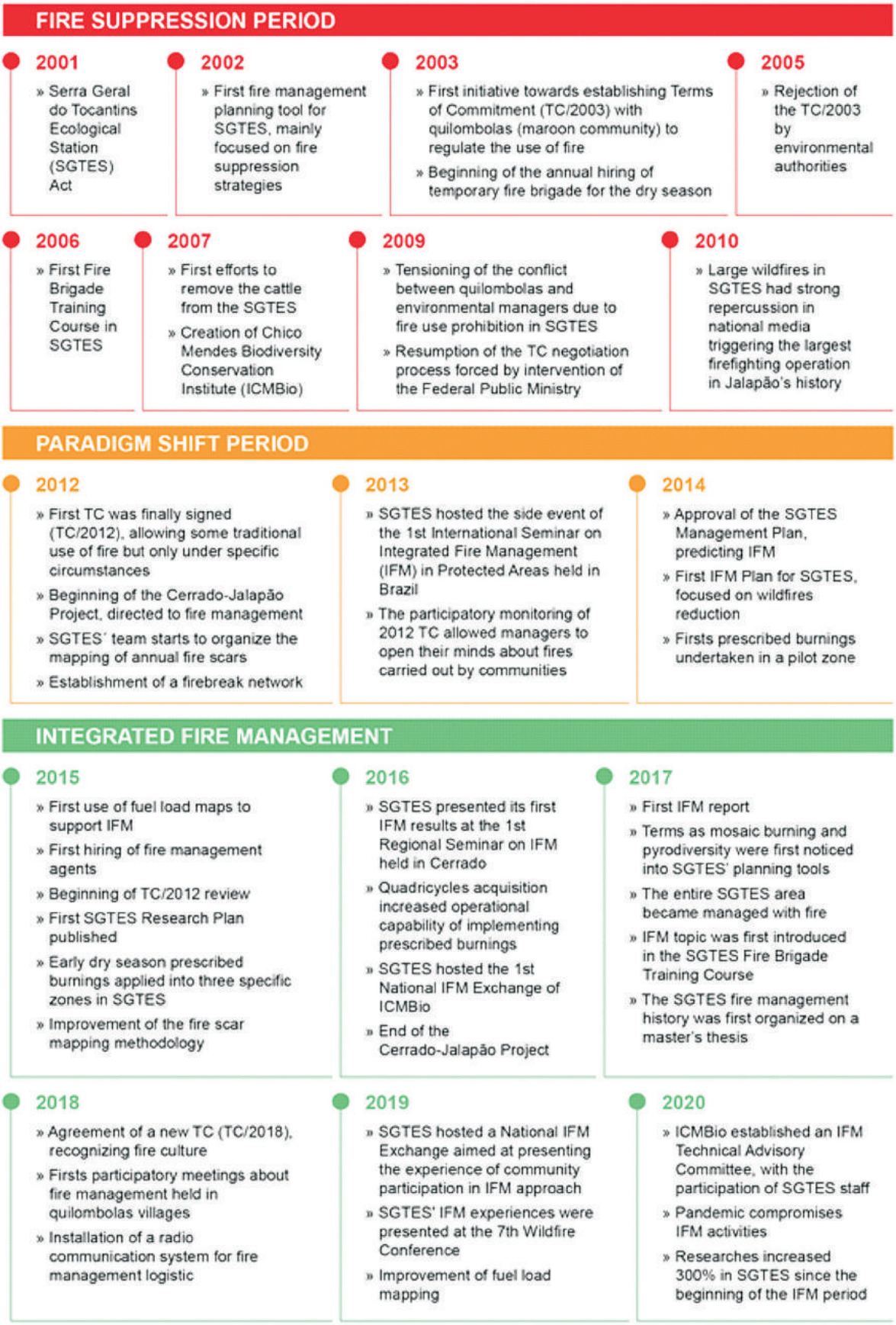

Figure 2 – Milestones in fire management across the last two decades in Serra Geral do Tocantins Ecological Station (2001-2020).

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 > 500km^2) 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 (~3200km^2) 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 octosetaceus*) – 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.

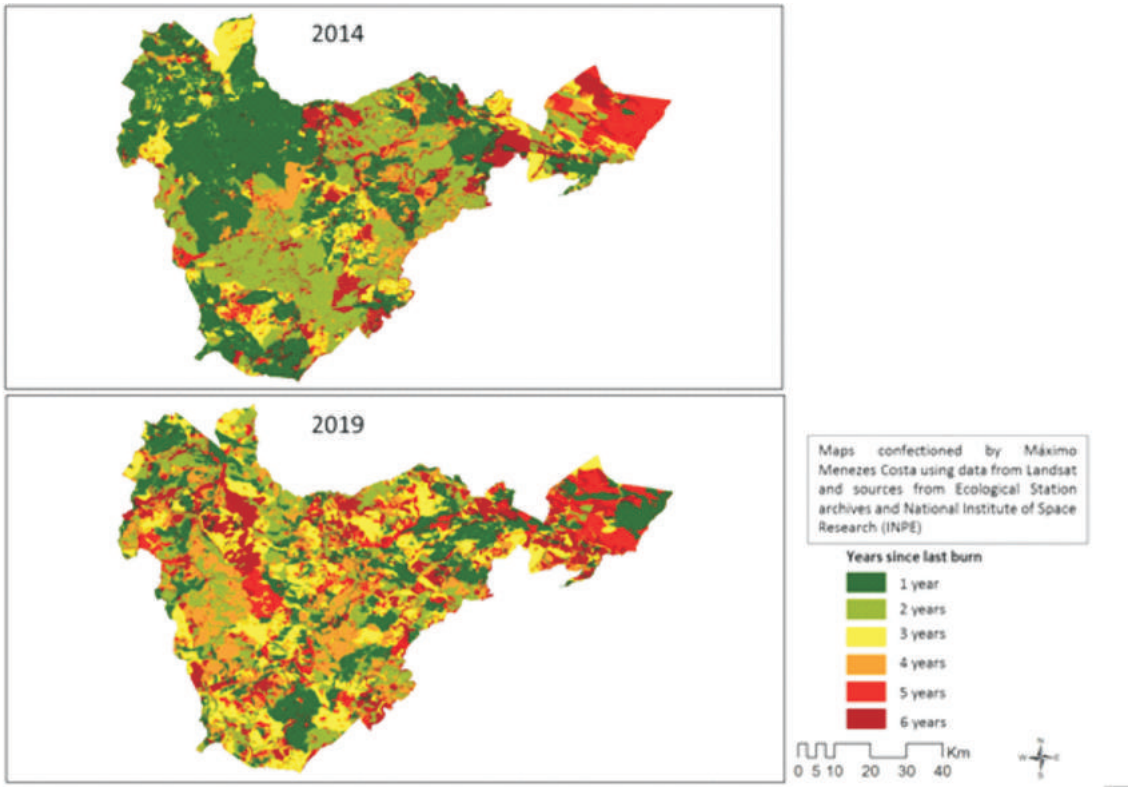

Figure 3 – Changes in burning patterns in the Serra Geral do Tocantins Ecological Station: comparison between fire scars landscapes in 2014 (fire suppression period) and 2019 (integrated fire management period).

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 (km²)	800	450	1070	710	880	250	320	150	30	110
Total area burned in the year (km²)	3200	2180	2850	2090	3030	2240	2150	1890	1400	1630

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

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.

Acknowledgements

There is no single story for the trajectory of fire policy in Serra Geral do Tocantins Ecological Station. The points of view here presented are based on our experiences and perceptions with strong participation of Marco Assis Borges and Máximo Menezes Costa (Ecological Station managers), who are part of this narrative. We thank all *brigadistas* and *quilombolas* who presented us different perspectives about fire management, questioning environmental policy and decolonizing thoughts about the hole of fire in Jalapão. Special thanks go to João Batista Rodrigues da Silva and Deusimar Evangelista Cardoso, *fire sorcerers*. Also thanks to two anonymous reviewers who kindly contributed to better clarity to the text, in the use of the English language.

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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 quemas 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; quemas 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 CO_2 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 1.2Mkm^2 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 (>100km^2) wildfires under progressively deteriorating fire-weather conditions (Figure 1b). On average, fires occur every five years over the entire 1.9Mkm^2 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

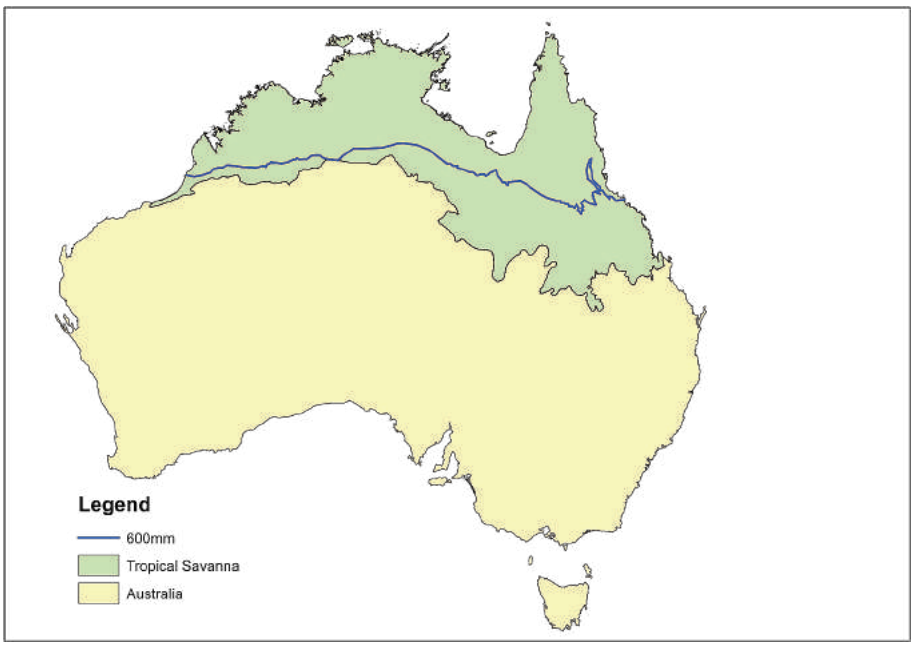

Figure 1(a) – Location of Australian tropical savannas highlighted in green. The blue line is 600mm annual rainfall isohyet with less than 50mm rainfall in the driest quarter (http://www.bom.gov.au/jsp/awap/rain/index.jsp). Savanna burning methodology applies above the 600mm rainfall isohyet.

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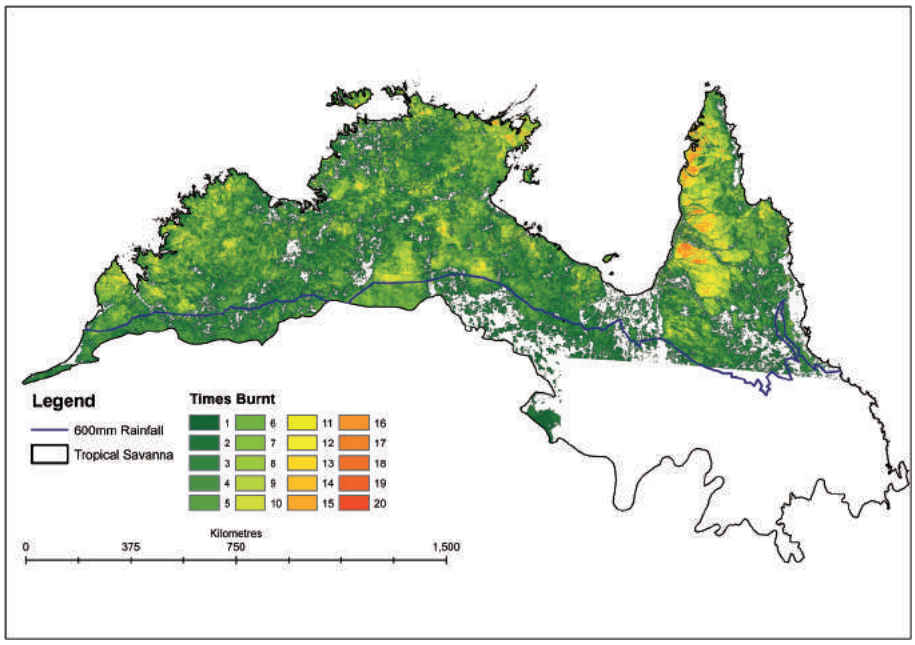

Figure 1(b) – Late dry season (August-December) fire frequency, 2000 – 2019, derived from the Northern Australia Fire information (NAFI) (https://firenorth.org.au/nafi3/) portal using MODIS 250x250m data for areas above the 600mm rainfall isohyet. Black hashed boxes are current (May 2020) savanna burning 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 CH_4, N_2O) 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 28,000km^2 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.CO_2-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 1.2Mkm^2 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 307,000km^2, 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 CO_2-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.

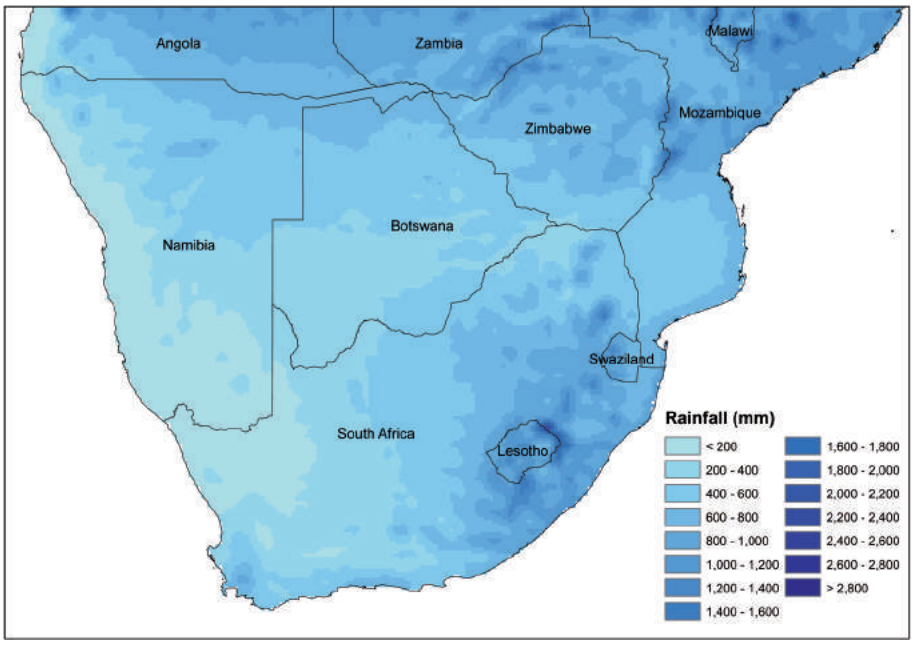

Figure 2(a) – Annual rainfall for southern Africa aggregated from ERA5 monthly averaged data 1979 – 2019 total precipitation.

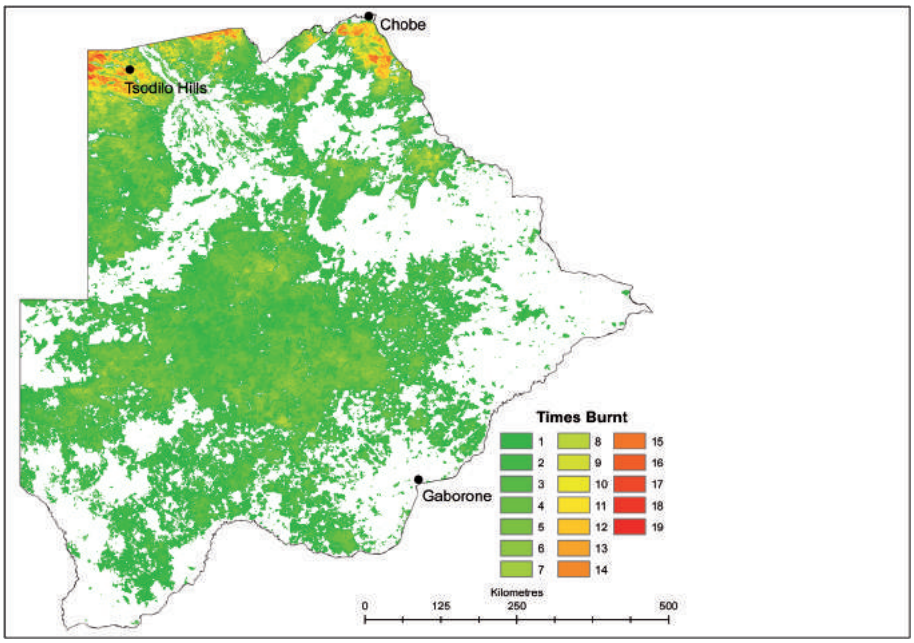

Figure 2(b) – Late dry season (July-December) fire frequency for 2001 – 2019 derived from MCD64A1 MODIS Burned Area Monthly Global 500m Version 6 product. The Tsodilo Hills and Chobe Pilot Sites, along with location of the capital city, Gaborone, are also given.

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 2Mkm^2 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).

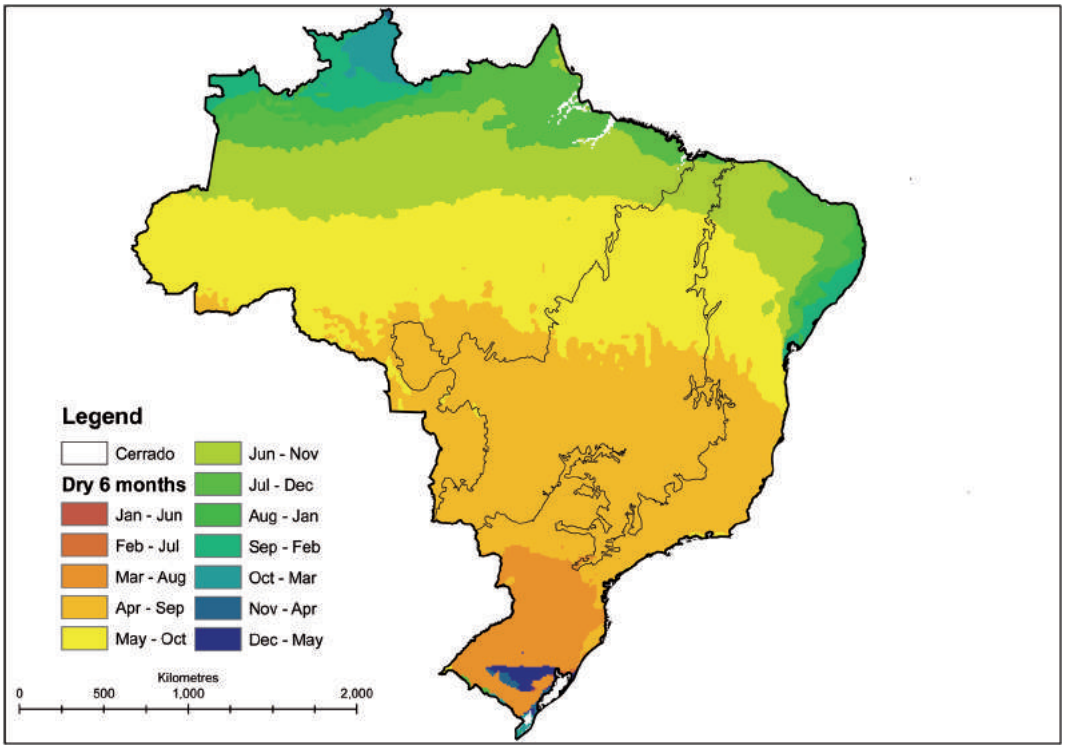

Figure 3(b) – Driest consecutive six-month period for Brazil, derived from ERA5 monthly averaged data 1979 – 2019 total precipitation. Cerrado outlined in black.

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

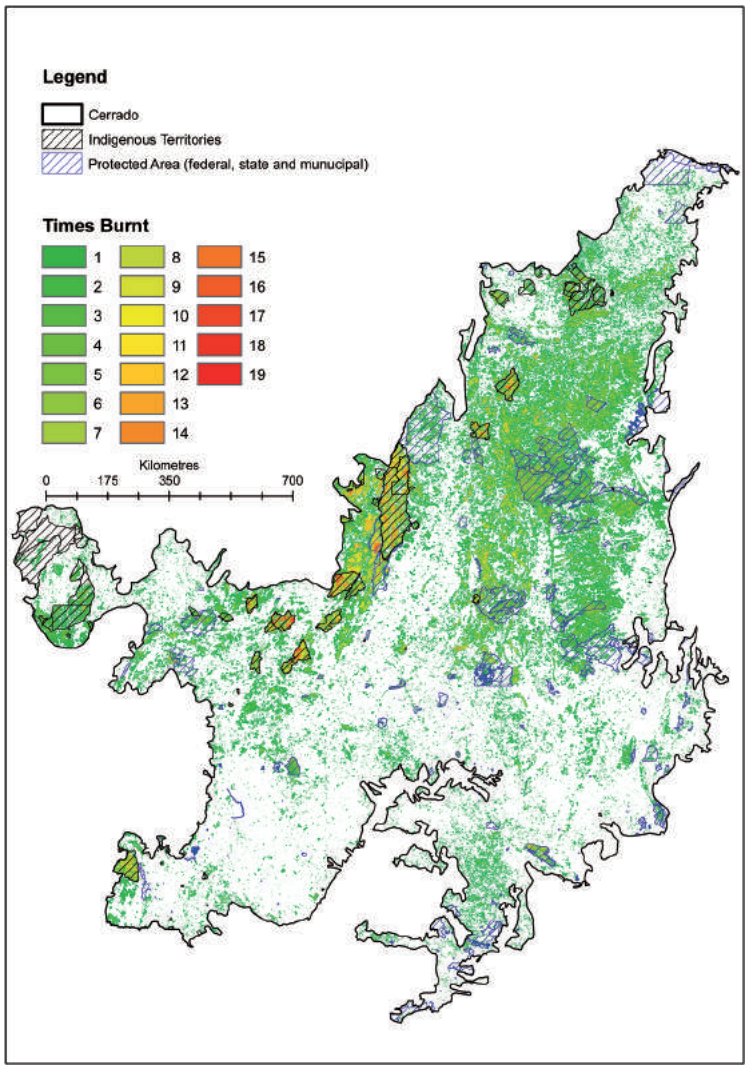

Figure 3(c) – Late dry season (July-December) fire frequency for 2001 – 2019 derived from MCD64A1 MODIS Burned Area Monthly Global 500m Version 6 product. Indigenous Territory in black striped areas and protect areas (federal, state, and municipal) in blue.

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	
Integrated fire management in Brazilian indigenous lands	National Center for Prevention of and Combating Forest Fires (Prevfogo/Ibama, Brazil)
Fire management and the interface with the territorial protection of the Xingu Indigenous Land Association (ATIX)	Xingu Indigenous Land Association (ATIX) and Socioenvironmental Institute (ISA, Brazil)
Fire management by the Javaé people in Ilha do Bananal	Javaé Indigenous Organization Council of the Ilha do Bananal (Conjaba, Brazil)
Parupa participatory and intercultural fire management network	Simón Bolívar University (Venezuela)
Overview of Integrated Fire Management Research in Brazil	Forestry Institute of São Paulo State (IF, Brazil)
Challenges of integrated fire management facing the academic knowledge gap to support forest fire management	National Center for Prevention and Combat of Forest Fires (Prevfogo/Ibama, Brazil)
Fire management in Brazilian federal protected areas: outcomes and perspectives	Chico Mendes Institute for Conservation of Biodiversity (ICMBio, Brazil)
The International Savanna Fire Management Initiative (ISFMI)	International Savanna Fire Management Initiative (ISFMI) and 321Fire! (Mozambique)
Australian experience with the development and application of Savanna Burning projects	International Savanna Fire Management Initiative (ISFMI) and Charles Darwin University (Australia)
Market-based instruments for incentivising sustainable fire management in fire-prone savannas	International Savanna Fire Management Initiative (ISFMI) and Charles Darwin University (Australia)
Selecting Savanna Burning demonstration sites – Examples from Australia and Brazil	International Savanna Fire Management Initiative (ISFMI), Charles Darwin University (Australia), and Nature Institute of Tocantins (Naturatins, Brazil)
Can integrated fire management deliver REDD+ results in Brazil?	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 (ISPN, 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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Sensoriamento Remoto e Geoprocessamento como Subsídio ao Manejo do Fogo e ao Combate aos Incêndios Florestais em Unidades de Conservação Federais

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RESUMO – O geoprocessamento é uma ferramenta muito importante na conservação do meio ambiente. As análises espaciais auxiliam na gestão das unidades de conservação não apenas por permitirem monitorar os impactos ambientais causados por agentes antrópicos e naturais, como desmatamento, incêndios florestais, inundações, etc., mas também por permitirem elaborar estudos aplicados às ações de mitigação desses impactos. Neste contexto, a Divisão de Monitoramento e Informações Ambientais/DMIF, da Coordenação Geral de Proteção/CGPRO do ICMBio é responsável por fornecer dados e realizar análises espaciais para subsidiar as ações de proteção ambiental das unidades de conservação federais brasileiras. Um dos temas de maior relevância na proteção é o fogo. A DMIF mapeia as áreas atingidas por fogo a partir de imagens de satélites diárias do sensor MODIS, fornece análises espaciais de concentração de focos de calor e produz, por meio do sensoriamento remoto, os mapas de acúmulo de combustível, ferramenta utilizada para indicar as áreas prioritárias ao Manejo Integrado do Fogo/MIF.

Palavras-chave: Geoprocessamento; sensoriamento remoto; unidades de conservação; proteção ambiental; fogo; manejo integrado do fogo.

Remote Sensing and Geoprocessing as a Subsidy for Fire Management and Fighting Forest Fires in Federal Conservation Units

ABSTRACT – Geoprocessing is a very important tool in environmental conservation. Spatial analyzes help on the management of protected areas not only by allowing to monitor the environmental impacts caused by anthropic and natural agents, such as deforestation, wildfires, flooding, etc., but also by allowing to elaborate studies on actions to mitigate these impacts. In this regard, Divisão de Monitoramento e Informações Ambientais/DMIF from Coordenação Geral de Proteção/CGPRO/ICMBio is responsible for providing data and carrying out spatial information to help the protection measures in the brazilian federal protected areas. One of the most important theme in protection is fire. DMIF uses satellite images from the sensor MODIS to map the burned areas, provides spatial analysis of fire's concentration and produces the fuel load maps, a remote sensing method used to indicate priority areas for Integrated Fire Management/IFM.

Keywords: Geoprocessing; remote sensing; protected areas; environmental protection; fogo; integrated fire management.

La Teledetección y el Geoprocesamiento como Subvención para el Manejo del Fuego y la Lucha Contra los Incendios Forestales en Unidades Federales de Conservación

RESUMEN – El geoprocesamiento es una herramienta importante en la conservación del medio ambiente. Los análisis espaciales ayudan en la gestión de las áreas protegidas no solo al permitir monitorear los impactos ambientales provocados por agentes antrópicos y naturales, como deforestación, incendios forestales, inundaciones, etc., sino también al permitir elaborar estudios sobre acciones para mitigar estos impactos. En este contexto, la Divisão de Monitoramento e Informações

Ambientais/DMIF de Coordenação Geral de Proteção/CGPRO/ICMBio es responsable por generar datos y realizar análisis espaciales para subsidiar las medidas de protección ambiental en las áreas protegidas federales brasileñas. Uno de los temas más importantes en la protección es el fuego. DMIF utiliza imágenes de satélite del sensor MODIS para mapear las áreas quemadas, genera un análisis espacial de la concentración de focos de calor y produce los mapas de carga de combustible, que se utiliza para indicar áreas prioritarias para el Manejo Integral del Fuego/MIF.

Palabras clave: Geoprocesamiento; detección remota; unidades de conservación; protección ambiental; fuego; manejo integral del fuego.

Introdução

O Brasil conta com 334 unidades de conservação federais (UC), sendo 149 de proteção integral e 185 de uso sustentável, que correspondem a uma área equivalente a 9% de todo o território continental e 25% do território marinho brasileiro. A gestão das unidades de conservação federais é de responsabilidade do Instituto Chico Mendes de Conservação da Biodiversidade/ICMBio, autarquia criada em 2007 e vinculada ao Ministério do Meio Ambiente.

Em algumas regiões do País, com destaque para o Bioma Cerrado, a gestão do fogo é um dos aspectos que mais demandam atenção por parte dos gestores das unidades de conservação. O fogo tem sido um fator determinante nos ecossistemas globais, tendo moldado a distribuição dos biomas e mantido a estrutura e função das comunidades que habitam as áreas propensas ao uso do fogo. O fogo é uma força evolucionária significativa e uma das primeiras ferramentas utilizadas pelas populações humanas para moldar suas formas de vida (Bond & Keeley, 2005).

No Brasil, alguns biomas são dependentes do regime de fogo, como o Cerrado, enquanto outros são sensíveis, como a Amazônia e a Mata Atlântica (Hardesty *et al*., 2005). Especificamente no bioma Cerrado, o fogo é considerado uma força dominante na evolução da biota (Simon *et al*., 2009). Nestes ambientes do tipo savana existem espécies altamente adaptadas ao regime de fogo. No entanto, um aumento na frequência de incêndios de alta intensidade pode afetar severamente a vegetação, principalmente a arbórea (Ratter *et al*., 1997). Já no caso das florestas tropicais, a resistência é ainda menor, as árvores são mortas após repetidas queimas e o material orgânico do solo, que serve de nutriente para as plantas, é incinerado ocasionando graves danos à estrutura da floresta (Cochrane *et al*., 1999).

O ICMBio conta com equipes especializadas para ações de combate a incêndios florestais e para a implementação do Manejo Integrado do Fogo/MIF. O MIF passou a ser discutido no ICMBio por volta de 2012 e ganhou impulso a partir do projeto "Prevenção, Controle e Monitoramento de Queimadas Irregulares e Incêndios Florestais no Cerrado", também conhecido como Projeto Cerrado-Jalapão, fruto de uma cooperação técnica e financeira entre Brasil e Alemanha. Esta estratégia utiliza o fogo de maneira integrada à conservação do meio ambiente e segue o conhecimento histórico do seu papel ecológico na manutenção de áreas de savana em diversas partes do mundo (Myers, 2006).

Impulsionados pelo Projeto Cerrado-Jalapão, os gestores de unidades de conservação foram estimulados a refletir sobre o papel do fogo em seus territórios de atuação, buscando entender se e de que forma o fogo poderia ser utilizado em favor da preservação do ambiente. O projeto instigou a busca pelo conhecimento de outras abordagens de gestão que vinham sendo adotadas em diversas unidades de conservação no mundo que também protegem ambientes dependentes do fogo (Barradas, 2017).

O Projeto Cerrado Jalapão também contribuiu na contratação de especialistas internacionais em sensoriamento remoto para o desenvolvimento de uma metodologia de elaboração de mapas de acúmulo de material combustível específica para a região do Cerrado Brasileiro. Foram feitas algumas capacitações das equipes tanto do ICMBio quanto do IBAMA, propiciando o repasse de conhecimento e a continuidade dos trabalhos após o encerramento do projeto.

O uso de geotecnologias é fundamental para a gestão de territórios, em especial os de grande extensão, como é o caso das unidades de conservação brasileiras. Com tais técnicas é possível obter rapidamente informações atualizadas,

facilitando o planejamento e gestão do território, permitindo levantar novas hipóteses de impactos ambientais futuros e elaborar mecanismos que auxiliem na desaceleração do desmatamento e nas medidas mitigadoras (Fitz, 2008). Em relação ao fogo, os atuais recursos computacionais voltados ao geoprocessamento, como o Sistema de Informação Geográfica/SIG e o sensoriamento remoto, permitem análises espaciais e temporais que facilitam estudos de prevenção e combate a incêndios (Pezzopane *et al.*, 2012)

Material e Métodos

A área técnica do ICMBio responsável pela geração e sistematização de dados e informações geoespaciais para subsidiar as ações de proteção, incluindo as relacionadas ao fogo, é a Divisão de Monitoramento e Informações Ambientais/DMIF, que faz parte da Coordenação Geral de Proteção/CGPRO.

As principais atividades desenvolvidas pela Divisão relacionadas à questão do fogo são: monitoramento e sistematização dos focos de calor nas unidades de conservação federais, análise de concentração de focos de calor, mapeamento das áreas atingidas por fogo a partir de imagens de satélite e geração de mapas de acúmulo de material combustível para subsidiar as unidades de conservação na realização do manejo integrado do fogo.

Os focos de calor representam o ponto de partida para o monitoramento do fogo nas unidades de conservação. Os dados são obtidos diariamente através da plataforma Banco de Dados de Queimadas, do Instituto Nacional de Pesquisas Espaciais/INPE e processados para as unidades de conservação federais. Os focos de calor são detectados através de imagens de vários satélites. A relação do foco com a queimada não é direta. Cada foco indica a existência de fogo em um elemento de resolução da imagem, o pixel, que, nos satélites usados para detectar os focos, varia de 375m por 375m até 5km por 4km. Neste pixel é possível haver uma ou várias queimadas distintas que a indicação será de um único foco (INPE, 2020).

Além de fornecer diretamente indicativos dos locais a serem monitorados com relação ao fogo, os focos de calor subsidiam a realização de análises espaciais, como por exemplo a concentração espacial de indicativos de fogo. Tais estudos podem fornecer importantes informações a respeito do comportamento do fogo nas unidades de conservação ao longo dos anos.

Juntamente com informações enviadas por equipes de campo, os focos dão subsídios para a localização das áreas a serem monitoradas através de imagens de satélite. Os dados de área atingida por fogo são gerados pela DMIF, prioritariamente com o uso de imagens do sensor MODIS, dos satélites Terra e Aqua da NASA, especificamente o seu produto de resolução espacial de 250 metros, e resolução temporal diária.

O sistema MODIS permite a quantificação e a detecção das mudanças da cobertura terrestre e do monitoramento dos processos naturais e antrópicos (Strahler *et al.*, 1999). Dados de 250m de resolução têm sido utilizados na detecção de conversão da cobertura vegetal como desmatamento de florestas, queimadas e inundações (Zahn *et al.*, 2002). Alguns impactos importantes das queimadas incluem a mudança do estado físico da vegetação, alteração nos solos, liberação de gases de efeito estufa e de gases reativos durante a queima da biomassa, e outros particulados, ocasionando mudanças passíveis de detecção nas imagens. O sensor MODIS foi desenvolvido para incluir características necessárias e específicas para a detecção de queimada (Anderson *et al.*, 2003). Outro aspecto importante sobre as imagens MODIS é a sua resolução temporal. Com uma revisita diária, as imagens oferecem uma ótima possibilidade de monitorar a vegetação com grande precisão temporal a uma resolução espacial aceitável (Lecerf *et al.*, 2005).

O mapeamento das áreas atingidas por fogo nas unidades de conservação federais é realizado pela DMIF desde 2010. A metodologia utilizada desde então é a interpretação visual das imagens de satélite. Apesar de ser uma metodologia bastante trabalhosa, ainda vem sendo utilizada, uma vez que outras iniciativas de classificação digital das imagens testadas apresentaram muitos erros de omissão e inclusão. Como os incêndios florestais acontecem continuamente, principalmente na estação seca do ano, a obtenção diária dos dados fornece subsídios fundamentais às ações de combate.

Atualmente estão sendo testadas e automatizadas, com resultados já bastante promissores, novas metodologias de identificação

de áreas queimadas em plataformas de código aberto e computação em nuvem como o Google Earth Engine. Os resultados devem, em breve, otimizar os esforços e melhorar a qualidade dos produtos gerados.

Para complementação dos dados também são utilizadas imagens do satélite Landsat-8 da NASA, de resolução espacial de 30 metros e do Sentinel-2, da Agência Espacial Europeia/ESA, de 10, 20 e 60 metros de resolução espacial, a depender das bandas. As unidades de conservação mapeadas seguem critérios de priorização de acordo com a quantidade de focos de calor e por demanda da Coordenação de Prevenção e Combate a Incêndios/COIN do ICMBio.

Nos produtos relacionados às ações de Manejo Integrado do Fogo, a DMIF gera os mapas de acúmulo de material combustível, metodologia desenvolvida por Jonas Franke, no âmbito do projeto Cerrado-Jalapão. Este processamento tem como objetivo estimar, através do sensoriamento remoto, o acúmulo de material combustível, que é o material seco (vegetação seca/morta), suscetível a queima na vegetação do cerrado. Assim como as áreas queimadas, o mapeamento e monitoramento do acúmulo de combustível auxilia a identificar áreas prioritárias para a realização do MIF no Cerrado (Franke *et al*., 2018).

A metodologia utilizada no processamento das imagens de satélite é a Análise de Mistura Espectral, técnica que identifica alvos menores que a resolução da imagem e permite conhecer a proporção de cada um dos três principais componentes da paisagem do Cerrado (vegetação verde, vegetação morta/seca e solo) em um determinado pixel. Assim, ao aplicar a 'Análise de Mistura Espectral' para áreas do Cerrado, estima-se qual a proporção de cada um desses três componentes na composição de um pixel. Em contraste a outras abordagens de sensoriamento remoto destinadas ao mapeamento do acúmulo de combustível como os índices de vegetação, a análise de mistura espectral se mostra mais eficiente por usar todas as bandas espectrais relevantes na diferenciação da vegetação verde da vegetação seca/morta (Asner *et al*., 2005). Esta metodologia é recomendada em imagens de média resolução espacial como as do satélite Landsat 8 e do Sentinel-2.

A partir do processamento da Análise de Mistura Espectral são geradas três imagens fração para cada um dos três componentes, conforme Figura 1. Cada imagem fração indica a proporção de um determinado componente dentro da menor unidade de uma imagem, o pixel. O mapa de acúmulo de combustível nada mais é que a composição colorida RGB dessas três imagens fração (*Red*: Vegetação Seca, *Green*: Vegetação Verde e *Blue*: Solo) (Figura 2). Quanto mais vermelho, maior a proporção de vegetação seca naquele pixel, quanto mais azul, maior a proporção de solo e quanto mais verde, maior a proporção de vegetação verde. Pixels com outras colorações intermediárias representam grande mistura desses componentes.

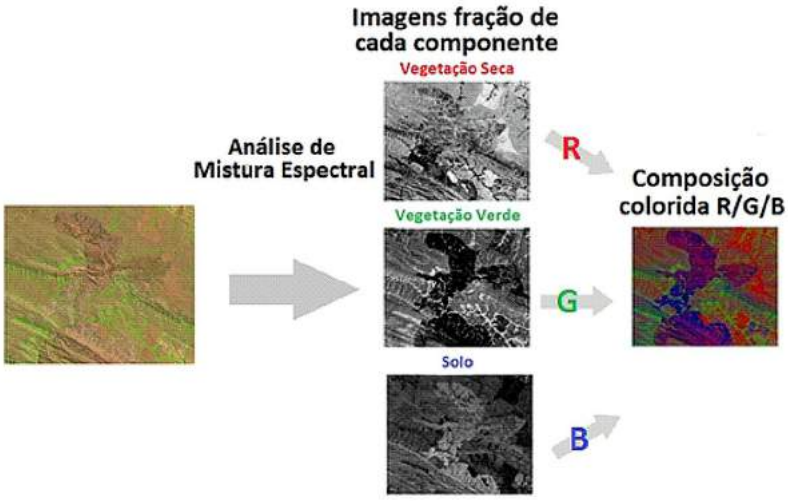

Figura 1 – Etapas do processamento do mapa de acúmulo de material combustível (Fonte: DMIF).

Com o mapa de acúmulo, os gestores de unidades de conservação com alto risco de incêndios podem identificar as áreas com maior acúmulo de material seco, representadas pelas áreas mais vermelhas no mapa, e determinar quando e onde as queimas prescritas e os aceiros devem ser aplicados (Frank *et al.*, 2018). A intenção destas queimas controladas é diminuir o material combustível antes da chegada da estação seca, minimizando os riscos da ocorrência de grandes incêndios.

Resultados e Discussão

Focos de calor

Diante do aumento da quantidade de focos de calor na Amazônia no ano de 2019, buscou-se analisar onde se encontravam as maiores concentrações destes indicativos de fogo, e qual a situação das unidades de conservação federais. Para isso foi gerada uma grade de 15 x 15km na Amazônia Legal e levantada a quantidade de focos em cada uma das grades. Então é gerado um raster em que a unidade é a própria grade e seu valor é a quantidade de focos presentes nesta unidade. Na representação do raster é usado a transformação 'Bilinear Interpolation' para visualização de dados contínuos. A análise de concentração dos focos permite uma outra forma de visualizar a distribuição espacial dos dados, conforme mostrado na Figura 2. No mapa, a variação de cores do amarelo ao vermelho indica a quantidade de focos de calor na Amazônia Legal no ano de 2019. Em branco são áreas que não apresentaram nenhum foco de calor. As unidades de conservação federais da Amazônia Legal que estão localizadas no bioma Cerrado, como as do Tocantins, leste do Mato Grosso e sul do Maranhão, estão em áreas de grande concentração de focos de calor. Já no bioma Amazônia, o mapa de concentração de focos de calor de 2019 mostra que, na maior parte das áreas, as unidades de conservação se comportam como barreiras contra o avanço do fogo (Figuras 2 e 3).

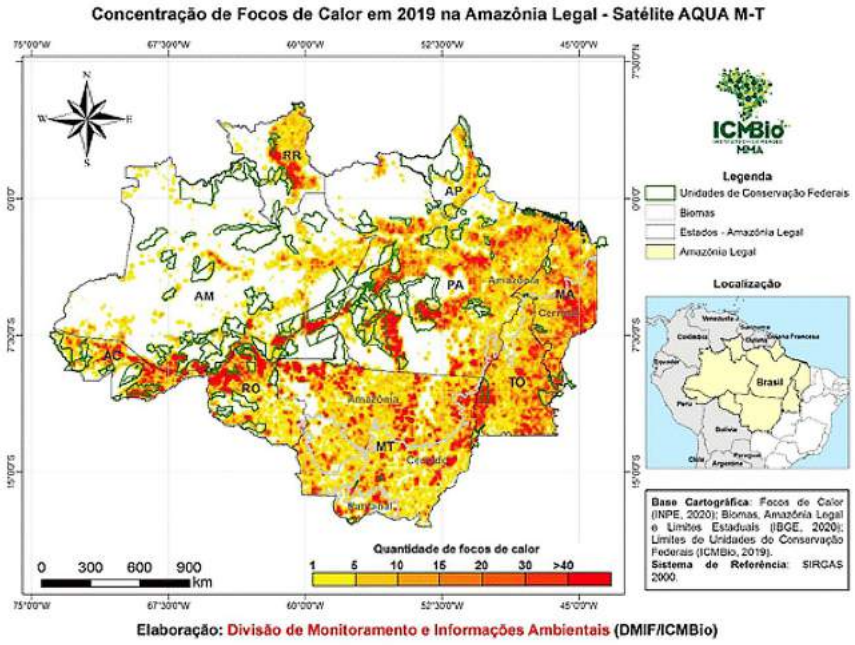

Figura 2 – Mapa de concentração de focos de calor no ano de 2019 do satélite de referência AQUA M-T.

Os mapas da Figura 3 mostram casos em que o entorno imediato das unidades de conservação federais concentra a maior parte dos focos de calor (áreas avermelhadas), em contraste com o interior das unidades de conservação federais, que se mantêm pouco afetado pelo fogo (Figura 3-A e 3-C). No mapa da Figura 3-B, a Estação Ecológica da Terra do Meio, localizada no centro do Pará, mostra-se bem menos afetada que a Área de Proteção Ambiental Triunfo do Xingu,

unidade de conservação estadual adjacente a ela. No caso do mapa D, da Figura 3, as unidades de conservação federais se apresentam como "ilhas" menos atingidas pelo fogo, em comparação com as áreas ao seu redor. Este caso evidencia o importante papel da conservação ambiental exercida pelas áreas protegidas, como as unidades de conservação e as terras indígenas.

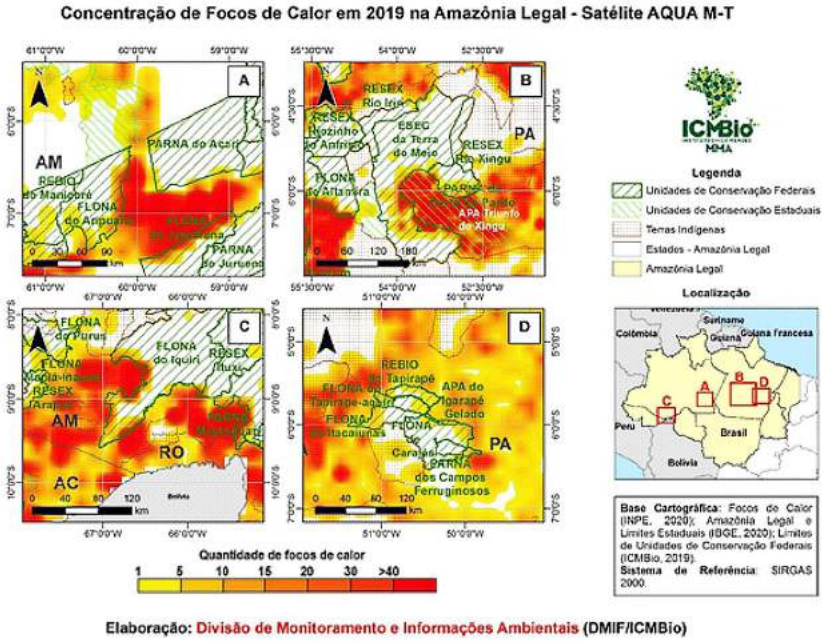

Figura 3 – Mapa de concentração de focos de calor no ano de 2019 – aproximação para algumas UCs.

Áreas atingidas por fogo

Em relação ao mapeamento de áreas atingidas por fogo, os dados gerados pela DMIF contam com uma série de 9 anos, que permite um acompanhamento da situação das queimadas nas unidades de conservação federais, bem como fornece subsídios ao planejamento das ações de proteção relacionadas ao fogo. As Tabelas 1 e 2 apresentam os dados de mapeamento de áreas atingidas por fogo nos anos de 2018 e 2019, enquanto o Gráfico 1 apresenta as informações de 2010 a 2019, conforme mapeamentos realizados pela DMIF. Todos os dados apresentados neste artigo são brutos, sem qualificação de classes como por exemplo áreas de manejo por queima prescrita, aceiros etc.

Tabela 1 – Área atingida por fogo nas unidades de conservação federais – 2018.

Área Atingida por Fogo nas Unidades de Conservação Federais – 2018				
Bioma	**Total de UC's**	**Área Total Queimada (ha)**	**Área Total UC's (ha)**	**% da Área**
Amazônia	20	155.032	16.258.168	1,0%
Caatinga	4	31.002	1.335.481	2,3%
Cerrado	11	452.110	2.972.661	15,0%
Mata Atlântica	4	1.036	107.568	1,0%
Total	**39**	**639.181**	**20.536.733**	**3,0%**

Tabela 2 – Área atingida por fogo nas unidades de conservação federais – 2019.

Área Atingida por Fogo nas Unidades de Conservação Federais – 2019				
Bioma	**Total de UC's**	**Área Total Queimada (ha)**	**Área Total UC's (ha)**	**% da Área**
Amazônia	22	237.015	17.052.679	1,39%
Caatinga	2	1.144	50.667	2,26%
Cerrado	18	908.617	4.228.347	21,49%
Mata Atlântica	5	51.600	281.534	18,33%
Total	**50**	**1.198.377**	**21.613.227**	**5,54%**

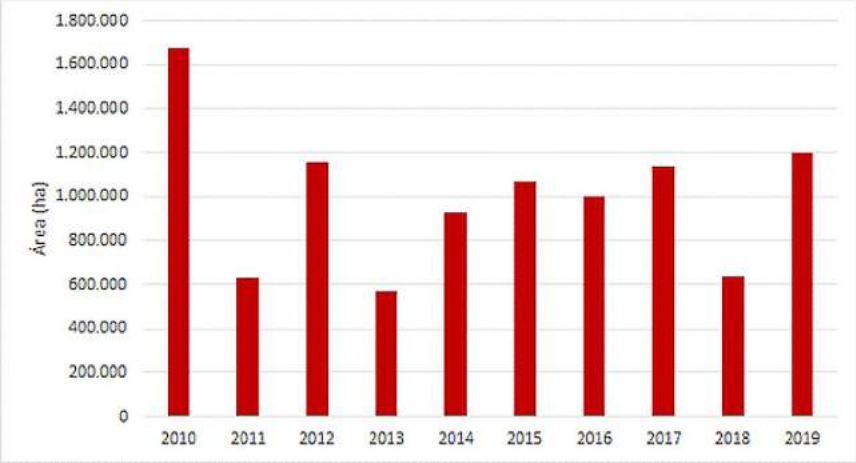

Gráfico 1 – Área atingida por fogo nas unidades de conservação federais – 2019.

Em 2019 foram mapeados 1.198.377 hectares de área atingida por fogo em 50 unidades de conservação federais. Das áreas mapeadas 75% encontram-se no Bioma Cerrado, 19% na Amazônia e 4% na Mata Atlântica. As UCs com maiores áreas mapeadas estão representadas na Tabela 3.

Tabela 3 – UCs com maiores áreas atingidas por fogo mapeadas em 2019.

Unidades de Conservação	Bioma	Área Queimada (ha)	Área UC (ha)	% da UC
PARNA do Araguaia	Cerrado	329.410,25	555.517,00	59,30
PARNA das Nascentes do Rio Parnaíba	Cerrado	196.611,26	724.329,32	27,14
ESEC Serra Geral do Tocantins	Cerrado	172.347,32	707.087,74	24,37
FLONA de Roraima	Amazônia	54.500,41	169.628,70	32,13
FLONA do Jamanxim	Amazônia	50.227,77	1.301.697,46	3,86
PARNA de Ilha Grande	Mata Atlântica	47.440,62	76.138,19	62,31
PARNA das Emas	Cerrado	46.500,67	132.787,86	35,02
PARNA da Serra da Canastra	Cerrado	41.897,36	197.971,96	21,16
PARNA da Chapada dos Veadeiros	Cerrado	41.889,35	240.586,56	17,41
ESEC de Uruçuí-Una	Cerrado	39.195,46	172.347,32	22,74

Em situações de combate de incêndios mais severos, quando a Coordenação de Combate e Manejo do Fogo/COIN é responsável pela coordenação direta das ações, a DMIF procura realizar o mapeamento das áreas atingidas por fogo diariamente, fornecendo subsídios para as equipes de campo nas decisões de combate. O mapeamento diário é feito por interpretação visual de imagens do sensor MODIS, dos satélites Terra e Aqua da NASA, especificamente o produto de resolução espacial de 250m, e resolução temporal diária.

A Figura 4 apresenta o resultado final de um mapeamento de área atingida, com evolução diária do fogo realizado em 2017, no Parque Nacional de Brasília.

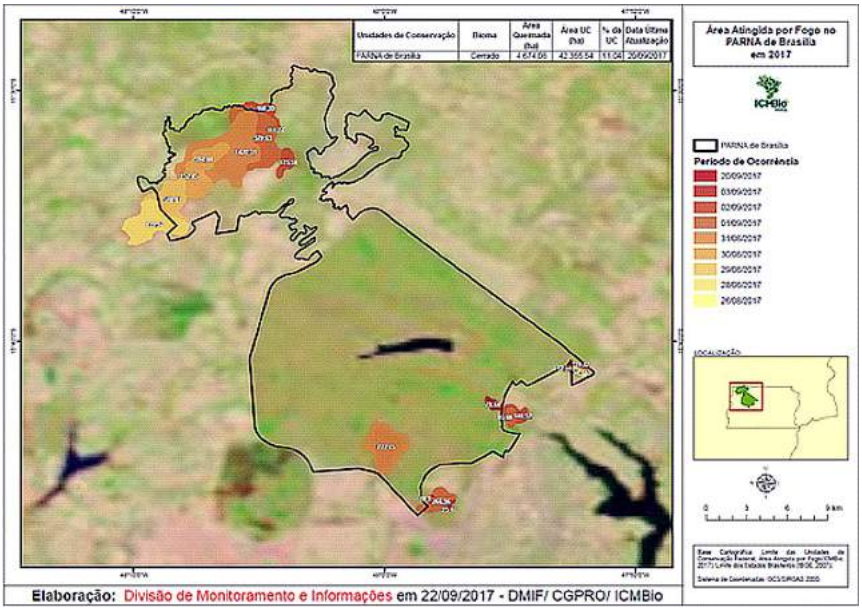

Figura 4 – Evolução diária de áreas atingidas por fogo, Parque Nacional de Brasília.

Mapas de acúmulo de material combustível

Diversos estudos apontam que o acúmulo de material combustível propicia a ocorrência de grandes incêndios em ambientes savânicos (Barradas, 2017). Este é um fator determinante tanto na ocorrência de incêndios, quanto na sua intensidade e na sua propagação. Por este motivo a identificação desse material é tão importante para o planejamento das atividades de manejo integrado do fogo, em especial para a identificação dos locais mais indicados para a realização das queimas prescritas, que são uma das técnicas utilizadas no MIF.

Algumas unidades de conservação federais vêm executando o manejo integrado fogo, inclusive com a utilização da técnica de queimas prescritas, que são realizadas antes do período mais seco do ano, diminuindo desta forma a disponibilidade de material combustível nos locais mais críticos, e desta forma a propagação de grandes incêndios.

A Figura 5 é o mapa de acúmulo de material combustível de 05/09/2019 no Parque Nacional das Emas/GO/MS. A data é do final da estação seca, momento ideal para analisar a situação do acúmulo de combustível que subsidiará a escolha das áreas prioritárias para as queimas prescritas do próximo ano. Nele é possível ver a distribuição do acúmulo de combustível pela unidade de conservação. As áreas em verde como as matas de galerias são áreas com pouco acúmulo de combustível, as áreas amareladas e alaranjadas apresentam grande mistura de vegetação seca e vegetação verde, e as áreas avermelhadas são áreas com grande acúmulo de combustível e que devem ser tratadas com maior atenção. No norte da UC é possível observar o componente solo se sobressaindo em uma área queimada próxima da data do mapa. Isto ocorre devido ao consumo da vegetação daquela área pelo fogo, deixando o solo exposto.

A Figura 6 apresenta dois casos da situação do acúmulo de combustível no Parque Nacional

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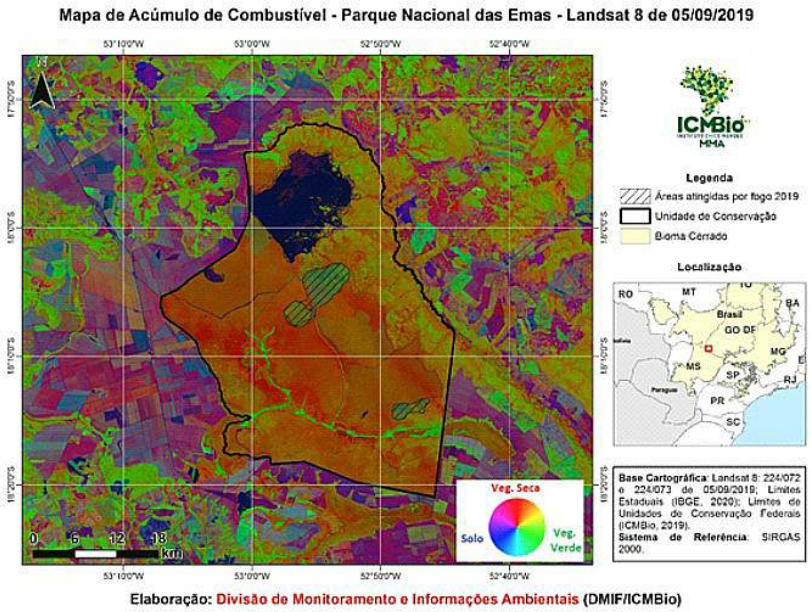

Figura 5 – Mapa de Acúmulo de Material Combustível de 2019, no Parque Nacional das Emas.

da Serra da Canastra/MG, antes e depois da implementação do manejo integrado do fogo na unidade de conservação. No caso 1 é possível notar, na imagem superior, que há uma grande quantidade de acúmulo de combustível em 22/05/2014, início do período de seca. Este acúmulo resultou em um grande incêndio na UC que causou vários danos, como visto pela cor azul referente ao solo exposto, bastante evidenciado na imagem inferior, de outubro de 2014. É possível notar, inclusive, danos às matas de galeria, em verde, que aparecem em menor proporção nesta imagem. Já no caso 2, após alguns anos de implementação do manejo integrado do fogo, a situação do acúmulo de combustível é bastante diferente. Ao final da estação seca de 2018, caso

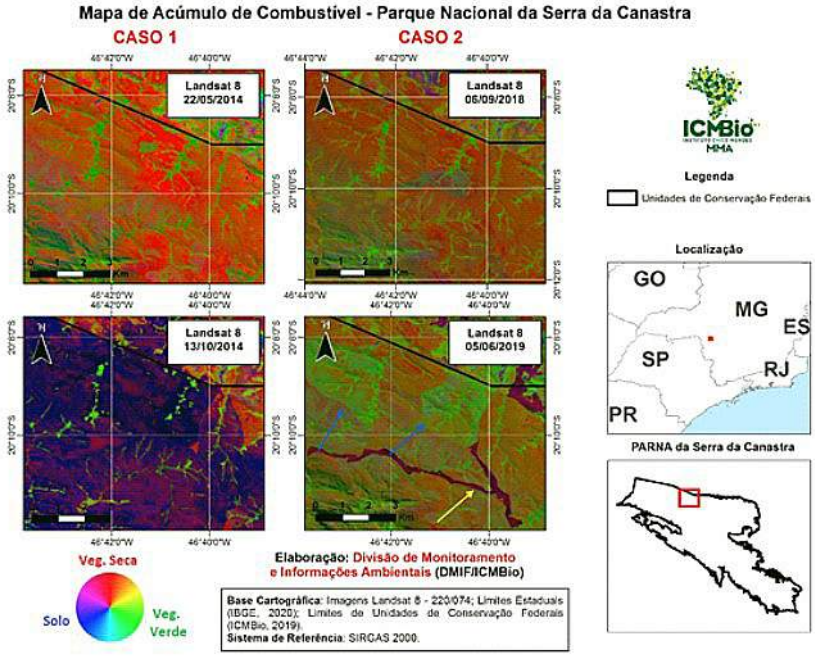

Figura 6 – Estudos de casos de mapas de acúmulo de combustível e manejo integrado do fogo no Parque Nacional da Serra da Canastra.

da imagem superior, a maior ausência de áreas bem avermelhadas indica que neste ano há um menor acúmulo de combustível nesta parte da UC. A imagem de baixo, de 05/06/2019, mostra que não somente as áreas permanecem com pouco acúmulo de combustível, como também, que há duas áreas de queimas prescritas, indicadas pelas duas setas azuis, e alguns aceiros, indicados pela seta amarela. Esse cenário fragmentado da distribuição do acúmulo de combustível é considerado o ideal. A continuidade do combustível é um fator determinante na propagação dos incêndios e qualquer descontinuidade pode atuar como barreiras (Cochrane & Ryan, 2009).

Considerações Finais

Os produtos gerados pela DMIF a partir de análises de sensoriamento remoto, como a identificação das áreas atingidas por fogo e das áreas de maior acúmulo de material combustível, e de Sistema de Informação Geográfica/SIG, como a identificação das áreas de maior concentração de focos de calor, são utilizados prioritariamente pela Coordenação Geral de Proteção para subsidiar decisões quanto aos processos fiscalizatórios e também a respeito do combate e manejo do fogo. Além disso, os dados também são fundamentais para a gestão das unidades de conservação e outros setores do ICMBio. Desmatamento e área atingida por fogo estão relacionados aos principais impactos negativos nas áreas protegidas.

A base de dados de áreas atingidas por fogo mapeadas pela DMIF já conta com uma série histórica de 10 anos, e apesar de necessitar de aprimoramento e de melhorias, principalmente quanto à qualificação dos dados, fornece subsídios para que o ICMBio possa planejar suas atividades relacionadas ao manejo e combate do fogo nas unidades de conservação federais, com maior conhecimento da realidade das mesmas. Levando-se em conta a série histórica, é possível identificar, por exemplo, quais são as áreas mais propensas a incidência de incêndios e também qual a frequência de ocorrência de fogo em cada área, e desta forma buscar soluções para minimizar o problema nas áreas mais críticas.

Outro produto que trouxe avanços para os trabalhos relacionados ao fogo foram os mapas de acúmulo de material combustível, pois são importantes ferramentas para o planejamento do manejo integrado do fogo, que vem sendo aplicado em mais unidades de conservação federais a cada ano.

A DMIF está constantemente buscando aprimorar as informações e os processos de trabalho, a fim de fornecer dados e informações confiáveis e consistentes, de forma a contribuir com os processos de proteção das unidades de conservação federais.

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The WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS): Concept, Current Capabilities, Research and Development Challenges and the Way Ahead

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ABSTRACT – Vegetation fires – including the application of fire in land use, land-use change and uncontrolled wildfire – affect the functioning of the Earth System and impose significant threats to public health and security. This paper presents the concept of a Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS). It describes the scientific rationale for the system and provides guidance for addressing the issues of vegetation fire and smoke pollution, including key research challenges. The paper proposes the establishment of VFSP-WAS regional centers and describes potential examples of this VFSP-WAS concept from two regions in (Southeast Asia and North America) where regional centers will partner with Regional Fire Monitoring/Fire Management Resource Centers.

Keywords: Fire and smoke pollution modeling; numerical weather prediction; atmospheric pollution observation; early warning systems.

Sistema de Consulta e Alerta de Poluição Causada pela Fumaça Decorrente do Fogo na Vegetação (VFSP-WAS) da Organização Meteorológica Mundial (WMO): Conceito, Capacidades Atuais, Desafios de Pesquisa e Desenvolvimento, e o Caminho a Seguir

RESUMO – O fogo na vegetação, incluindo a aplicação do fogo no uso da terra e na mudança de uso da terra, assim como os incêndios florestais, afetam o funcionamento do sistema terrestre e impõem ameaças significativas à saúde e segurança públicas. Este documento apresenta o conceito de um Sistema de Avaliação e Alerta de Poluição causada por Fumaça decorrente do Fogo na Vegetação (VFSP-WAS, na sigla em inglês). Apresenta-se o fundamento científico do sistema e diretrizes para abordar as questões de fogo na vegetação e poluição por fumaça, indicando-se os principais desafios para a pesquisa. O artigo propõe o estabelecimento de centros regionais VFSP-WAS e mostra exemplos potenciais do conceito VFSP-WAS em duas regiões (sudeste da Ásia e América do Norte), onde centros regionais VFSP-WAS trabalham em parceria com Centros Regionais de Monitoramento de Fogo/Manejo de fogo.

Palavras-chave: Modelagem da poluição por fumaça e fogo; previsão meteorológica numérica; observação da poluição atmosférica; sistemas de alerta precoce.

Sistema de Consulta y Alerta de Contaminación Causada por el Humo Resultante del fuego en la Vegetación (VFSP-WAS) de la a Organización Meteorológica Mundial (WMO): Concepto, Capacidades Actuales, Desafíos de Investigación y Desarrollo, y el Camino Adelante

RESUMEN – El fuego en la vegetación, incluida la aplicación del fuego en el uso de la tierra, en el cambio de uso de la tierra y los incendios forestales, afectan el funcionamiento del sistema terrestre e imponen amenazas importantes para la salud y la seguridad públicas. Este documento presenta el concepto de un sistema de alerta y evaluación de la contaminación causada por el humo del fuego en la vegetación (VFSP-WAS, por su sigla en inglés). Se presentan el fundamento científico del sistema y directrices para abordar los problemas del fuego en la vegetación y la contaminación por humo, indicándose los principales desafíos de la investigación. El artículo propone el establecimiento de centros regionales VFSP-WAS y describe ejemplos potenciales de este concepto VFSP-WAS de dos regiones (Sudeste de Asia y América del Norte) en donde los centros VFSP-WAS se asocian con Centros Regionales de Monitoreo de Fuego/Manejo de Fuego.

Palabras clave: Modelamiento de la contaminación por humo y fuego; pronóstico meteorológico numérico; observación de la contaminación del aire; sistemas de alerta temprana.

Introduction

Vegetation fires – including the application of fire in land use, land-use change and uncontrolled wildfire – affect the functioning of the Earth System (Goldammer, 2013). Vegetation fires release large amounts of particulate matter (PM) and toxic gases including carbon monoxide, nitrogen oxides, and non-methane organic compounds into the atmosphere. Large and frequent wildfires impact local and regional air quality and are a threat to human health. Recent studies estimate that around 180,000 to 340,000 premature deaths could be attributed to exposure from wildfire smoke (Bowman & Johnston, 2005; Lelieveld *et al.*, 2015; Johnston *et al.*, 2012). Studies have clearly and consistently demonstrated that wildfire smoke PM is associated with respiratory (Henderson *et al.*, 2011) and cardiovascular effects (Dennekamp *et al.*, 2015) and that exposure to fire emissions represents the highest risk to vulnerable subsets of the population i.e. people with existing respiratory or cardiovascular illnesses, infants and the elderly (e.g. Statheropoulos *et al.*, 2013). Health studies have primarily focused on PM so that the effects of other smoke components remain unclear, particularly effects with longer latencies (Reisen *et al.*, 2015).

The Southeast Asian region is regularly impacted by vegetation fires. In some years (most recently in 1997-1998 and in 2015), the extent of the fires can be severe. For example during 2015, visibility in southern Sumatra and southern Kalimantan was reported as 5-10% of normal (Field *et al.*, 2016). However, as argued regarding the use of fires in land-use change in Indonesia, "if the 2015 Indonesian fires were not the worst air pollution event of the past few decades, it is only because they were surpassed by the 1997 fires" (Burki, 2017). Model-based estimates of premature mortality due to smoke exposure during the episode vary widely, and range from 11,880 (Crippa *et al.*, 2016) to 100,300 excess deaths (Koplitz *et al.*, 2016) depending on different model assumptions and whether the effects on neighboring countries are included. In the aftermath of the 1997-98 Indonesian fires. the World Health Organization (WHO) produced Health Guidelines for Vegetation Fire Events (Schwela *et al.*, 1999). This guide recommended that a comprehensive approach to reduce the risk posed by emissions from vegetation fires on human health should include (Schwela *et al.*, 1999):

- Characterization of the magnitude and composition of the emissions and their transformations during transport;
- Quantification of resulting concentrations of ambient air pollutants in populated areas;
- Evaluation of likely exposure scenarios for affected populations (both indoors and outdoors);
- Assessment of consequent health risks posed by such human exposures.

These guidelines point to the need for integrated fire and smoke management, which include physical, social, economic, cultural and

ecological evaluations for planning and operational systems, critical to reduce the vulnerability of people and landscapes to wildfires. Integrated fire management is built on technological and communication tools that incorporate observations and prediction. For example, satellite derived products offer real-time fire observations, which provide information and data on active fires, burned areas, and smoke emissions (noting that active fire observations more readily detect flaming fires rather than low-temperature smoldering fires). Identifying and mapping areas at risk of fires is crucial to integrated fire management and should be transparent and involve all agencies and stakeholders. This includes areas presenting significant fire risks and potential for generating transboundary haze pollution events.

Fire early warning systems are a key component of integrated fire and smoke management and build resilience against the increasing severity of future fire regimes under climate change (de Groot & Flannigan, 2014). The Third UNISDR International Conference on Early Warning (EWC III) and related consultations, recommended that the fire early warning system used in the Southeast Asia region and elsewhere should be based on early warning systems such as the Global Fire Early Warning System (Global Fire EWS) (de Groot & Goldammer, 2013) and/or the European Commission (EC) Joint Research Center Global Wildfire Information System which could be complementary to the fire danger rating systems used by Indonesia, Malaysia, and the Association of Southeast Asian Nations (ASEAN) (de Groot *et al*., 2007).

The Global Wildfire Information System (GWIS) is a joint initiative of the Group on Earth Observations (GEO) and the Copernicus Work Programs (see: http://gwis.jrc.ec.europa.eu/static/gwis_current_situation/public/index.html). GWIS builds on the ongoing activities of the European Forest Fire Information System (EFFIS), the Global Terrestrial Observing System (GTOS) Global Observation of Forest Cover – Global Observation of Land Dynamics (GOFC-GOLD) Fire Implementation Team, and the associated Regional Networks. The development of GWIS is supported by the partner organizations and space agencies such as the National Aeronautics and Space Administration (NASA).

The foundation of fire early warning systems such as the Global Fire EWS and the GWIS platform is the Canadian Forest Fire Weather Index (FWI) System, which provides globally information (Di Giuseppe *et al*., 2016) and is the most widely used fire danger rating system around the world (de Groot *et al*., 2015). The FWI danger rating system uses weather variables to assess fire danger. Currently FWI calculations in Southeast Asia are performed utilizing observations made at synoptic stations sparsely distributed in the most fire prone regions of equatorial Southeast Asia. Under GWIS, FWI information for the region is being improved using weather data inputs from satellites under NASA's Group on Earth Observations Work Programme.

Furthermore, the use of advanced numerical weather prediction models, makes possible longer-range predictions of FWI (for example one to two weeks in advance), enabling better planning and resource sharing within and between countries. The Global Fire EWS uses the deterministic Canadian Meteorological Centre forecast, while GWIS uses both a deterministic weather forecast and the European Center for Medium Range Weather Forecasts (ECMWF) ensemble prediction system and provides probabilistic fire weather index calculations up to 15 days ahead. The weather forecasts rather than observations mean that FWI values might be affected by model biases, which may be amplified or damped by nonlinear transformations in the fire model. For example, a dry bias in the model in a certain region will lead to the persistent prediction of relatively high fire danger values.

Good post processing tools minimize these errors by, for example, defining "model based" warning levels. To support the use of fire forecast data, ECMWF has developed a freely available post-processing tool called CaliVer (Calibration and Verification, an R package https://github.com/ecmwf/caliver) to define warning levels from model outputs at regional level (Vitolo *et al*., 2018). Others such as the "ranking" of FWI indices compared to historical time series of FWI values also provide information on the local variability of fire danger.

Regional calibration of the FWI System has been recently updated for Southeast Asia and is in the process of being implemented in the Global Fire EWS. Investigations to further strengthen the calibration with new datasets are ongoing and is seen as an important aspect to improve the usability of the systems in the region (for more

information visit http://data.giss.nasa.gov/impacts/gfwed). Furthermore, in the context of GEO, NASA has funded a project for "Enhancements to the Global Wildland Fire Information System: Fire Danger Rating and Applications in Indonesia", to enhance the potential support of GWIS at regional level. GWIS already provides daily information on fire emissions derived by Copernicus Atmospheric Monitoring Services (CAMS, see https://atmosphere.copernicus.eu).

Sub-seasonal to seasonal weather forecasts have been shown to be skillful in predicting fire activity in Southeast Asia (Spessa *et al.*, 2015). As proposed fire early warning systems are based on weather forecasts it is straightforward to also extend the prediction to seasonal lead times. There is a growing interest across the scientific community to explore the benefit of merging weather and climate forecasts as showcased by the ongoing joint WMO World Weather Research Programme (WWRP) – World Climate Research Programme (WCRP) Sub-seasonal to Seasonal Prediction Project (S2S) (Vitart *et al.*, 2017). Forecasts in the S2S range are not only informative with regard to anomalous conditions but also provide "actionable" information produced as short-range forecasts (White *et al.*, 2017). ECMWF has been particularly active in promoting the S2S timescale with the recent extension up to 46 days of its extended range ensemble prediction system and it is planning to provide fire forecast up to two months ahead. At longer lead times, the role played by model uncertainties becomes relevant and should be quantified. This can be achieved thanks to the availability of the information provided by the 51 runs of the ensemble prediction system, which can be translated in probability of occurrence.

Global fire early warning systems can provide a useful overview of cross-boundary fire danger conditions, and initial and boundary conditions for further downscaling. However, at the local level the utility of these global systems can be limited due to coarse calibrations. Therefore, the development of specific regional and national fire early warning systems, tailored to national and local needs, that "bridge the last mile" to the end-user, are required.

Collective international efforts are needed to address impacts of vegetation fires that are of transboundary nature and affect common global assets of the atmosphere and climate, natural and cultural heritage, and human health and security. Systematic application of principles of integrated fire management, based on the wealth of traditional expertise and advanced fire science, contributes to sustainable land management, ecosystem stability and productivity, maintenance and increase of terrestrial carbon stocks, and reduction of unnecessary emissions of pollutants that affect human health and contribute to climate change. In 2015, the participants of the 6th International Wildland fire Conference encouraged the COP 21 to acknowledge the role and endorse the support of IFM as an accountable contribution to reduce greenhouse gas emissions, maintain or increase terrestrial carbon pools in all vegetation types and ensure ecosystem functioning (IWFC, 2015a, 2015b).

Concept and methodology of the VFSP-WAS

The 18th World Meteorological Congress in June 2019 endorsed an ambitious plan to advance the integration of weather, climate, water and environmental applications and services for health, and work closely with the World Health Organization (WHO) to reduce risk to human health. Populations both near and downwind of wildfires are keenly interested in receiving better warnings about the fires themselves and related air quality risk levels, both of which pose serious threats.

WMO has responded to urgent requests for assistance in several impacted regions by initiating a Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS). The VFSP-WAS provides guidance for addressing both smoke and fire danger and proposes to support the potential foundation of regional centers.

Global and regional monitoring, prediction and warning systems are complex. As with any complex system, all the components of a VFSP-WAS need to be functional before the system can be fully operational and able to achieve the goals set for it by the international community.

The first research and development phase of the VFSP-WAS was launched in 2018. The most advanced research and development stage is currently in Singapore, where regional models are being run and forecasts from various centers are being collated to produce multi-model ensemble smoke forecasts (http://www.weather.gov.sg/vfsp-

was/home/). Canada is also scheduled to set up a demonstration VFSP-WAS center for Northern America.

The principles, relationships and components of the VFSP-WAS center are described in the following sections of the paper. Before approval as an operational Regional Specialized Meteorological Centre (RSMC) for VFSP-WAS, the centers must be evaluated by WMO Technical Commissions and further included into the Global Data-processing and Forecasting System (GDPFS) (WMO, 2017).

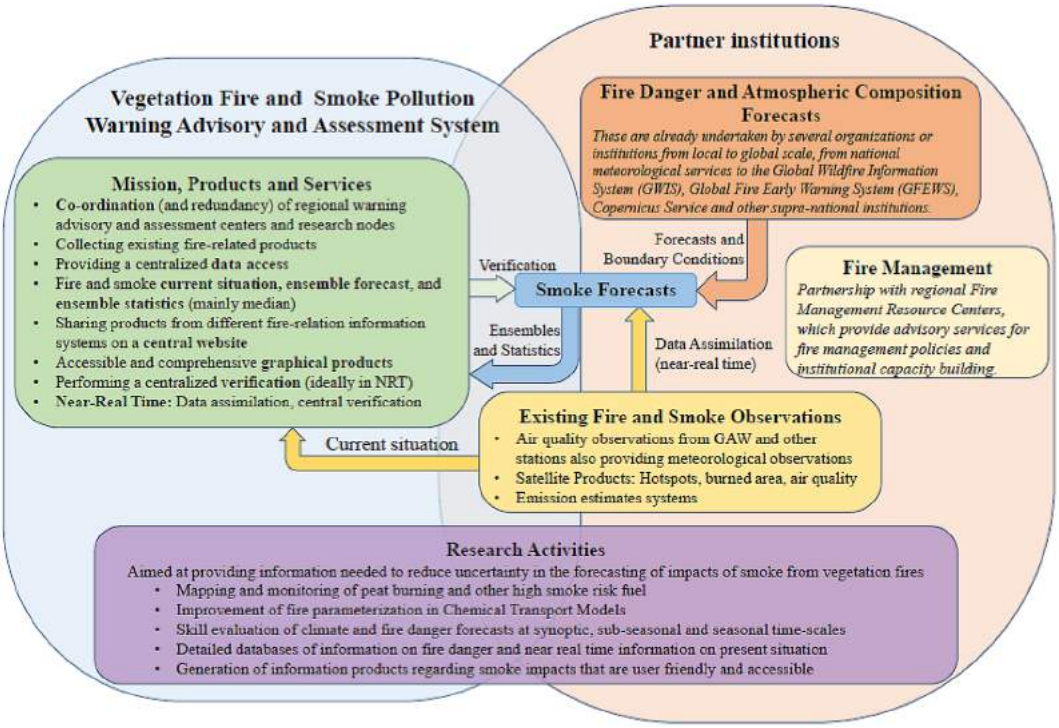

Figure 1 – Overview of a potential Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System.

Figure 1 demonstrates the overall concepts and activities of a potential VFSP-WAS, including the nature of the interactions between the system's components. The proposed warning and advisory system should build upon the experience acquired through comparable initiatives such as CAMS, WMO RSMCs, the ASEAN Specialised Meteorological Centre – ASMC, in Singapore, the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS; e.g. its regional centers in Barcelona and in Beijing), the Global Air Quality Forecasting and Information System (GAFIS, https://community.wmo.int/activity-areas/gaw/science-for-services/gafis) and the International Cooperation for Aerosol Prediction (ICAP). These initiatives demonstrated that relatively small efforts can add significant value to the end-user by making use of existing products.

A VFSP-WAS should have a federation structure with regional nodes and involve a program of research activities that provide information needed to reduce uncertainty in the forecasting of impacts of smoke from vegetation fires. Research activities are shown in Figure 1.

The VFSP-WAS should be an international network of research, national operational centers and users organized through regional nodes (similar as it is realized for SDS-WAS, see WMO, 2015) assisted by VFSP-WAS regional centers (Figure 2). It should be coordinated by the VFSP-WAS Steering Committee.

At the level of regional nodes, VFSP-WAS should be structured as a federation of regional partners. A federated approach allows flexibility, growth and evolution, while preserving the autonomy of individual institutions. It involves a variety of participants (universities, research organizations, meteorological services, emergency management bodies, health organizations, etc.) gathered to cooperate and benefit without requiring changes to their own internal structures and existing arrangements.

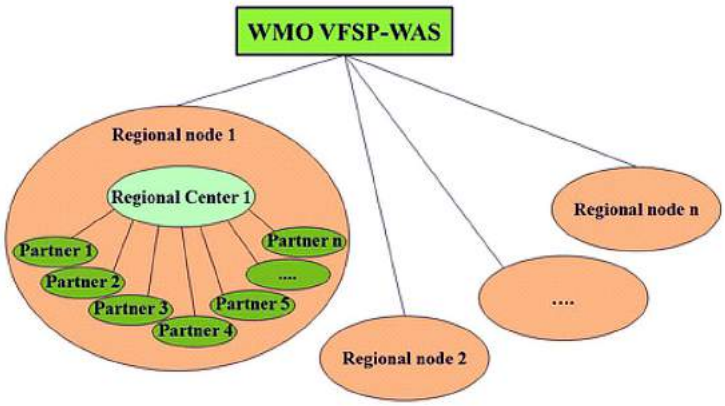

Figure 2 – Suggested regional structure of the Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System.

Research topic-related challenges and recommendations for VFSP-WAS

The research challenges facing fire and smoke prediction were evaluated by the Interdisciplinary Biomass Burning Initiative/IBBI and GAW Applications Science Advisory Group/APP-SAG (Kaiser & Keywood, 2015; Benedetti *et al.*, 2018; WMO, 2018). The implication of some of these challenges on the realization of the VFSP-WAS are presented in the following section.

Fire danger and seasonal forecast

Currently a variety of fire danger indices are provided at the global and regional levels. For example, in Southeast Asia, the operational products provide up-to seven days forecast of fire danger (WMO, 2018). These products include the Indonesian Fire Danger Rating System, the ASEAN Fire Danger Rating System (developed and produced by Met Malaysia), the Global Fire EWS and the GWIS. All systems are based on the Canadian Forest FWI System, a subsystem of the Canadian Forest Fire Danger Rating System/CFFDRS, which has been calibrated for equatorial Southeast Asia only in a broad sense (de Groot *et al.*, 2007). The systems provide index information on fire danger, but do not reflect potential/current level of atmospheric pollution associated with smoke. In addition, ENSO (Barnston *et al.*, 2017) and regional precipitation (Spessa *et al.*, 2015; Setiawan *et al.*, 2017) can be reasonably predicted several months ahead, with other relevant modes such as the Indian Ocean Dipole (Shi *et al.*, 2012; Zhu *et al.*, 2015) and the Madden Julian Oscillation predictable at varying lead times (Li & Robertson, 2015).

Research and development needs

The initial FWI calibration of de Groot *et al.* (2007) was focused on equatorial Southeast Asia and was known to over-estimate fire danger in the "Upper ASEAN" region. The FWI system therefore required a separate calibration for Thailand, Vietnam, Laos, Cambodia and Myanmar. Further calibration of the FWI system within Indonesia is also needed to account for differences in fuel types and land use intensity. The 2013 episode in Riau province in Central Sumatra, for example, indicated that acute fire emissions events affecting Singapore occur under less severe drought conditions than in other fire prone regions (Gaveau *et al.*, 2014), likely related to the intensity of land use (Hansen *et al.*, 2013), suggesting that the drought conditions may not be the best overall emissions potential indicator in that region, or that the drought conditions require a different calibration. A more detailed calibration will also benefit from longer records of space-based fire and pollution data than were available when the initial calibration of de Groot *et al.* (2007) was conducted.

Research and development are also required to support long-term fire management planning through seasonal predictions, emphasizing the risks and usefulness to local agencies. Shawki *et al.* (2017) demonstrated the potential for combining seasonal climate forecasts with Indonesia's

calibrated FWI system in operationalizing long-lead fire danger forecasts, but emphasized that further research is needed to determine how skill at different lead times, in different fire-prone regions, and for different models translates into predictions of fire danger. A VFSP-WAS should work together with the WWRP S2S project for regional downscaling and facilitate the development of sub-seasonal to seasonal predictions of fire severity in the area. To this end, there could be a clear benefit in accessing fire danger forecast produced by ECMWF at the S2S time scale.

In addition to the seasonal prediction of anomalous dry conditions, the sub-seasonal to seasonal time range can also provide actionable information with great potential for advance planning. ECMWF has already implemented a "seamless" forecasting system for floods and drought, which provides frequent forecast updates with up to six months horizon and performs well at the S2S time scale. The same approach can be implemented for fire forecasting in the region.

Fire emissions and haze forecast

Reasonably fast and comprehensive estimates of smoke constituent emissions are derived from satellite observations of fires using the approaches described below.

Fire radiative power

The thermal radiation of a fire can be observed from satellites in real time in the middle infra-red (MIR) spectral range. Such observations are called "active fire" observations. A quantitative signal can be interpreted as "fire radiative power" (FRP) product. FRP has been shown to be proportional to the biomass combustion rate under certain conditions. Subsequently, instantaneous emission rates of various smoke constituents can be calculated with published emission factors (Wooster *et al*., 2005). The advantages of this approach are the immediate availability of the observations and emission estimates (even while the fires are still burning) and the relatively weak dependence on the fire type for above-ground burning. Also, a quantitative characterization of the fires with a spatial resolution to 375m (e.g. with the National Polar-orbiting Partnership – Visible Infrared Imaging Radiometer Suite/NPP-VIIRS) and a temporal resolution of 10 minutes (e.g. from Himawari-8) is possible when all available satellite data are used. This approach is used, for instance, by the CAMS Global Fire Assimilation System/GFAS (Kaiser *et al*., 2012), and the Integrated System for wild-land fires IS4FIRES (Sofiev *et al*., 2009; Soares *et al*., 2015). It is also one of the methodologies available at the PREC-CHEM-SRC (Freitas *et al*., 2011; Frassoni *et al*., 2018), a flexible software suitable to regional and global domains developed to prepare emissions estimates of trace gases and aerosols. It has been used with the following regional models: Brazilian developments on the Regional Atmospheric Modelling System/BRAMS (Freitas *et al*., 2009; Longo *et al*., 2011) and the Weather Research and Forecasting/WRF model coupled with Chemistry (WRF-CHEM) (Grell *et al*., 2005), and the Flow-following finite-volume Icosahedral Model/FIM (Bleck *et al*., 2010).

Smoke detection

Smoke plumes can be readily detected in the atmosphere using remote sensing tools. Aerosol optical depth and carbon monoxide are relatively well observed by satellites and are used to infer fire emissions with "inversion" methods. While the atmospheric effect is relatively directly constrained for the observed species and the effect of any unobserved fire is also included, this methodology cannot distinguish the sources of observed constituents, e.g. from fire or from other sources (e.g. urban emissions) and has limited temporal and spatial resolution.

Burned area

The detection and quantification of burned area using satellite products is well established. Scaling burned area with fuel load and combustion completeness yields burned biomass, from which smoke emission can be calculated as in the FRP-based method described above. In addition, the similarity to *in-situ* methods employed locally by foresters on the ground means that significant validation and calibration has been carried out. Since area burned is persistent, it can be detected even after an observation gap, due to cloud cover for example. The spatial resolution is also relatively high (down to 250m for global coverage). However, since the area burned can only be observed after a burn has occurred, it is not suitable for true real-time applications. Active fire satellite observation

that can only distinguish between "fire" and "no fire", e.g. due to its MIR channel saturation the satellite can only produce binary "high-temperature event"/HTE products. Sometimes, relatively simple assumptions are used to estimate burned area from such products and emissions can subsequently be calculated as described above. This approach is being used to correct for missing small fires in the Global Fire Emissions Database/GFED (Randerson *et al*. 2012) or to calculate emissions in real time, e.g. with FINN (Fire Inventory from NCAR; Wiedinmyer *et al*. 2011) and to estimate emissions in the European Forest Fire Information System/EFFIS) and in the Air Quality Forecast System in operation at the Brazilian National Institute for Space Research, Center for Weather Forecasting and Climate Research/INPE/CPTEC (Freitas *et al*., 2017).

These emission estimates are a key input to atmospheric composition and transport models that represent a main tool for haze and air pollution forecasts. A Regional Vegetation Fire and Smoke Pollution Warning Advisory and Assessment Center/VFSP-WAC could coordinate multi-model ensemble forecasts of air pollutants dispersion in the region through atmospheric transport using regional expertise and capacities. To support this, WMO Members outside of the focus region informally proposed to contribute to such a multi-model ensemble forecast and analysis (e.g. sharing outputs of the lower resolution global aerosol models).

Within the international atmospheric chemistry community, including ICAP, GAFIS and the International Global Atmospheric Chemistry/IGAC project, there exist a number of global aerosol models that include emissions from vegetation fires and could be included in a multi-model ensemble forecast. Only half of these models are operational, the others remaining in a research and development stage (for some, only the vegetation fire component is not operational).

Several real-time smoke forecasting products exist. The most established global aerosol forecasts are represented in the ICAP and GAFIS communities. Four models include dedicated smoke treatment: (i) CAMS ECMWF and partners; (ii) Model of Aerosol Species IN the Global AtmospheRe (MASINGAR) Meteorological Research Institute, Japan Meteorological Agency, MRI-JMA (see Tanaka *et al*., 2003); (iii) Goddard Earth Observing System model, version 5 (GEOS-5) NASA, (see: Rienecker *et al*., 2008); (iv) NAAPS: Navy Aerosol Analysis and Prediction System (US Navy, see https://www.nrlmry.navy.mil/aerosol_web/Docs/globaer_model.html), and System for Integrated modeLling of Atmospheric coMposition SILAM (see http://silam.fmi.fi); where the first two use emissions from GFAS (see http://apps.ecmwf.int/datasets/data/cams-gfas/), the third – from a similar FRP-based inventory of the Quick Fire Emissions Dataset/QFED, see https://geos5.org/wiki/index.php?title=Quick_Fire_Emission_Dataset, the fourth – from the active fires detected by the Fire Locating and Modeling of Burning Emissions/FLAMBE, see http://www.nrlmry.navy.mil/flambe/index.html, system and the fifth one – from IS4FIRES (http://is4fires.fmi.fi). In Australia, the Smoke Forecasting System/AQFx is currently being developed by CSIRO and the Australian Bureau of Meteorology https://www.csiro.au/en/Research/OandA/Areas/Assessing-our-climate/Smoke-forecasting.

The ICAP is an international forum for aerosol forecast centers, remote sensing data providers and lead system developers to share best practices and discuss pressing issues facing the operational aerosol community (Xian *et al*., 2019). The ICAP initiative itself has demonstrated that simply collecting different forecasts in a single database and generating web pages with common plotting conventions is an effective tool for the developers to assess and improve their forecasting systems.

EU's CAMS is using its global atmospheric composition forecasts and GFAS fire emissions as common boundary conditions for an ensemble of seven operational regional air quality forecasting systems for Europe, including smoke (Marécal *et al*., 2015). A common real-time verification with station data greatly helps the interpretation and further developments of the individual models. The median of all models has been shown to benefit from the individual strengths of the seven models, as this statistical "analysis" is more accurate than any single forecast.

The ASMC provides operational and regularly updated information and products on the weather and smoke haze situation in the ASEAN region (http://asmc.asean.org). Using the fire distribution from CAMS-GFAS, means that it is similar to a member in the CAMS ensemble of European air quality models. The Bluesky Modelling Framework is a possible approach that

has been successfully applied in North America, and in which the testing of different emissions scenarios as input to transport models is relatively straightforward.

Truly prognostic smoke forecasts require emissions forecasts. One approach for generating emission forecasts is to better understand the relationship between historical emissions and simple meteorological or fire weather parameters. Despite the role of non-weather factors in controlling fire activity, this approach is likely to be useful in Indonesia because of the strong climatic controls on fire activity and emissions relative to other fire-prone regions in the world (Bedia *et al*., 2015). ECMWF applies the FWI to modulate the global emissions of fires estimated from FRP data (Di Giuseppe *et al*., 2016). The daily emissions are modulated by a linear relationship between FWI and FRP during CAMS integration process. Novel techniques have been applied to attempt to forecast prescribed fires in order to improve air quality regional models (e.g. Agastra, 2020). The CAMS-GFAS (Kaiser *et al*., 2012) inventory is a widely used example of such a combined inventory (e.g. by ECMWF, NASA, JMA, ASMC and GWIS).

Research and development needs

Despite its application in other regions, the implementation of ensemble forecasts for transboundary haze events in Southeast Asia still requires substantial development. Since all CAMS services are freely available, the CAMS concept of implementing an ensemble of forecasts with common boundary conditions, presentation and verification could be applied to the smoke in Southeast Asia with ASMC already providing the first operational, high-accuracy ensemble member. Other VFSP-WAC could follow a similar roadmap for application to their own region.

Observation gaps that may result from cloud cover or lack of satellite coverage create gaps in the emission estimates. At the same time, consistent merging of FRP from different satellites still represents an open research topic. Furthermore, the FRP signal from peat fires is relatively small and its relationship to fuels consumed is less certain for these fires than for above-ground fires. Finally, the emission factors vary for individual fires so that estimates on a small scale have a limited accuracy.

The uncertainties in emission estimates from smoke observations remain large due to variable and relatively poorly known optical properties of aerosols, the poorly characterized errors in atmospheric chemistry and transport models, and noise in the satellite observations.

There is a need to better quantify the errors that lead to the use of the scaling factors and to improve the emission datasets and/or the models to reduce their use (Benedetti *et al*., 2018). A recent example of an inversion of Southeast Asian fire emissions is given in Huijnen *et al*. (2016).

Observations and data production for verification and assimilation

To support the assessment of fire impacts, measurements of the combustion species (aerosols, reactive and greenhouse gases) are needed. Monitoring stations across the globe operate under the WMO Global Atmosphere Watch Programme/GAW and other networks such as the Aerosol Robotic Network/AERONET (Holben *et al*., 1998) and the GAW Aerosol Lidar Observation Network (GALION). While these networks can support verifications of haze forecasts, the density of stations in these networks is low and the timeliness of data delivery is limited. To improve this coverage, ground-based reference instruments could be complemented by satellite observations and low-cost sensor (LCS) networks.

Recent developments in the production of low-cost, compact air pollution sensors have sparked the interest of air quality professionals, scientists, and communities concerned about air pollution (Morawska *et al*., 2018). The WMO produced a relevant report on LCS on behalf of international organizations working on atmospheric composition. We refer the reader to this report for more information (Lewis *et al*., 2018). This report highlights that: "As a class of device, LCS encompass a very wide range of technologies and as a consequence they produce a wide range of quality of measurements". LCS are currently not able to replace reference instruments, particularly for mandatory monitoring, and tend to be limited to measuring a handful of pollutants, (e.g. CO, NOx, O3, and PM). Recent evaluations have found that some dust sensors are proving effective for the measurement of particulate matter in smoke and networks of these sensors are being used to feed real time data on PM2.5 concentration into smoke

forecasting systems. For example, the Smoke Observation Gadget/SMOG is used in Southeast Australia to provide data for the AQfx (https://ecos.csiro.au/smog/). Lastly, while there are transparent and open-source sensors available, many LCS rely on opaque (black box) or proprietary algorithms to estimate pollutant concentration. See Karagulian *et al.* (2019) and Lewis *et al.* (2018) for details on individual sensors.

Regional VFSP-WAC could also provide centralized data access to a variety of observations, from satellite observations to ground observations of fire and smoke. While not making observations directly, a regional VFSP-WAC should encourage the regional use and dissemination of observations.

Research and development needs

While some studies have investigated LCS for smoke monitoring (e.g. Gupta *et al.*, 2018), the vast majority of studies have focused on urban air quality. Studying the performance of LCS specifically for smoke pollution will also enable the calibration of these sensors to detect pollutant concentrations most relevant for fire smoke monitoring. Furthermore, this would enable the application of Machine Learning algorithms (e.g. Zimmerman *et al.*, 2018).

Both satellite and LCS observations should be compared and calibrated with accurate, but geographically sparse ground stations. Each VFSP-WAC can also seek to fill gaps in observations using regional atmospheric composition monitoring networks. While studies have shown the potential of near real time data assimilation for atmospheric composition (Bocquet *et al.*, 2015; Innes *et al.*, 2015), further research and development can assess the effectiveness of these assimilation methods for operational haze and smoke predictions.

VFSP-WAS regional centers and examples of their realization

Key principles and suggested structure of a Regional Center

At the regional level, VFSP-WAS can be organized as a federation of regional partners contributing to Nodes and realized through a Regional Center. The organization of regional nodes' research and development and forecasting activities can be defined and led by a VFSP-WAS Regional Steering Group (RSG) and practically realized by the Regional VFSP-WAC. The Nodes would be an open federation of different partners from interested countries of the region with equal votes of each partner involved (see Figure 1). The VFSP-WAS can be hosted by one or several countries/organizations (on the agreement of the Node members and its RSG) and focus on technical realization of the Regional VFSP-WAC and providing regional vegetation fire smoke pollution forecasts. A scheme of the governance structure of Regional VFSP-WAC is presented in Figure 3.

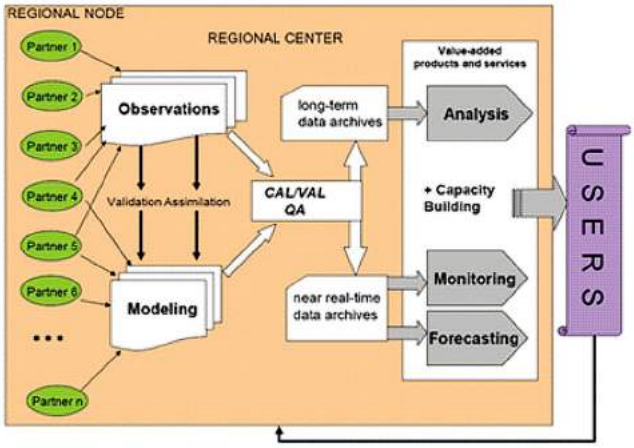

Figure 3 – Scheme of the governance structure of a Regional Node and Fire and Smoke Pollution Warning Advisory and Assessment Center (VFSP-WAC).

The establishment of a VFSP-WAS for a specific region would require existing providers of related services to collaborate with one central organization hosting the Regional VFSP-WAC, which would include capability to collect, analyze and publish products. A common verification system would provide quality checks and facilitate further research and continued improvements of operational systems. Such arrangements would ensure acknowledgement of product sources and allow linkages with existing regional activities in a flexible way.

The strength of such a Regional VFSP-WAC will be the production of ensemble forecasts based on the already available products, e.g. for Southeast Asia by ASMC and national hydro-meteorological services (NHMSs) in the region as well as partners outside of the region willing to contribute to the center. Lateral and surface boundary conditions for regional forecasts could be provided by external partners with advanced capabilities (for instance, CAMS).

A Regional VFSP-WAC could provide information in support of fire and emergency management. The often significant impact of fire and smoke pollution necessitates the provision of data and information that can inform decisions made by health and fire management sectors. While the provision of this information is central to the Regional VFSP-WAC mission and guides the developments of the user relevant products and services, the VFSP-WAC would not itself lead on policy advice but instead contribute to collaborating entities.

The process of establishing a Regional VFSP-WAC should begin with an understanding of potential partners. The ensuring dialogue with potential partner organizations could take place through stakeholder workshops. This step should ensure that relevant agencies from the global, to the regional, national and local level are involved in the dialogue. The stakeholder groups involved in this dialogue should include: meteorological departments, land (including peatland) and forestry management, fire management and firefighters, and health management and health practitioners. Understanding user needs is key to determining the type and quality of products and services required. This process would also be important for finalizing a statement of the goals of the VFSP-WAC.

Once a set of user-focused and impact-based products and services have been identified, as well as an indication of accuracy needed for their operational use, the implementation plan should follow a comprehensive series of steps, from initial research and validation efforts to impact-based services that are operationally generated (WMO, 2018).

A Regional VFSP-WAC (Figure 4) should aim to ensure that partners appropriately and systematically use the center's warning and advice to ensure harmful fire episodes are reacted upon appropriately. Because fire and smoke predictions still need considerable development, any center should also aim to bridge the gap between research and operational work.

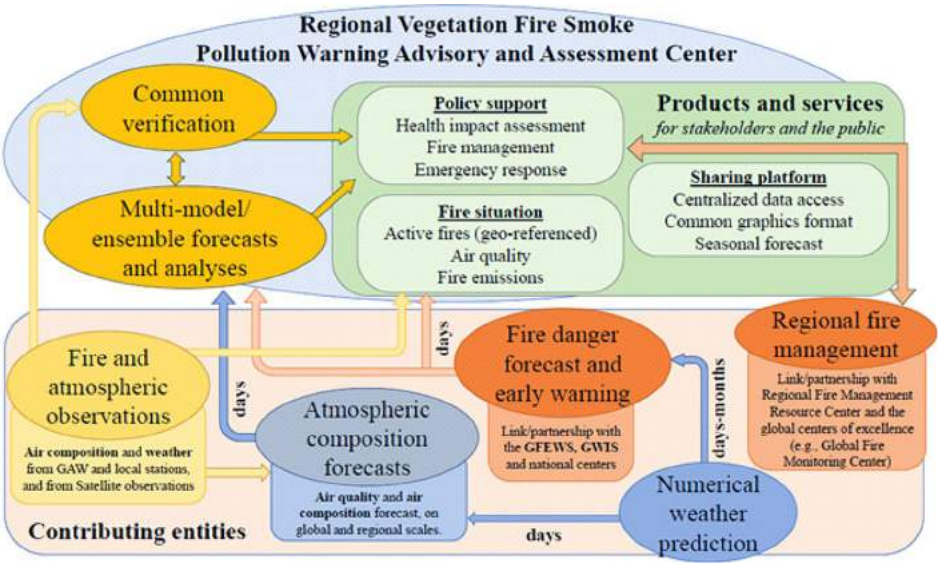

Figure 4 – Workflow of the proposed Regional Fire and Smoke Pollution Warning Advisory and Assessment Center.

As an example, the proposed VFSP-WAC (Figure 4), for the ASEAN region would maintain strong links with partner institutions that provide Fire Danger forecasts and Early Warnings (the ASMC for Southeast Asia), and national and regional institutions that support fire management, e.g. the Regional Fire Management Resource Center – South East Asia (RFMRC-SEA, see https://rfmrc-sea.org/). The VFSP-WAC would provide centralized access to products and services aimed at stakeholders and the public. Regional partners would contribute these products while the VFSP-WAC would facilitate their availability (website and data access). The VFSP-WAC would be responsible for providing multi-model ensemble of atmospheric composition forecasts and analyses and longer-term fire danger forecasts (e.g. sub-seasonal or seasonal). It would also perform a common verification of all of these.

Singapore VFSP-WAS regional center for Southeast Asia

The first regional VFSP-WAC was proposed in Southeast Asia and hosted by the ASEAN Specialised Meteorological Centre (ASMC), building on more than 20 years' experience at ASMC in monitoring fires and smoke haze for the region. ASMC, hosted by the Meteorological Service Singapore (MSS), was designated in 1997 as the official ASEAN center to monitor fires and transboundary haze in Southeast Asia (Regional Haze Action Plan, 1997). ASMC issues alerts when haze is expected to affect any ASEAN Member State and provides operational products and information on the regional weather and haze situation on its website. ASMC also serves as technical advisor for ASEAN committees on transboundary haze and conducts capability development programs for users including environment, forestry, meteorological and related agencies in the region.

To initiate the Southeast Asia VFSP-WAC, collaboration was sought with interested partners and existing providers of relevant products and services, particularly, for the development of a new multi-model ensemble from global and regional modelling centers. The Southeast Asia VFSP-WAC also leveraged the experience of the WMO SDS-WAS and its regional centers in Barcelona, Spain and in Beijing, China, as well as the ICAP.

A pilot website for the Southeast Asia VFSP-WAC was first released in 2018 and launched in research and development phase in 2019 (http://www.weather.gov.sg/vfsp-was/home/). The initial efforts focused on establishing the multi-model ensemble and near real-time forecast evaluation. The amount and quality of the content published is planned to progressively increase. An upgraded version of the website is under development and will include the addition of observation and fire risk products.

A review of the current weather and smoke haze situation, and outlook over the next few days issued by ASMC is available on the main page of Southeast Asia VFSP-WAC website. Products will be organized into three categories: Forecasts, Observations and Fire Risk, as detailed below. From the website, users can access links to various partner institutions including modelling centers, observation networks, fire risk and fire management centers relevant to the region.

1) *Forecasts* include individual and multi-model ensemble predictions of smoke aerosol optical depth (AOD) and surface particulate matter concentrations, as well as weather forecast information for the region. Near real-time forecast evaluation and evaluation metrics are available.

a. Multi-Model Ensemble Smoke Forecasts

There are six contributing model members as of mid-2020, five are from global models: ECMWF-CAMS (Europe), JMA MASINGAR (Japan), NASA GEOS-5 (USA), NCEP-NGAC (USA), FMI SILAM (Finland) and one from a regional model: MSS-UKMO NAME (Singapore). While most of the ensemble members have built-in aerosol optical models to compute AOD, MSS-UKMO NAME (Hertwig *et al.*, 2015) derives $PM_{2.5}$ aerosol optical properties based on an empirical study of biomass burning smoke over Singapore by Lee *et al.*, 2016. The center retrieves available 00 and 12 UTC forecasts from the various models and represents them using a common grid resolution of 0.5° x 0.5° and geographical domain covering major burning areas and smoke transport pathways in the Southeast Asia region. The

forecast variables are smoke AOD at 550 nm and surface concentrations of PM_{10} and $PM_{2.5}$. Individual models' and multi-model ensemble forecasts are provided at 3-hourly intervals up to 48 hours ahead. The ensemble has two products describing centrality (multi-model median and mean) and another two describing the spread (standard deviation and range of variation). Figure 5 shows example products from the multi-model ensemble median forecast of smoke AOD and $PM_{2.5}$ surface concentration.

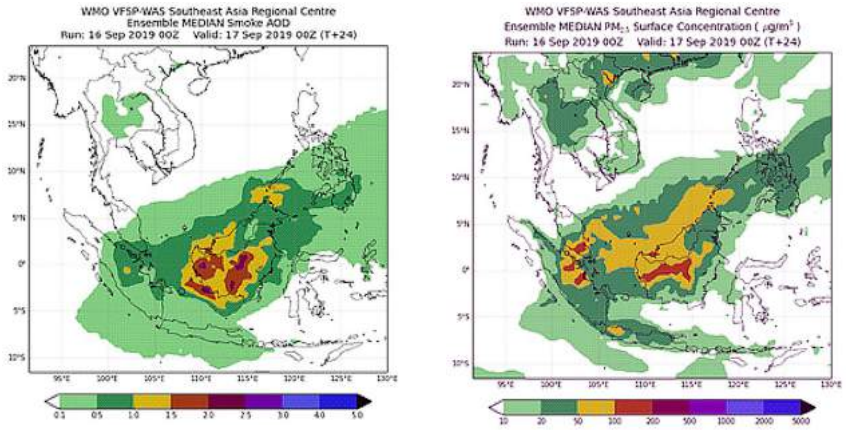

Figure 5 – Example Southeast Asia VFSP-WAC multi-model ensemble median 1-day forecast of smoke AOD (left) and $PM_{2.5}$ surface concentration (right) for the Southeast Asia region in September 2019.

b. ICAP Ensemble

The ICAP multi-model ensemble is constructed from the following global aerosol models: CAMS, GEOS-5, NAAPS, MASINGAR, NGAC, MOCAGE and SILAM (see Sessions *et al*., 2015). Smoke AOD forecasts from the ICAP ensemble are shown in this section alongside the Southeast Asia VFSP-WAC ensemble for comparison.

c. Weather Forecasts

Sub-seasonal outlooks of rainfall and temperature provided by ASMC for the Southeast Asia region are published. For the upcoming website upgrade, NWP forecasts of winds at various height levels over the region will be added.

2) *Observations* of the regional fire and smoke situation include satellite images, weather and air quality station measurements. This section will be added in the upcoming website upgrade.

a. Satellite observations

Product images from geostationary (Himawari-8) and polar-orbiting (NOAA20, SUOMI-NPP, AQUA, TERRA) satellites including true/false color, natural, fire temperature and night images will be published.

b. Weather and Air Quality Observations

The ground weather observation reports collected through the WMO Global Telecommunication System (GTS) will be displayed on a map showing wind, visibility and weather conditions e.g. smoke haze. Available station measurements of surface particulate matter concentrations will be provided.

3) *Fire risk* provides information to identify areas in the region at risk of fire occurrence based on prevailing weather conditions. This section will be added in the upcoming website upgrade.

a. ASEAN Fire Danger Rating System (FDRS)

The ASEAN FDRS is based on the Fire Weather Index (FWI) System developed by Canada and has been calibrated for the

Southeast Asia region (de Groot *et al.*, 2007). The ASEAN FDRS product is produced daily by the Malaysian Meteorological Department.

b. Global Fire Weather Database (GFWED)

GFWED integrates different weather factors influencing the likelihood of a vegetation fire starting and spreading and is similarly based on the FWI System. Details on the development and testing of GFWED can be found in Field *et al.* (2015), and evaluation of GFWED products in Field (2020).

Forecast Evaluation and Evaluation Metrics

To evaluate the VFSP-WAC forecasts, the 1-day ensemble forecasts of smoke AOD are compared to total AOD as observed at 22 NASA AERONET sites across Southeast Asia. Eleven of these AERONET sites are situated in Peninsular Southeast Asia (i.e., Cambodia, Laos, Myanmar, Thailand, Vietnam), while the other eleven are situated in the Maritime Continent (i.e., Brunei, Indonesia, Malaysia, Philippines, Singapore). Many of these sites have been set up in collaboration with local government and researchers and enhanced during the 7SEAS (7-Southeast Asian Studies; Reid *et al.*, 2013) and CAMP2Ex (Cloud, Aerosol and Monsoonal Processes: Philippines Experiment) programs.

For near real-time forecast assessment, AERONET Level 1.5 products (Version 3) are used. Although the AERONET sun photometers do not measure AOD at 550 nm for direct comparison with model outputs, this metric can be calculated from AOD measured in other wavelengths, namely 440, 675 and 870 nm, using the Angstrom Law. Clouds, especially cirrus clouds, are endemic in Southeast Asia and are a source of potential bias in passive aerosol remote sensing datasets such as AERONET (e.g. Chew *et al.*, 2011), thus in addition to the standard AERONET cloud screening (Smirnov *et al.*, 2000), a threshold of Angstrom Exponent (440 – 870 nm) > 0.75 is applied to screen for cloud contamination in the region (e.g. Salinas *et al.*, 2009; Chew *et al.*, 2013). An example of the near real-time forecast evaluation product is shown in Figure 6.

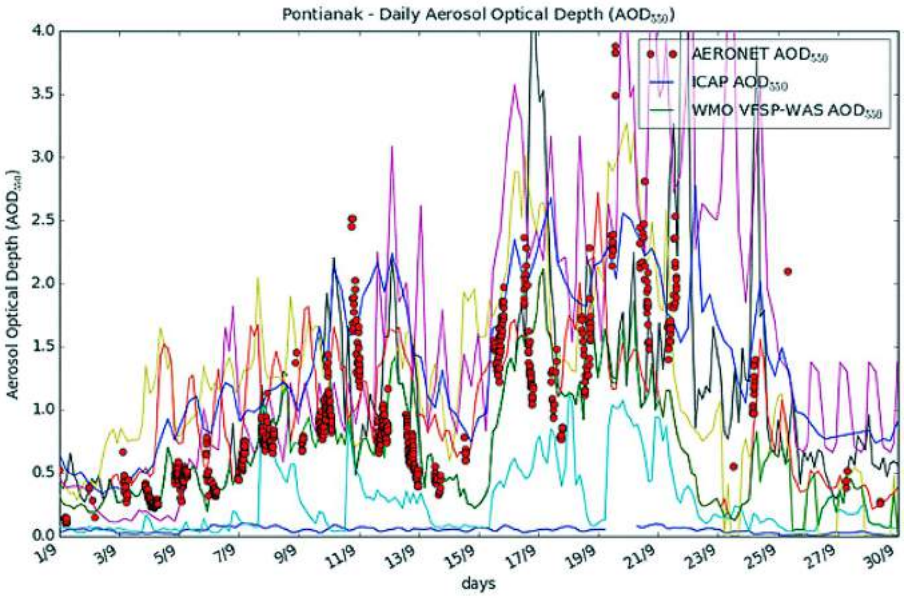

Figure 6 – Near real-time Southeast Asia VFSP-WAC forecast evaluation over Pontianak, West Kalimantan, during the peak of fire activity in September 2019. Unlabeled colored lines represent individual model members of the Southeast Asia VFSP-WAC ensemble.

Besides near-real-time forecast evaluations, evaluation metrics for modelled and observed AOD comparisons are calculated monthly, seasonally and annually. The evaluation metrics for the forecasts currently comprise of mean bias error (BIAS), root mean square error (RMSE), correlation coefficient (CORR) and fractional gross error (FGE). The AERONET AODs closest in time to the model outputs within a 30-minute window are compared with the modelled outputs in computing the evaluation metrics. These statistics will be included in the upcoming website upgrade.

The monthly and annual statistics are computed retrospectively. The seasonal statistics are derived for February – April (FMA), May – July (MJJ), August – October (ASO) and November – January (NDJ) to best group the dominant regional monsoonal circulations with regional burning processes observed annually (Reid *et al*., 2012). In Southeast Asia, there are two primary monsoon seasons, i.e., the Northeast Monsoon during the boreal winter (December – March) and the Southwest Monsoon (June – September) during the boreal summer, which are separated by relatively shorter inter-monsoon periods (April – May and October – November). During north hemisphere winter, the ITCZ (Intertropical Convergence Zone) and a secondary South Pacific convergence zone result in dual zonal rain bands embedded within the trade winds in the Central Pacific (Masunaga & L'Ecuyer, 2010). The associated monsoonal trough changes from being a zonal feature across the Maritime Continent in winter to a diagonal one extending over Peninsular Southeast Asia and into the Northern South China Sea in summer (Reid *et al*., 2012). The biomass burning seasons are generally anti-correlated with the monsoonal trough as it oscillates through the year, thus the biomass burning season for Peninsular Southeast Asia occurs in the boreal winter, while the biomass burning season for the Maritime Continent occurs in the boreal summer (Reid *et al*., 2013), although off-season burnings are occasionally observed outside these seasons (Chew *et al*., 2013).

Table 1 illustrates the evaluation statistics consolidated for eleven sites in the Maritime Continent for ASO 2019 and eleven sites in the Peninsular Southeast Asia for FMA 2020 when biomass burning for the respective region occurred. The Southeast Asia VFSP-WAC ensemble has almost no bias as the ensemble members have both positive and negative bias in their forecasts, thus averaging out within the ensemble. The ensemble also has the lowest RMSE and one of the lowest FGE among members, as the ensemble consists of skillful and independent models for the region and is likely to perform better than any individual member (e.g., Sessions *et al*., 2015). The ensemble AOD is well-correlated with AERONET observations as indicated by correlation coefficient of 0.72 for the Maritime Continent in ASO 2019 and 0.76 for the Peninsular Southeast Asia in FMA 2020, despite extensive cloud obscuration in the region frequently hindering satellite-based fire observations used to derive smoke emission inputs in the models.

Table 1 – Evaluation Statistics for 11 sites in the Maritime Continent for ASO 2019 and 11 sites in the Peninsular Southeast Asia for FMA 2020.

Region	Evaluation metrics	Southeast Asia VFSP-WAC ensemble
Maritime Continent (ASO, 2019)	BIAS	-0.04
	RMSE	0.34
	CORR	0.72
	FGE	0.69
Peninsular Southeast Asia (FMA, 2020)	BIAS	0.04
	RMSE	0.15
	CORR	0.76
	FGE	0.46

Environment and Climate Change Canada VFSP-WAS regional center for North America

The Government of Canada has recently completed several studies related to wildfire pollution and associated population exposure over North America (Matz *et al.*, 2020, Munoz-Alpizar *et al.*, 2017) using the operational Environment and Climate Change Canada (ECCC) air quality system, named FireWork (Chen *et al.*, 2019; Pavlovic *et al.*, 2016). The economic cost for Canada regarding the population health impacts from wilfire-$PM_{2.5}$ exposure was estimated at $410M-$1.8B per year for acute health impacts and $4.3B-$19B for chronic health impacts (Matz *et al.*, 2020). The importance of these impacts is one of the drivers for improving international collaboration in data sharing supporting wildfire preparedness and response. In 2019, ECCC, a department of the Government of Canada, responded to the WMO's initiative and volunteered to create a North American (NA) Regional VFSP-WAC. As such, ECCC has been working on product development planned for NA VFSP-WAC with the objective to start disseminating the products in 2020. This NA centre will be the world's second Regional VFSP-WAC. ECCC is planning to have products similar to the Southeast Asia's VFSP-WAC with near-real-time wildfire-related forecasts and data collected from various observation networks and modelling systems. The creation of this NA regional centre involves close and effective collaboration with different national and international organizations, such as NOAA, NASA, USFS, NRCan, ECMWF, JMA, FMI, etc. This partnership is essential for data collection and product tailoring with respect to the various national and international user needs.

The NA VFSP-WAC plans to disseminate products under two sub-groups: *Current* and *Forecasted* wildfire-related information.

Under the *Current* section, two products are planned:

1) Hotspots Maps over North America

   These maps will be available for the period covering the last 24 hours and previous 7-day period. This product will provide information about current and most recent wildfire activity as detected by satellites.

2) Fire Danger Map

   This collaborative map product is under development and is currently produced daily by combining the fire danger products produced for Canada and Mexico through the Canadian Wildfire Information System (CWFIS) and the fire danger products from the US Wildland Fire Assessment System (WFAS). This map displays fire danger as classified by Canadian provincial, territorial and US state fire management agencies. Data Sources: Canada/Mexico – NRCan-CWFIS; Contiguous USA – USFS-WFAS, and Alaska – MesoWest. Some of these maps are already disseminated by USFS-WFAS (US Forest Service – Wildland Fire Assessment System).

Under the *Forecasted* section, five products are planned:

1) Ensemble $PM_{2.5}$/PM_{10} Forecast:

   The multi-model ensemble PM forecast will be based on six members, two of which are regional [ECCC FireWork (Canada) and NOAA NCEP NAQFC (USA)] and four are global [ECMWF CAMS-IFS (Europe), FMI SILAM (Finland), JMA MASINGAR (Japan) and NASA GEOS-FP (USA)]. In addition to the ensemble, forecasts from each member will be presented separately. The common lead-time for these ensemble members is 48h, and it is planned to update the related forecast products once daily.

2) $PM_{2.5}$/PM_{10} Performance Evaluation Statistics: Ensemble and Model-Specific Forecast

   Performance evaluation for particulate matter concentration forecasts will be done using ground-level measurements from NA networks. The evaluation performance will be done using ECCC's Verification of Air QUality SModels (VAQUM) system. This system was developed in 2017 by ECCC in collaboration with ECMWF-Copernicus CAMS-IFS and NOAA, and is used for operational AQ multi-model performance analysis over North America (Pavlovic *et al.*, 2018). It is planned to have different ensemble

windows over NA, as two regional (NOAA's and ECCC's) systems do not entirely cover the NA continent.

3) ICAP Smoke Aerosol Optical Depth (AOD)

The ICAP Multi-Model Ensemble smoke AOD products are constructed from the following aerosol forecast systems: ECMWF CAMS-IFS, NASA GEOS-FP, NRL NAAPS, and JMA MASINGAR. It is planned that products from ICAP will be displayed on the NA VFSP-WAC web page (Figure 7).

4) Fire Weather Index (FWI)

The Canadian FWI equations, provided by National Resources Canada (NRCan), are used to calculate FWI over NA using ECCC's Operational Regional Deterministic Weather Forecasts. The latter is at 10-km horizontal grid spacing and is launched twice daily producing 72h lead-time forecasts. It is planned to provide this FWI product in forecast mode, with maps valid at TT+ 24h, TT+48h and TT+72h (Figure 7). These maps are under development as different options for the provision of risk forecast products are being discussed between partners.

5) Sub-Seasonal Outlook

ECCC is producing sub-seasonal precipitation and temperature anomaly maps using the Global Ensemble Prediction System (GEPS). A 20-year climatology study (1998-2017) of this prediction system obtained from a reforecast is used to calculate forecasted anomalies. The monthly forecast is updated every Thursday and covers the following 28 days, starting on Monday. Information about this system and more recent updates can be found in Lin *et al*. (2019).

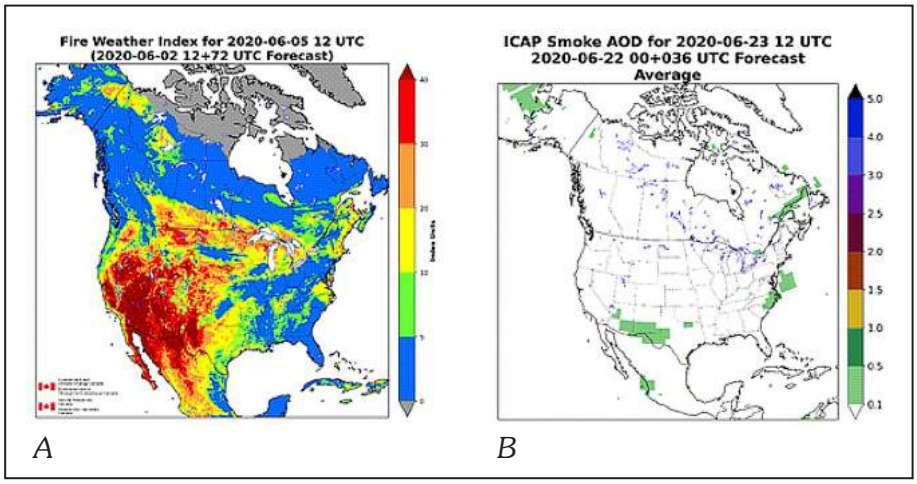

Figure 7 – (A): Forecasted FWI valid at 2020-06-05 12UTC, from 2020-06-02 12UTC initial run; (B): forecasted average ICAP Smoke AOD valid at 2020-06-23 12UTC, from 2020-06-22 00UTC initial run.

Products planned for North American Regional VFSP-WAC, briefly presented here, are under development and can be changed, modified or expanded in the near future. ECCC will continue to work in collaboration with its partners, and in consultation with the user community, to enhance the value of the proposed NA Regional Vegetation Fire and Smoke Pollution – Warning Advisory and Assessment Centre.

Opportunities for other Regional VFSP-WAC

Several other regions are interested or have demonstrated infrastructure necessary to host a Regional Center for the realization of VFSP-WAS and also have good experience and research. For example, in Latin America, INPE in Brazil maintains a well-established operational routine

to monitor biomass burning in South and Central Americas, as well as Caribbean and Mexico, making use of remote-sensed data and weather forecasts. INPE's Wildfire Monitoring Program "Queimadas" (for more information visit http://queimadas.dgi.inpe.br) routinely produces a spatial-based product of vegetation fire risk (FR) available for the Latin American domain. FR takes into account environmental variables like the number of consecutive days with no rain, the maximum daily air temperature, minimum relative humidity, characteristics of vegetation type, topographic elevation and latitude, as well as active fires detected by remote sensing (Setzer *et al.*, 2019). In addition, the "Queimadas" Monitoring Program also offers daily FR forecast up to five days, which is based on meteorological forecasts provided by global modeling. As one of the WMO Global Producing Centers for long-range forecasts, INPE/CPTEC produces operationally seasonal climate forecasts (Coelho *et al.*, 2012), integrating the GDPFS. More recently, Guimarães *et al.* (2020) provided an optimal configuration for the INPE/CPTEC global sub-seasonal prediction system and assessed the ability of up to 4-week retrospective predictions of meteorological variables. Sub-seasonal to seasonal predictions are key ingredients to provide predictions of fire severity in the sub-seasonal to seasonal timescales for Latin America. The Brazilian Institute also provides operational air quality forecasts with temporal resolution of 3h up to the 72h lead-time in a 20km horizontal resolution. Air quality products like graphical displays of ozone and carbon monoxide concentrations, smoke, AOD among others, are freely available at INPE/CPTEC webpage (http://meioambiente.cptec.inpe.br). Forecasts are based on the fully coupled meteorology/chemistry regional model BRAMS (http://brams.cptec.inpe.br/), the main component of the Air Quality Forecasting System in operation since 2003 at INPE/CPTEC (Freitas *et al.*, 2017). As a way forward for the implementation of a VFSP-WAS in Latin America, it is needed to deepen partnerships among different actors in Latin American countries, regional and local agencies. INPE is currently part of the "La Red Latinoamericana de Teledetección e Incendios Forestales" (RedLaTIF), a regional network with the aim to integrate efforts in the field of observation and management of forest fires in all Latin American countries (for more information, visit http://www.redlatif.org). In addition, INPE and the Operations and Management Center of the Amazonian Protection System (CENSIPAM) are joining efforts to integrate Amazon monitoring systems, whose data support actions to mitigate environmental crimes in the region (INPE, 2020).

Conclusions

In addition to the direct threat from burning, including the risk to many communities, wildfires also release harmful pollutants including particulate matter and toxic gases such as carbon monoxide, nitrogen oxides, and non-methane organic compounds into the atmosphere.

The 18th World Meteorological Congress in June 2019 endorsed the plan to advance the integration of weather, climate, water and environmental applications and services for health, and work closely with WHO to prevent health risks. Populations both near and downwind of raging wildfires are keenly interested in receiving better warnings about the fires themselves and related air quality risk levels as both are serious threats to life and health.

WMO has initiated a Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS). Arising from the keen interest of WMO Members in several impacted regions, the concept provides guidance for addressing the issues of vegetation fire and smoke pollution.

The following research topic-related challenges have been identified and recommendations have been made for further VFSP-WAS related research: (i) Fire danger and seasonal forecast; (ii) Fire emissions and haze forecast (including the fire radiative power, smoke and burnt area detection, global forecast and regional downscaling); (iii) Observations and data production for verification and assimilation; (iv) Links and coordination with GWIS, GFMC and Regional Fire Management Resource Centers.

The first research phase of the system was launched in 2018. This paper provides a description of two examples of the most established research and advanced development stage: in Singapore, where regional models are being run and forecasts from various centers are being collated to produce multi-model ensemble smoke forecasts for the Southeast Asia region, and ECCC in Canada,

where a demonstration VFSP-WAS center for North America is being established. These examples are recommended as prototypes for Regional VFSP-WACs.

Successfully linking research to services and building close partnership between regional VFSP-WACs and end-users in order to deliver timely fit-for-purpose information requires collaboration and co-design. It is particularly important to link Regional VFSP-WAS with the communities of policy makers, practitioners and civil society.

In 2010, the Global Fire Monitoring Center (GFMC) initiated a process to build thematic centers of excellence in various regions of the world. The mandate and services of "Regional Fire Monitoring Centers" (RFMCs)/Regional Management Resource Centers" (RFMRCs) includes advisory support to nations and to the regional organizations in:

- development and implementation of cross-sectoral landscape fire management policies;
- support of participating countries of the region to develop informal or formal agreements/protocols for cross-boundary cooperation in fire management, including mutual emergency assistance;
- capacitation of state institutions in integrated landscape fire management at national level, based on principles of transdisciplinary innovation, integration, coherence, cohesiveness and interagency coordination;
- involvement of civil society (community-based fire management);
- integrated and nature-based fire management solutions.

The following Regional Fire Monitoring/Fire Management Resource Centers are available for coordination and collaboration with VFSP-WAS:

- Regional Fire Monitoring Center: Southeast Europe/Caucasus Region (RFMC) (Skopje, Republic of North Macedonia);
- Eastern Europe Regional Fire Monitoring Center (REEFMC) (Kyiv, Ukraine);
- Regional Fire Management Resource Center in Central Asia (RFMRC-CAR) (Ulaanbaatar, Mongolia);
- Regional Fire Management Resource Center in South East Asia (RFMRC-SEA) (Bogor, Indonesia);
- Regional Central Eurasia Fire Monitoring Center and Russia (Krasnoyarsk, Russia).

Regional Fire Management Resource Centers in South America (RFMRC-SAR), Eastern Subsahara Africa (Madagascar) and Eastern Asia (Harbin, P.R. China) are currently being planned. These centers will allow to bring the VFSP-WAS service to the target groups that need to receive the information generated by VFSP-WAS.

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Bridging the Services of the WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System (VFSP-WAS) to Politics, Policies and Land Management: the South East Asia Example and Global Visions

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ABSTRACT – The use of fire in land management and land-use change and wildfires affecting forests and peatlands in South East Asia constitute a major threat to the environment and society. Fire applied in land-use change contributes to a net increase of radiatively active trace gases (greenhouse gases) in the atmosphere, thus constituting a major anthropogenic contribution to microclimate change. Close-to-ground air pollution results in serious threats to human health and security. In addition, land-use fires and wildfires affect fire sensitive ecosystems such as equatorial tropical rainforests and peatland biomes where they have detrimental impacts on ecosystem processes, biodiversity and livelihood of indigenous populations. Sustainable management of these ecosystems, which are vulnerable to excessive modification by humans and to fire must be based on the field experienced, because single factor management could not work alone as Indonesia is looking for the permanent solutions. The Regional Fire Management Resource Center – South East Asia/RFMRC-SEA provides the bridge from the services of the planned WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System/VFSP-WAS to the development of sustainable land and fire management policies and management practices.

Keywords: Peat fire; Indonesia; policy; greenhouse gases; Regional Fire Management Resource Center-Southeast Asia.

Integrando os Serviços do Sistema de Consulta e Alerta de Poluição Causada pela Fumaça Decorrente do Fogo na Vegetação da Organização Meteorológica Mundial (VFSP-WAS-WMO) nas Políticas Públicas e Estratégias de Gestão Territorial: o Exemplo do Sudeste Asiático e Visões Globais

RESUMO – O fogo como ferramenta no uso e na mudança do uso da terra, e os incêndios florestais que afetam as áreas de floresta e de turfa no sudeste asiático constituem uma grande ameaça ao meio ambiente e à sociedade. O fogo utilizado na mudança do uso da terra contribui para um aumento líquido de gases traço ativos radioativamente (gases de efeito estufa) na atmosfera, constituindo assim uma importante contribuição antropogênica para a mudança do microclima. A poluição do ar próxima ao solo resulta em sérias ameaças à saúde e segurança humanas. Além disso, a aplicação do fogo no uso da terra e os incêndios florestais afetam ecossistemas sensíveis ao fogo, como florestas tropicais equatoriais e turfeiras, onde têm impactos prejudiciais sobre os processos do ecossistema, a biodiversidade e a subsistência das populações indígenas. Considerando que a Indonésia está buscando soluções permanentes, o manejo sustentável desses ecossistemas, que são vulneráveis às excessivas modificações antropogênicas e ao fogo, deve basear-se na experiência de campo, uma vez que o manejo de um fator único poderia não funcionar sozinho. O *Regional Fire Management Resource Center – South East Asia/RFMRC-SEA* estabelece a conexão entre os serviços do *WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System/VFSP-WAS* para o desenvolvimento de políticas públicas sustentáveis de manejo do solo, manejo do fogo e práticas de gestão.

Palavras-chave: Fogo de turfa; Indonésia; políticas públicas; gases de efeito estufa; Fire Management Resource Center-Southeast Asia.

Integrando los Servicios del Sistema de Consulta y Alerta de Contaminación por Incendios de Vegetación y Humo de la Organización Meteorológica Mundial (VFSP-WAS-WMO) en las Políticas Públicas y Estrategias de Gestión Territorial: el Ejemplo del Sureste Asiático y Enfoques Globales

RESUMEN – El fuego como herramienta para el uso de la tierra y el cambio de uso de la tierra, así como los incendios forestales que afectan las áreas de bosques y turberas en el sudeste asiático representan una gran amenaza para el medio ambiente y la sociedad. El fuego aplicado en el cambio de uso de la tierra contribuye a un aumento neto de gases traza radiactivamente activos (gases de efecto invernadero) en la atmósfera, lo que constituye una importante contribución antropogénica al cambio del microclima. La contaminación del aire cerca del suelo resulta en serias amenazas para la salud y la seguridad humanas. Además de eso, el fuego como herramienta para el uso de la tierra y los incendios forestales afectan los ecosistemas sensibles al fuego, como los bosques tropicales ecuatoriales y las turberas, donde tienen impactos perjudiciales en los procesos de los ecosistemas, la biodiversidad y los medios de vida de las poblaciones indígenas. Teniendo en cuenta que Indonesia está buscando soluciones permanentes, el manejo sostenible de estos ecosistemas, que son vulnerables a cambios antropogénicos excesivos y al fuego, debe basarse en la experiencia de campo, ya que la gestión de un solo factor podría no funcionar por sí sola. El *Regional Fire Management Resource Center – South East Asia/RFMRC-SEA* establece el puente entre los servicios del *WMO Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System/VFSP-WAS* para el desarrollo de políticas públicas sostenibles de manejo de la tierra, manejo del fuego y prácticas de gestión.

Palabras clave: Fuego de turba; Indonesia; políticas públicas; gases de efecto invernadero; Fire Management Resource Center-Southeast Asia.

Introduction

Transboundary haze pollution due to the smoke from using fire in land preparation has continued to be a big problem in Indonesia every year, especially during the dry season. It has been found that most of the smoke originates from illegal use of fire in converting native vegetation – forests and peatlands – to oil palm and industrial forest plantations (60%-80% of all fires). The traditional use of fire in shifting cultivation, which constitutes a minor share of all burning activities, is usually blamed for the smoke pollution (Saharjo, 2017). Planned and unplanned peat fires are the main source of local and regional smoke pollution.

Fires in Indonesia have consequences from local to regional scale, including burning forest that is home to endemic and endangered flora and fauna, emitting smoke that compromises human health and impacts economies across the region, and converting peatlands from a major carbon sink to a major source of CO_2. Identifying the sources of fire ignitions and Land Use and Land Cover/LULC classes associated with fire ignitions is a key factor for reducing fire on this landscape, as this will allow us to more pointedly target management and policy interventions (Cattaua *et al*., 2016).

Ignitions in Indonesia, as in many parts of the tropics, are primarily of anthropogenic origin (Bompard & Guizol, 1999; Bowen *et al*., 2000), resulting from either accidental or deliberate fires. The human contribution to changing fire regimes and our capacity to manage fire remains somewhat uncertain (Bowman *et al*., 2009, 2011). Thus, a key component to understand changing fire regimes in the tropics is to identify the sources of fire ignitions and the land use/land cover (LULC) classes associated with fire ignitions (Cattaua *et al*., 2016).

In 2015, forest and land fires burned about 2.6 million ha in Indonesia and released about 1.74 Gt CO_2e. Under the Business as Usual/BAU scenario, these emissions were roughly 60% of the 2030 target (2.88 Gt CO_2e) of Indonesia's Intended Nationally Determined Contribution (INDC). Fire prevention activities have, therefore, become critical for Indonesia to achieve its 29% GHG emissions reduction goal by 2030 (NPA *et al*., 2017).

The strategic choices for suppressing wildfires and carrying out prescribed burning largely depend on how fires are expected to behave, *i.e.* rates of the spread, direction of travel, intensity and severity (Saharjo, 2016). The aspects of fire behaviour that are pre-requisites for the start and spread of fire are flammable fuels, sufficient heat energy to bring fuels to the ignition temperature and adequate oxygen concentrations (Lorimer, 1990). Fire

behavor is determined by a number of interacting factors such as fuels, weather, topography as well as seasonal changes, time of day (Lorimer, 1990) and vegetation (Silviana *et al*., 2019a).

Fire suppression efforts, lost timber and crop resources, missed workdays, and travel disruptions incur high economic costs (Tacconi, 2003; Ruitenbeek, 1999). It is estimated that Indonesia lost US$20.1 billion during the 1997/98 fire season alone (Varma, 2003). Prior to 2015, both national and international policies have been implemented in attempts to reduce fire in Indonesia prior to the 2015 (*e.g.*, ASEAN Agreement on Transboundary Haze Pollution, Singapore's Transboundary Haze Pollution Act, and Indonesia's national law [Act n. 41/1999]) banning corporations from using fire to clear land for palm-oil plantations), but with limited success (Cattaua *et al*., 2016). Given the variety and severity of the consequences from tropical peatland fires, particularly those in Indonesia, it is of global interest to understand this changing disturbance regime and reduce fire occurrence (Harrison *et al*., 2009).

Forest and land fire significantly affect the quantity and quality of natural resources and ecosystems by reducing the diversity of flora and fauna, decreasing soil quality, changing hydrological functions and contributing to climate change (Goldammer 1991, 1993, 1999, 2006; Goldammer & Seibert, 1990). A further dimension is the sensitive political aspects of transboundary smoke pollution from fires which not only disrupt the Indonesian environment but also conditions in neighbouring countries (Saharjo, 2016; Wasis, 2018).

Forest fires and peatland fires

Who is responsible for fire ignitions in Indonesia is highly contested, and reports of ignition sources are many and varied (Dennis *et al*., 2005; Page *et al*., 2013), often resulting in a chain of finger pointing. Although some large holders clear land mechanically, most land in Indonesia is cleared using fire (Stolle *et al*., 2003). Because fires set for clearing can 'escape' beyond their intended boundaries, both large and small holders have been held responsible (Stolle *et al*., 2003; Page *et al*., 2006, 2013), as is often the case in rainforest fires more generally (Goldammer, 1991). Burning to clear land has been the traditional practice of smallholders and indigenous groups, and there is some evidence that smallholders' use of fire has historically been relatively small-scale and well-managed (Tomich *et al*., 1998; Bowen *et al*., 2000).

However, this is likely not the case today. The scale of land clearing using fire has expanded substantially, with increased use of burning by both smallholders and larger-scale rubber and oil palm concessions (Brauer & Hisham-Hashim, 1998; Potter & Lee, 1998; Stolle *et al*., 2003). Originally, the Indonesian government blamed smallholder shifting cultivators for widespread fires, but later publically claimed that it was more likely larger-scale companies opening land on commercial plantations for palm oil, pulpwood, and timber, some of which was promoted by government policies themselves (Brown, 1998; Page *et al*., 2013).

Drainage of peatlands has resulted in very dry conditions when rainfall is lacking (*e.g.* dry seasons and droughts) that enable fire to burn across these carbon-rich wetlands. These fires can cause irreversible hydrophobic changes to exposed peat soils that eliminates the peat's ability to store and absorb water (Ritzema, 2007).

Drained peatlands are highly susceptible and frequently subjected to fire, resulting in greenhouse gas emissions (Field *et al*., 2016) and transboundary haze pollution that cause human health problems (Kunii *et al*., 2002; Marlier *et al*., 2013), economic losses (World Bank, 2016) and international tension throughout the region. Fires are started for the purposes of land clearing and claiming, fishing, hunting, cooking and non-timber forest product collection (Sinclair *et al*., 2020). However, in drained, degraded landscapes, these surface fires are often difficult to control or properly extinguish, and can escalate into wildfires and persistent smouldering peat fires. Drainage also stimulates biological oxidation of peat in the upper peat profile, and the resultant greenhouse gas emissions are equal to if not greater than those from fire (Hooijer *et al*., 2014; Miettinen *et al*., 2017).

Fire is also used as an agricultural tool to clear vegetation (Carlson *et al*., 2012; Page *et al*., 2002, 2006). These human disturbances can make peatlands particularly prone to fire. In 2015, 53% of fires in Indonesia occurred on peatland, which made up only 12% of the land area (Miettinen *et al*., 2017).

Burn depth depends on the level of the water table and the water content of the peat, with increased burn depth when the water table is lowered and the peat dries out (Ballhorn *et al*., 2009; Rein *et al*., 2000). Konecny *et al*. (2016) also suggest that burn depth changes based on the frequency of fire, with reduced burn depth for repeat fires at the same location. Information on the spatial and temporal variability of burn depth is limited and current emission inventories make broad assumptions regarding these parameters (Kiely *et al*., 2019).

The different fuel characteristics (size, moisture, bed depth and type) of various levels of peat decomposition (fibric, hemic, sapric) significantly affect fire behavior and the depth of peat destructionResearch has shown that peat with low levels of decomposition (fibric) experiences lower fire spread rates, higher flame heights, and related fire intensity, but less total peat destroyedHigh fire intensities make these fires relatively difficult to control. Among the three peat decomposition types (sapric, hemic, and fibric) that burn, flaming fires in fibric peat is the most difficult to control but smoldering burns in sapric peat will be the most severe (Saharjo, 2006).

When peat forests are disturbed, the peat typically begins to subside (KFCP, 2014). The subsidence rate is correlated, to some extent, with drainage depth (depth of the water table) across a wide range of environmental conditions, suggesting that it may be a useful proxy for the rate of peat decomposition. However, a range of other factors such as vegetation cover and prior fire disturbance also affect subsidence, although their effects are difficult to quantify. Couwenberg *et al*. (2009), in their survey of the literature, found a linear relationship between subsidence rate and water depth for Southeast Asian tropical peat soils, with subsidence increasing by ~0.9cm yr-1 for each 10cm of additional drainage depth. This is substantially more than in other parts of the world (Hooijer *et al*., 2006; Couwenberg *et al*., 2009).

Peat destruction due to heat penetration depends on how much fuel is present and peat characteristics, especially moisture content (Saharjo & Munoz, 2005). Peat destruction was prevented through high peat moisture content resulting from the water from the canal surrounding the burn area. Another important factor is the drying process, which determines smoke production during burning and the time needed for burning available fuels. In order to let the fire spread naturally and minimize peat destruction, it is recommended to leave only small diameter (< 5cm) branches for burning and to make sure that materials are dried to no more than 10% moisture content. Without these changes, it is difficult to say that land preparation can be done with less impact (Saharjo & Munoz, 2005).

Peat fire emissions

GHG emissions from fires that burn above-ground fuels are reasonably well understood, but are very different in character to peat fires that are very poorly understood (KFCP, 2014). Smouldering peat fires produce more CO relative to CO_2, and there can be significant loss of C as other volatile compounds. In an excellent study in which the smouldering of blocks of peat was realistically achieved under a range of moisture contents, Rein *et al*. (2009) found that only 60% of the C in combusted peat was emitted as $CO+CO_2$ (*i.e.* there were emissions of many other volatile C compounds). This contrasts with about 95% of combusted C released as CO_2+CO for surface fires.

Peat fires in Southeast Asia, and Indonesia in particular, are consequently a major cause of smog and particulate air pollution (Hayasaka *et al*., 2014; Reddington *et al*., 2014), with consequences for human health (Schwela *et al*., 1999, Goh *et al*., 1999; Kunii *et al*., 2002; Marlier *et al*., 2013; Wooster *et al*., 2012) and local blocking of sunlight that can suppress plant photosynthesis (Davies & Unam, 1999). In addition, peatland fires are responsible for forest habitat loss and degradation of flora and fauna, including those in marine systems (Jaafar & Loh, 2014; Posa *et al*., 2011; Yule, 2010).

Page *et al*. (2002) reported that during four months (July – October), the 1997 peat fire in Indonesia emitted about 0.81 to 2.57 gigatons (Gt) carbon to the atmosphere which was higher than that calculated for the 2015 peat fires (Harris *et al*., 2015). The reasons for this discrepancy was that the 1997 peat fire burned much larger area of peatlands (about 6.8 million ha), and the same emission factors were used for Sumatra, Kalimantan and Papua peat fires.

In 2015, the increase in emissions above baseline was mainly due to large amounts of

emissions from peat fires during droughts caused by the El Niño event that resulted in huge fires throughout the country (Sugardiman, 2018). The total area of peatlands affected by fire was 869,754ha, with emissions of about 549.4 million t CO_2e. Deforestation also increased above the baseline rate, *i.e.* up to 1.09 million ha. In 2016, implementation of fire prevention programmes and efforts to avoid deforestation helped to reduce emissions, with only 97,787ha of peat fires and just 0.63 million ha of deforestation (Sugardiman, 2018). Overall, this sector was able to reduce emissions by approximately 132.256 million t CO_2e in 2016.

Indonesia contains large areas of peatland that have been drained and cleared of natural vegetation, making them susceptible to burning (Kiely *et al.*, 2019). Peat fires emit considerable amounts of carbon dioxide, particulate matter (PM) and other trace gases, contributing to microclimate change and causing regional air pollution. However, emissions from peat fires are uncertain, due to uncertainties in emission factors and fuel consumption (Kiely *et al.*, 2019).

Peat characteristics vary greatly spatially due to differences in vegetation and variation in environmental factors that affect peat formation. Stocks of C and N in peat, by depth, represent the starting point for estimating GHG emissions following disturbance (e.g. drainage, or combustion by fire). There is a critical need for a better, finer-scale mapping of peat C and N stocks by depth to which the areas and nature of disturbance (*e.g.* depth of drainage, depth of peat burned in fire) can be linked (KFCP, 2014).

The depth of peat burn is a crucial factor controlling emissions from peat fires but it is poorly constrained. Using satellite remotely sensed surface soil moistures to control the assumed depth of peat burn improves simulations of particulate matter (PM) emissions. However, there is little data available on the relationship between surface soil moisture and burn depth, more work on this could lead to further simulation improvement. Work is also needed to examine whether this is consistent for years other than 2015 (Kiely *et al.*, 2019).

The same authors estimated that peat burning contributed 71% of total primary PM 2.5 emissions from fires in Indonesia during September–October 2015. Using satellite-retrieved surface soil moisture to modify the assumed depth of peat burn improved the correlation between simulated and observed PM emissions from 0.48 to 0.56. Overall, it is suggested that peat fires in Indonesia produce substantially higher PM emissions than estimated in current emission inventories. Indonesia contains 36% of the world's tropical peatland (Kiely *et al.*, 2019), the largest of any country in the tropics (Dargie *et al.*, 2017; Page *et al.*, 2013). Undisturbed peatlands typically have high moisture content, making them naturally resilient to fire (Wösten *et al.*, 2008). Indonesian peatlands are experiencing deforestation and conversion to agriculture, oil palm and timber plantations (Hansen *et al.*, 2013; Gaveau *et al.*, 2014; Miettinen *et al.*, 2017). During this conversion, drainage canals are installed, lowering the water table and making the peatland more susceptible to burning (Konecny *et al.*, 2016).

Fires on peatland can burn into these underground organic layers and smoulder for weeks after surface fires have gone out (Roulston *et al.*, 2018), resulting in substantially greater emissions compared to surface vegetation fires (Heil *et al.*, 2006). Peat fires are estimated to contribute 3.7% of global fire carbon emissions (van der Werf *et al.*, 2017). In Indonesia, peatland fires are the largest contributor to fire emissions in the region (Reddington *et al.*, 2014; van der Werf *et al.*, 2010). For the 2015 fires, Wooster et al. (2018) found that 95% of the particulate matter (PM2.5) emissions came from peatland fires.

Kiely *et al.* (2019) found that emissions from peat combustion make up a substantial fraction of total fire emissions from the region. Estimated peat combustion contributed 55% of total CO_2 emissions and 71% of primary PM2.5 emissions during September–October 2015. Peat combustion contributed 76% of fire-derived surface PM2.5 concentrations over Sumatra and Borneo during this period. This highlights the importance of peat fires and the need for better estimates of emissions from peat combustion.

Peat restoration as part of the solution

During 2014, in order to save peatlands from destruction and increase future productivity, the government launched Government Regulation n.71, which provides important tools for protecting peat from fire. Regulation n.71 states that the ground water level (GWL) of 0.40m below the

peat surface is a critical point that should not be exceeded. This groundwater threshold level was based on scientific evidence of more than 30 years of dedicated research.

Usup *et al*. (2004), Wösten *et al*. (2008) and Putra & Hayaska (2011) have suggested the critical ground water level of 40cm below peat surface should not be breached in order to prevent destructive peat fires. However, field findings suggest that shallower GWL below peat surface should be maintained to prevent peat fire occurrences in dry-degraded peatlands (Putra *et al*., 2016). Fires were found to occur during GWL conditions between 15 and 30cm below the peat surface, such as in February 2011 (-30cm), March 2011 (-16cm) and December 2011 (-17cm). Most of the fires occurred with shallow GWL conditions of 25 – 30cm below the peat surface, but fire occurrences with GWL of less than 5cm below peat surface strongly suggest that degraded peatlands are very vulnerable to fires even under relatively moist conditions. Therefore, degraded peatlands should be maintained in wet conditions, critical GWL less than 5cm below peat surface, to prevent surface peatfires. Dry conditions of degraded peatlands create suitable conditions for fires to burn downward and ignite deeper peat layers, resulting in devastating conditions with emissions in the area (Putra *et al*., 2016).

Given development of global climate policy and the high emissions associated with drained organic soils, it has been argued that rewetting and restoration of these soils should be included in mitigation strategies (Joosten *et al*., 2012; IPCC, 2014). Rewetting is the deliberate action of raising water tables in soils that have previously been drained for forestry, agriculture (crop production and grazing), water supply, peat extraction and other human-related activities, in order to re-establish and maintain water saturated conditions, *e.g*. by blocking drainage ditches, construction of dams or disabling drainage pump facilities. Rewetting can have several objectives such as nature conservation, GHG emission reductions and the promotion of leisure activities or paludiculture on saturated organic soils (Wilson *et al*., 2016a).

Research conducted by Putra *et al*. (2018) in the ex-MRP showed that most fires in the study area occurred with GWL conditions of 30 to 39cm below the peat surface, but that fire occurrences with GWL of less than 10cm below peat surface indicate that degraded peatlands are very vulnerable to fires even under relatively moist conditions. Therefore, degraded peatlands should be maintained in wet conditions with critical GWL of less than 5cm to prevent surface peat fires from occurring.

Putra *et al*. (2018) showed that degraded peatlands lose their capacity to absorb and retain water from rainwater droplets, keeping them in drier than natural conditions for most of the year, and therefore are very vulnerable to fire. Rising Niño 3.4 STT anomalies predict significant fire risk that might yield large fire occurrences. Time lags between the low precipitation levels and resulting drops in GWL may also provide some abilities to predict fire risk in advance. Were proposed the critical GWL of less than 5cm below peat surface to prevent degraded peatlands from experiencing surface peat fires that may escalate to becoming devastating deep peat fires (Putra *et al*., 2018).

Groundwater level (> 40cm) can be used as an early warning system for risk of forest and land fire dangers (Silviana *et al*., 2019b) because peatland fire occurren is preceded by low water levels in peatlands. During the dry season, rainfall amounts are lower and GWLs drop, making peatlands very dry and prone to burning. This is especially true during extreme weather conditions and drought during El Niño years (Silviana et al., 2019a, 2019b). The highest level of fire risk based on GWL > 40cm (danger category) is 99.63% in March, making this region very vulnerable to forest fires. GHG fluxes in rewetted organic soils are controlled by a wide range of external and internal factors, which include the prevailing climate, nutrient status, water table position, previous land use history, time since rewetting, absence or presence of vegetation and vegetation composition (Wilson *et al*., 2016b).

However, there are currently active restoration efforts underway. Based on our field experience, these efforts, much like local fire teams, are effective but small-scale and underfunded. Indonesia has recently established a Peatland Restoration Agency with the goal of preventing peatland fires and restoring about 2 million ha of fire-damaged peatland across the nation. Although specific spatially-explicit target areas have not yet been identified, this agency could make peatland restoration more feasible by providing funding and capacity beyond that currently available in the region (Cattaua *et al*., 2016).

Research clearly shows that regrowth of secondary peat swamp forest will benefit from these mitigation activities. Canal blocking results in a better environment for vegetation to grow up naturally through succession and increasing surface water levels during more of the year could help peat formation and retention. Aboveground biomass increases significantly in such areas compared to secondary peat swamp forest areas that are repeatedly burned (Saharjo *et al*., 2011).

Rewetting of organic soils results in a decrease in CO_2 and N_2O emissions as well as DOC losses and overall GHG emissions, calculated based on global warming potentials; but total CH_4 emissions are increased. Ultimately, carbon sequestration can be achieved by avoiding drainage of organic or peaty soils that are known to contain high densities of carbon, or by re-establishing high water tables in disturbed areas (Freibauer *et al*., 2004).

A study carried out in Pelalawan, Indragiri Hulu and Indragiri Hilir, Riau Province, revealed that it is difficult for farmers to follow the Government's zero-burning policy on peatland (Rohadi, 2017). As a result, a number of landowners decided to leave their farms as their harvests could not compensate for the high production cost of land preparation (Murniati & Suharti, 2018). To resolve the problem, Rohadi (2017) suggested that there should be a flexible approach in the implementation of zero-burning policy on peatland so as not to harm small farmers in the long run. Genuine farmers should be allowed to implement controlled land burning. Traditional community wisdom makes it possible to apply the technique with the guidance of government officials in the field. Furthermore, as compensation for the farmers' efforts in applying "zero burning" in land preparation, adequate incentives should be provided (Murniati & Suharti, 2018). Agustira & Ranola (2017) also stated that there is a need to provide incentives for smallholder farmers in implementation of sustainable oil palm plantations on peatland since the current situation of plantations in Siak District, Riau Province leads to greater social cost than social benefit.

Conclusions

Data and information taken from field research is really important and needed for better fire prevention management, reducing emissions of GHGs from peat fires, and bridging of policies and government regulations. Policies to be enacted by governments and subsequent implementation action and law enforcement need to be based in the scientific evidence gained in field research.

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Investigación Criminal de Incendios Forestales: la Participación de INTERPOL en la Armonización de los Procedimientos

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RESUMEN – Desde la perspectiva de la lucha contra la emergencia, los incendios forestales siempre han recibido una atención preferente por parte de los gestores medioambientales basada en la extinción y la prevención de actividades de riesgo. Sin embargo, quizá por estar fuera de su ámbito habitual de trabajo y por la complejidad y el consumo de recursos altamente especializados que entraña, esos gestores medioambientales han obviado históricamente en muchos lugares del planeta la investigación criminal de los autores. La aceleración de los procesos de cambio climático, sin embargo, está colocando la investigación criminal de los incendios forestales como una necesidad creciente en algunos de esos países, por lo que resulta cada vez más necesaria la creación de estructuras capaces de dar respuesta a esas necesidades, no sólo para poder conocer más en profundidad las motivaciones que dan lugar a los incendios, de forma que se puedan establecer medidas de prevención eficaces, sino también para la persecución por parte de la Justicia y las agencias de aplicación de la Ley de conductas contempladas como delito en la normativa penal de la inmensa mayoría de los países del planeta, ya sea de manera específica como delito de incendio forestal o como delito de incendio genérico. En ese sentido, para tratar de paliar la dificultad de contar con herramientas de formación a nivel internacional, se describen en este estudio los esfuerzos que INTERPOL está desarrollando en los últimos dos años para contribuir a armonizar y potenciar los procesos de investigación criminal de incendios forestales a nivel mundial.

Palabras clave: Incendios forestales; delitos forestales; investigación criminal transnacional; armonización de procedimientos; INTERPOL.

Investigação Criminal de Incêndios Florestais: Participação da INTERPOL na Harmonização de Procedimentos

RESUMO – A partir da perspectiva de combate a emergências, os incêndios florestais sempre receberam atenção preferencial dos gestores ambientais, baseada na extinção e prevenção de atividades de risco. Entretanto, talvez por estar fora do seu escopo normal de trabalho e devido à complexidade de procedimentos e à necessidade de recursos altamente especializados que acarreta, esses gestores ambientais têm historicamente dedicado atenção insuficiente à investigação criminal dos infratores em muitas partes do mundo. Por outro lado, a aceleração dos processos de mudança climática vem colocando a investigação criminal de incêndios florestais como uma necessidade crescente em alguns países, tornando cada vez mais importante a criação de estruturas capazes de responder a essas investigações. Não apenas com o objetivo de conhecer em maior profundidade as motivações que originam os incêndios, para que se possam estabelecer medidas preventivas eficazes, mas também para aperfeiçoar os processos de julgamento pelos órgãos de justiça e agências de fiscalização das condutas previstas como crime na regulamentação penal da grande maioria dos países do planeta, seja especificamente como crime de incêndio florestal ou como crime genérico de incêndio. Nesse sentido, são descritos neste estudo os esforços que a INTERPOL tem desenvolvido nos últimos dois anos a fim de contribuir para a harmonização e o aprimoramento dos processos de investigação criminal em todo o mundo, além de auxiliar na mitigação das dificuldades de contar com ferramentas de capacitação em nível internacional.

Palavras-chave: Incêndios florestais; delitos florestais; investigação criminal transnacional; harmonização de procedimentos; INTERPOL.

Forest Fire Criminal Investigation: INTERPOL's Participation in the Harmonization of Procedures

ABSTRACT – From the perspective of fighting the emergency, forest fires have always received preferential attention from environmental managers based on extinction and the prevention of risky activities. However, perhaps due to being outside their normal work environment and due to the complexity of procedures and the need of highly specialized resources required, these environmental managers have historically paid insufficient attention to the criminal investigation of perpetrators in many places on the globe. The acceleration of climate change processes, however, is placing criminal investigation of forest fires as a growing need in some of these countries, making it increasingly necessary to create structures capable of responding to these needs, not only to be able to know in more depth the motivations that give rise to the fires, so that effective prevention measures can be established, but also for the prosecution by the Justice and Law enforcement Agencies of conducts contemplated as a crime in criminal regulations of the vast majority of countries on the planet, either specifically as a crime of forest fire or as a crime of generic fire. In this regards, the efforts that INTERPOL has been developing in the last two years to contribute to harmonizing and promoting criminal investigation processes worldwide, and also to try to alleviate the difficulty of having training tools at an international level, are described in this study.

Keywords: Forest fires; transnational criminal investigation; harmonization of procedures; INTERPOL.

De acuerdo con las estimaciones de la Organización para la Agricultura y la Alimentación (FAO) de las Naciones Unidas, los incendios forestales suponen anualmente la destrucción de aproximadamente 350 millones de hectáreas de terreno forestal, equivalente a 5130 millones de toneladas de combustible vegetal quemado, lo que tendría su reflejo también en unas emisiones a la atmósfera equivalentes a 8201 millones de toneladas de CO_2.

En concreto, la destrucción de las masas forestales tiene un impacto directo e inmediato fundamentalmente sobre las comunidades locales, en algunos casos siendo ese impacto positivo desde una perspectiva muy local (incremento de productividad del terreno, ampliación de tierras disponibles para cultivo o ganadería, entre otros) y en otros destruyendo vidas y medios de subsistencia de esas comunidades locales con un perjuicio absoluto cuando las mismas no son las beneficiarias de las nuevas rentas generadas.

Por su parte, la segunda consecuencia más trascendente de los incendios forestales, esto es, la emisión de un volumen inmenso de gases de efecto invernadero, tendría un efecto pernicioso sobre el ser humano de forma indirecta y a largo plazo, pero con consecuencias de nivel planetario.

En cualquier caso, hay una componente derivada de los incendios forestales que raramente ha recibido una atención destacada por parte de los gestores forestales nacionales o las organizaciones internacionales. Nos estamos refiriendo a la dimensión criminal de un número muy elevado de los incendios forestales que derivan en esas devastadoras consecuencias.

Resulta evidente que, salvo un puñado de excepciones, la problemática derivada de los incendios forestales no tiene una dimensión transnacional, sino que cada país afronta generalmente de manera individual el diseño de las estrategias de lucha contra este fenómeno. Pese a ello, es cierto que existen diversos foros internacionales de intercambio de experiencia en este ámbito.

Sin embargo, esos foros de intercambio siempre han estado enfocados fundamentalmente a la gestión de la emergencia y al desarrollo de metodologías comunes de dirección y empleo de medios de extinción, muchas veces con vistas a una posible integración de equipos extranjeros en los dispositivos nacionales de extinción en caso necesario. Ese apoyo se viene prestando generalmente entre países con dispositivos homogéneos en cuanto a experiencia y normativa o bien por parte de países con mayor experiencia y cualificación que apoyan a países con deficiencias estructurales para luchar contra un fenómeno de relevancia creciente en sus territorios derivada del cambio climático. Por el contrario, hasta la fecha, muy pocos eventos de ámbito internacional han prestado atención a la mejora de capacidades o la armonización de procedimientos para la investigación criminal de los incendios forestales.

En ese sentido, desde la creación del Programa de Seguridad Medioambiental de INTERPOL, coincidiendo con el día mundial del medio ambiente (5 de junio) de 2010, la lucha contra los fenómenos delictuales que contribuyen a la deforestación ilegal, máxime en aquellos ámbitos con impacto global, como sucede en el caso de los incendios forestales criminales, ha sido una de las principales razones de ser de ese Programa. Tanto es así, que dos años más tarde, en junio de 2012, se creó en el seno de INTERPOL el primer Proyecto específico de lucha contra la deforestación y el comercio ilegal de madera.

Desde el mismo momento de su creación, el Proyecto LEAF (*Law Enforcement Assistance for Forests* – Asistencia a las Agencias de Aplicación de la Ley para los Bosques) integró la perspectiva de la investigación criminal de los incendios forestales en una buena parte de sus actividades. Sin embargo, no fue hasta mediados de 2018 cuando el Equipo Global de Delitos Forestales de INTERPOL asumió decididamente el liderazgo a nivel internacional en la tarea de homogeneización de los procedimientos y cualificaciones en la investigación criminal mediante el desarrollo de una serie de iniciativas propias o la participación en otras diseñadas por alguno de sus países miembros u organizaciones asociadas.

Esas iniciativas, por orden cronológico, son las siguientes:

Panel de Expertos en Incendios Forestales durante la reunión del Grupo de Trabajo de Delitos Forestales – Lyon (Francia), septiembre de 2018.

El Grupo de Trabajo de Delitos Forestales reúne a los especialistas más destacados en delitos forestales de las agencias de aplicación de la ley a nivel mundial y, además de servir para el intercambio de información y experiencia de forma directa, constituye un panel asesor externo que proporciona a la Secretaría General de INTERPOL información útil y actualizada en cuanto a las nuevas tendencias criminales en el sector.

Ante la relevancia de la investigación de los incendios forestales que había sido puesta de manifiesto en anteriores sesiones de ese Grupo de Trabajo, durante la última reunión del mismo (2018) se diseñó un panel específico con la participación como ponentes de especialistas de INTERPOL, Italia y Chile y con la asistencia de alrededor de 188 investigadores de 54 países de todo el mundo.

Colaboración en capacitación de la Policía de Investigaciones de Chile – Santiago de Chile (Chile), noviembre de 2018.

En este caso, la Secretaría General de INTERPOL colaboró en una actividad de ámbito exclusivamente nacional mediante la aportación de un experto de su Programa de Seguridad medioambiental.

En concreto, ese experto contribuyó a la formación de alrededor de 40 oficiales de la Policía de Investigaciones de Chile (PDI) a lo largo de una de las cinco jornadas completas de las que constaba ese curso específico de investigación criminal de incendios forestales.

Participación en el seminario internacional EMPACT – Castel Volturno (Italia), junio de 2019.

En esta actividad, dirigida por el Arma de Carabinieri de Italia en el marco de un proyecto europeo de lucha contra el crimen del que la Secretaría General de INTERPOL es socia, su Programa de Seguridad Medioambiental aportó un especialista propio, así como hizo posible la participación también de especialistas de Indonesia y Chile.

Capacitación para la Policía Federal Argentina – Buenos Aires (Argentina), septiembre de 2019.

De manera similar a la formación desarrollada para la Policía de Investigaciones de Chile, un especialista de INTERPOL participó en una actividad formativa para miembros de la División de Bomberos de la Policía Federal Argentina.

En este caso, la formación se prolongó durante una única jornada dirigida por el especialista de INTERPOL.

Conferencia Internacional de INTERPOL sobre Investigación Criminal de Incendios Forestales/WILDFIRE 2019 – Campo Grande (Brasil), octubre de 2019.

Desarrollada como evento paralelo a la 7ª Conferencia Internacional sobre Incendios Forestales-Wildfire 2019, es ésta, sin duda, la actividad dirigida por la Secretaría General de

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INTERPOL, en este caso en colaboración con la Oficina Central Nacional de INTERPOL integrada en la Policía Federal de Brasil, más relevante hasta la fecha en lo que concierne a la investigación criminal de incendios forestales, por lo que, más allá de este párrafo introductorio, se le va a dedicar una atención muy destacada a lo largo del presente relato de experiencia.

Capacitación internacional conjunta INTERPOL/Policía de Investigaciones de Chile – Santiago de Chile (Chile), diciembre de 2019.

Nuevamente en colaboración con la Policía de Investigaciones de Chile, la Secretaría General de INTERPOL coorganizó en diciembre de 2019 una actividad formativa sobre investigación criminal de incendios forestales, en este caso de ámbito internacional, mediante la aportación de un experto de su Programa de Seguridad medioambiental, un experto de la Policía Judiciaria de Portugal y seis alumnos extranjeros. De esos alumnos extranjeros, dos provenían de la vecina Argentina, dos más de Uruguay, uno de Paraguay y una última de México.

Esos seis alumnos y formadores extranjeros compartieron esa capacitación con otros treinta y cinco alumnos locales de la PDI.

En concreto, ese experto contribuyó a la formación de alrededor de 40 oficiales de la Policía de Investigaciones de Chile a lo largo de una de las cinco jornadas completas de las que constaba ese curso específico de investigación criminal de incendios forestales.

Ciclo de Seminarios Virtuales de INTERPOL sobre investigación criminal de incendios forestales - junio de 2020.

Con motivo de las restricciones impuestas para las actividades presenciales derivadas del escenario planteado por la pandemia de COVID-19, con el ánimo de mantener activa a la comunidad de investigadores criminales de incendios forestales, INTERPOL optó por la organización de un ciclo de seminarios virtuales sobre la investigación criminal de incendios forestales.

Inicialmente, estaba previsto que esa iniciativa se desarrollase en 4 jornadas (una por semana) a lo largo del pasado mes de junio. Sin embargo, dada la excelente acogida entre esa comunidad internacional de investigadores criminales y para evitar descartar a algunos de ellos en el proceso de selección de alumnos, se optó por replicar los tres primeros seminarios, diseñados específicamente para alumnos hispanoparlantes y dedicados respectivamente a aportar información desde una perspectiva global el primero, desde una perspectiva mediterránea el segundo y desde una perspectiva sudamericana el tercero, en un segundo día de la semana.

De esa manera, finalmente fueron siete los seminarios impartidos en el Ciclo, dos de ellos impartidos por un especialista de INTERPOL, dos impartidos por un especialista de la Guardia Civil española, otros dos impartidos por un especialista de la Policía de Investigaciones de Chile y el séptimo impartido para la comunidad angloparlante de investigadores conjuntamente por parte de especialistas de INTERPOL y del Servicio Forestal de los Estados Unidos.

Desafortunadamente, a diferencia de lo que sucedió con todas las anteriores, una capacitación internacional conjunta INTERPOL/Policía Federal Argentina similar a la que se desarrolló en diciembre de 2019 en Santiago de Chile y que debió haberse desarrollado en Buenos Aires (Argentina) el pasado mes de junio, hubo de ser suspendida sin nueva fecha con motivo de los efectos que el SARS-CoV-2 está teniendo en ese país.

En cualquier caso, la Secretaría General de INTERPOL es consciente de que la formación más útil para mejorar las capacidades de la comunidad internacional de investigadores de incendios forestales y, como consecuencia, los resultados de las investigaciones es, sin duda, aquella que se desarrolla de manera presencial y en convivencia con otros formadores más experimentados, por lo que, una vez recuperada la normalidad con respecto a la pandemia, la prioridad de su Programa de Seguridad Medioambiental volverá a ser el desarrollo de iniciativas similares a la Conferencia Internacional de INTERPOL sobre Investigación Criminal de Incendios Forestales desarrollada en la Conferencia Wildfire (2019) en Campo Grande (Brasil).

Con respecto a la misma, el objetivo que buscó INTERPOL con su organización como evento paralelo a la 7ª Conferencia Internacional sobre Incendios Forestales-Wildfire 2019 era, no solo reunir a un número significativo de investigadores criminales de algunos de los principales países afectados por los incendios

Bosque primario arrasado por un incendio. INTERPOL.

forestales, sino también dar visibilidad a la labor que desarrollan esos investigadores entre el colectivo de gestores de emergencias por incendios forestales y viceversa. De esta forma, se pretende ir creando una conciencia global de las sinergias que genera la integración de la investigación criminal en la lucha global contra los incendios forestales, de forma que se pueda desarrollar una mejor gestión forestal a medio plazo por parte de los gestores de emergencias por incendios basada en información fiable procedente de las investigaciones criminales a la par que se garantiza que los investigadores criminales cuentan a corto plazo con el apoyo y la información de una fuente tan enriquecedora como supone el personal de los servicios forestales.

En concreto, la Secretaría General de INTERPOL seleccionó inicialmente a 23 expertos internacionales para participar en su actividad. No obstante, desde un primer momento se barajó la posibilidad de incorporar a las sesiones a representantes de organizaciones gubernamentales con los que los investigadores criminales de incendios forestales han de convivir habitualmente, de forma que estos últimos tomasen consciencia de la realidad de la labor policial. En ese sentido, finalmente fueron más de 70 los participantes en cada una de las dos jornadas de duración de la Conferencia Internacional de INTERPOL. Debido a la limitada capacidad de la sala, más de 100 solicitudes de participación debieron ser rechazadas.

A lo largo de esas dos jornadas y tomando como base las exposiciones desarrolladas por los expertos, se puso de manifiesto la importancia de la labor del colectivo de investigadores criminales para los gestores forestales y viceversa. Tanto es así, que existe un colectivo tradicionalmente englobado en las estructuras forestales de sus respectivos países, pero que en algunos casos cuenta incluso con soporte legal para la investigación criminal y cuya labor, en muchos casos, es determinante para el esclarecimiento de las causas que dan origen a los incendios forestales, así como para la identificación posterior de sus autores. Esa figura de guardaparque, agente forestal o denominación equivalente en función del país (en Brasil, ese personal sería perteneciente al Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis/IBAMA y al Instituto Chico Mendes de Conservação da Biodiversidade/ICMBio, así como a sus equivalentes estatales) puede y debe ser aprovechada por el investigador criminal, si es que ese rol no lo ostenta ya el propio guardaparque,

integrándolo en el equipo investigador para que aporte su experiencia en el conocimiento del comportamiento del fuego, así como su conocimiento de la conflictividad social local.

Esta integración resulta tanto más importante cuanto más escasa sea la comunidad nacional de investigadores criminales, dado que la distancia entre el territorio concreto en el que se produzca el incendio y el entorno habitual de trabajo del investigador criminal va a ser mayor. Es más, en algunos casos, el propio investigador criminal, ostentando legalmente la condición de responsable de la investigación criminal, puede no estar familiarizado con el peculiar método para la localización del escenario del delito de incendio forestal. Lógicamente, si no es posible localizar ese lugar, muy difícilmente se va a poder iniciar una buena investigación con base en las evidencias recogidas en él.

Por lo tanto, independientemente de quien lo conozca y lo aplique, lo importante es que se aplique bien el método de las evidencias físicas y que a ello acompañe luego una buena investigación criminal.

En ese sentido, y aunque no es el objetivo de este relato de experiencia desgranar todos los detalles de la compleja investigación criminal de incendios forestales, lo que resultaría imposible en un documento de este tipo, se va a desgranar brevemente a continuación lo que sería una investigación criminal de un incendio forestal, aportando alguna de las ideas muy relevantes que se pusieron de manifiesto a lo largo de la Conferencia de Internacional de INTERPOL. En esencia, sin diferir en exceso de otros tipos de investigaciones criminales nada más que en las etapas 3 y 4, el ciclo de este tipo de investigaciones que desde INTERPOL se considera más idóneo sería el siguiente:

1. *Conocimiento del hecho*
2. *Recopilación de información y llegada al punto*
3. *Reparto de tareas: Inspección Técnico-Ocular y exploración de testigos*
4. *Definición del área de origen y determinación del punto de origen*
5. *Determinación de la causa*
6. *Identificación de los autores*
7. *Finalización del procedimiento*

Se desarrollan a continuación cada una de esas etapas:

1. *Conocimiento del hecho*

Con respecto al conocimiento del hecho por parte de los investigadores criminales, lo más reseñable que aportó la Conferencia es la necesidad de que el personal forestal y el personal policial tengan una vía fluida de intercambio de información, de forma que la presencia del equipo investigador en el lugar del incendio se produzca lo antes posible.

Aun cuando la información sea transmitida correctamente, dadas las limitaciones de personal y medios en las unidades policiales y la alta concentración en el tiempo y en el espacio del fenómeno de los incendios forestales, es posible que por parte de las unidades de investigación criminal se deba priorizar las investigaciones a iniciar. En esa priorización debe primar, en todo caso, el resultado lesivo del hecho, máxime si se producen víctimas mortales o daños graves en viviendas, si bien la superficie forestal afectada no tiene siempre por qué ser determinante para otorgar a un incendio una alta prioridad.

2. *Recopilación de información y traslado al incendio*

Conviene resaltar con respecto a esta fase que, al contrario de lo que sucede con otro tipo de delitos, es conveniente dilatarla todo el tiempo necesario para completar adecuadamente la tarea de documentación. Cualquier omisión en esa tarea va a ser muy difícil de enmendar posteriormente, una vez los investigadores se encuentren en una zona remota y posiblemente sin conexión a los medios habituales de intercambio de información.

Por lo tanto, una recomendación esencial en esta fase sería la de mantenerse paciente y ser minucioso en la recogida de datos e informaciones.

3. *Reparto de tareas: Inspección técnico-ocular y exploración de testigos*

En este caso, la tradicional actividad de inspección ocular del lugar de comisión del crimen será la que marque la diferencia fundamental con otro tipo de investigaciones criminales.

A diferencia de la metodología que se emplea generalmente en los escenarios de delito por parte del personal de las unidades criminalísticas, los investigadores de incendios criminales de incendios forestales emplean la que se conoce generalmente como Método de las Evidencias Físicas.

Esa metodología permite identificar en muchos casos (desafortunadamente, no en todos) el punto exacto en el que ha comenzado el incendio, de forma que los investigadores criminales puedan, partiendo de ese punto, localizar los indicios y evidencias, así como ubicar a posibles personas en ese lugar en el momento en el que comenzaron las llamas, estableciendo de esa forma hipótesis sostenibles sobre la autoría del incendio.

En síntesis, el Método consiste en hacer una regresión del avance del fuego mediante el análisis de los rastros que el impacto del avance de las llamas deje en los objetos a su paso. De esa forma, empleando una serie de indicadores (vestigios), algunos de ellos muy evidentes y otros no tanto, se puede acabar por acotar un área más o menos extensa desde la que partieron las llamas.

4. Definición del área de origen y determinación del punto de origen

Una vez identificada esa área, dará comienzo una etapa minuciosa de análisis visual de la misma centímetro a centímetro, de forma que se pueda localizar algún elemento que permita identificar sin lugar a duda el punto exacto de inicio de las llamas.

Si bien determinar el área de inicio del incendio puede ser complicado, dado el comportamiento tan errático de los fuegos incipientes, la localización exacta de ese punto no resulta menos complicada en la mayor parte de las ocasiones.

Afortunadamente, los colegas que se encargarán en paralelo a la inspección ocular de la exploración de testigos pueden en ocasiones aportar información vital para esa localización del punto de inicio, aunque nunca debe basarse esa localización únicamente en las manifestaciones de testigos que, de una manera u otra, pueden tener algún tipo de interés particular en entorpecer la investigación criminal.

En cualquier caso, en ese punto de inicio, resulta recomendable, además de la recogida de todos los elementos vinculados con el origen del fuego, la toma y remisión a un laboratorio de una muestra del sustrato por debajo del punto, lo que permitirá conocer si se ha empleado algún tipo de acelerante de la combustión. Ello aportaría una importante certeza respecto a la intención criminal del autor o autores del incendio.

5. Determinación de la causa

Con los elementos obtenidos en las fases anteriores, y poniéndolos en relación con los indicadores de actividades de riesgo de incendio en la zona (actividades agrícolas y ganaderas, o presencia de tendidos eléctricos, entre otros) si no son suficientes esos elementos por sí mismos para determinar la causa del incendio, se puede ir acotando la actividad o actividades que, con mayor probabilidad, han acabado por dar origen al incendio.

Como se indicó también para el punto anterior, conviene no concentrar toda la atención sobre la actividad de riesgo más evidente en el lugar, dado que, en algunos casos, los delincuentes incendiarios encubren su acción criminal haciéndola pasar por otras actividades de riesgo que se dan habitualmente en la zona.

6. Identificación de los autores

Una vez establecida la causa más probable y obtenidos los elementos de prueba presentes, puede resultar sencillo identificar al autor del incendio forestal. En otras ocasiones, por muy exhaustivo que haya sido el trabajo previo, la autoría va a quedar sin esclarecerse.

Las tasas de esclarecimiento de este tipo de delitos son relativamente bajas en comparación con otros aparentemente más sofisticados. Ello se debe en gran medida a la presencia del fuego, elemento imprescindible en un incendio y que en otras tipologías delictivas se emplea para el encubrimiento de acciones y la destrucción de pruebas.

No obstante, la identificación de los autores, formas y medios de ignición empleados mediante la investigación criminalística en el escenario del delito debe ser refrendada por otros elementos comúnmente empleados en la investigación criminal, entre los que los testimonios de los testigos y equipos de emergencia suelen resultar especialmente esclarecedores.

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7. *Finalización del procedimiento*

Una vez identificada la causa y el autor del incendio forestal, para una adecuada finalización del procedimiento investigador, cabe preguntarse en primer lugar si la conducta que ha originado el incendio es delictiva. En ese sentido, en un número importante de países que sufren recurrentemente la lacra de los incendios forestales se han incorporado a los respectivos Códigos Penales (o normas análogas) tipos penales específicos para el delito de incendio forestal.

Esos tipos penales pueden contemplar o no los incendios negligentes o accidentales, pero siempre van a incorporar los incendios intencionados entre aquellos con repercusión penal.

En otras ocasiones, el investigador va a tener que recurrir a los tipos penales genéricos de incendio, ya sea forestal, ya sea agrícola o en estructuras, para justificar la acción penal contra su autor.

En ese sentido, en ocasiones, la detención del autor se constituye como el único elemento empleado para determinar el éxito de una investigación, obviando el hecho de que algunas excelentes investigaciones finalizan precisamente con la confirmación de la inexistencia de responsabilidad criminal.

Se produzca finalmente la detención o no del responsable o los responsables del incendio, el procedimiento investigador finaliza con la entrega de los documentos elaborados a la autoridad judicial en caso de determinarse la existencia de responsabilidad criminal. En caso contrario, el investigador criminal tiene la responsabilidad de entregar esa información a la autoridad forestal que corresponda, de forma que por la misma se pueda utilizar toda esa información para implementar las medidas más adecuadas de prevención en la zona.

Incendio activo sobre área de bosque primario previamente deforestada. INTERPOL.

En definitiva, una de las principales conclusiones que se pudieron extraer de la Conferencia Internacional de INTERPOL sobre Investigación Criminal de Incendios Forestales es, precisamente, la trascendencia de conocer por qué arde el bosque y quién lo quema, ya sea para el establecimiento de medidas preventivas, ya sea para la represión de la criminalidad. Es esa una responsabilidad compartida entre los investigadores criminales y los gestores forestales y, como tal, requiere que ambos colectivos coordinen sus esfuerzos con lealtad, de forma que el número de incendios que son objeto de investigación, bien inicialmente administrativa bien desde un principio con una perspectiva criminal, sea lo más elevado posible.

Igualmente, una segunda conclusión que se pudo extraer de esa Conferencia es la utilidad de contar con sistemas nacionales para la integración efectiva y acorde con las leyes nacionales de equipos internacionales de apoyo a la investigación criminal

de los incendios forestales. Tal y como sucede con la integración de unidades extranjeras en tareas de extinción, dada la alta concentración de los incendios forestales en el tiempo y en el espacio, el despliegue de equipos de apoyo a la investigación sería factible técnica y económicamente. En ese sentido, INTERPOL estaría en condiciones de proporcionar soporte a sus países miembros afectados por esta problemática, bastando para ello simplemente con establecer un marco regulatorio nacional adecuado en el que las Oficinas Centrales Nacionales de INTERPOL serían las encargadas de efectuar las solicitudes formales de apoyo, así como de coordinar de la recepción y despliegue de esos equipos de apoyo exterior.

La relevancia de contar con investigadores extranjeros de refuerzo integrados en los equipos de investigación local quedó muy claramente de manifiesto el pasado mes de agosto de 2019 tras la ola de incendios sufrida a lo largo de la franja sur de la masa forestal amazónica. No es posible para un Estado dimensionar un dispositivo de investigación capaz de afrontar los miles de focos de incendio detectados en unas pocas semanas, pero la respuesta de las agencias de aplicación de la Ley nacionales puede multiplicarse si los equipos locales pueden desdoblarse al contar con el refuerzo de investigadores extranjeros altamente cualificados procedentes de regiones con baja incidencia de incendios en ese mismo periodo del año.

En la medida de sus posibilidades, INTERPOL apoya y continuará apoyando a sus estados miembros en esas tareas mediante nuevas iniciativas como las descritas a lo largo de este documento.

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