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Technical note

Explore inhabitants' perceptions of wildfire and mitigation behaviours in the *Cerrado* biome, a fire-prone area of Brazil

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Abstract - Fire represents an important natural feature of Brazilian landscape, especially in the *Cerrado* biome. The Cerrado is the economic livelihood of thousands of people from rural areas in Brazil. It is one of the most important hotspots of biodiversity in the world but also it is a fire-prone area thanks to the high flammability index of the vegetation. Residents and native people of this environment use fire very frequently. The majority of wildfires are caused by humans, though there are some aggravating natural factors affecting the risk, intensity and severity of wildfires. Since residents are continuously involved in fire suppression activities, understanding their perceptions is important for the decision makers who must assess the local capacity to preserve natural resources. This study explores perceptions about wildfire risk and fire mitigation behaviours within three municipalities of the state of Tocantins (Brazil). The study demonstrates that survey participants perceived wildfire risk as rather high, although the perceptions were complex and conflicting among interviewees. A wide range of confused perceptions regarding fire ignition and heterogeneous points of view have emerged from the survey. However, the residence of interviewees and their educational attainment result in variables that significantly affect the inhabitants' perceptions.

Keywords - Perceptions; fire risk; mitigation behaviors; Cerrado; Brazil

Introduction

Although fire is an important ecological factor, it is also a natural disturbance and one of the most significant threats to forest and savannah ecosystems worldwide. It prevents the effectiveness of forest ecosystems to provide the ecosystem services and socio-economic benefits. This is of particular relevance in Latin America, especially in Brazil's Cerrado biome, which is characterized by vegetation with a high flammability index (Klink and Machado 2005). Although lightning represents the principal natural ignition origin (Ramos-Neto and Pivello 2000), the most common causes of wildfire in Brazil are anthropogenic (Pereira Jr. et al. 2014). Anthropogenic ignition is often related to improper use of fire in agricultural and livestock practices, carelessness in fishing and hunting, cigarettes butts discarded along roadsides and the burning of trash (Klink and Machado 2005, Mistry and Bizerril 2011, Pivello 2011).

Over recent history, population growth and the expansion of agricultural areas (Klink et al. 2002, Phalan et al. 2013, Welch et al. 2013) have increased the use of fire. Most landowners use fire as a tool when they are attempting to replace natural vegetation with crop cultures or pastures, to perform shifting (slash-and-burn) cultivation, and also to stimulate the regrowth of grasses to feed cattle during the dry season (Klink and Machado 2005). Moreover, native populations augment fire frequency and fire risk through traditional uses, such as using fire in rituals, for signals, to kill or drive away pests and snakes, to eliminate waste, to slash-and-burn and to attract or drive game during hunting (Hecht 2009, Mistry et al. 2005, Welch et al. 2013).

Therefore, the Cerrado biome is continuously under strong fire peril, which threatens one of the most important hotspots of biodiversity in the world (Myers et al. 2000). The situation is exacerbated by climate change, which increases the fire risk by creating warmer and drier conditions (Maezumi et al. 2015, Ribeiro, JF and Walter 2008). Likewise, international agreements aimed at reducing the carbon emissions from deforestation and forest degradation in the Amazonian rainforest have allowed the replacement of savannah ecosystems with forest plantations. Thus, climate change mitigation, economic pressure and human carelessness all contribute to the spread of wildfire within the Cerrado.

Assessing the relationships between socio-ecological systems is of paramount importance in order

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to discover the key drivers that determine changes in forest ecosystems (Ferrara et al. 2016). Similarly, the socio-economic context (Kosmas et al. 2016) of fire-prone areas could exacerbate negative fire-related phenomena such as land degradation and depletion of natural resources, with subsequently loss of biodiversity and other ecosystem services (Sallustio et al. 2015, Vizzarri et al. 2015).

Within the vegetation of the Cerrado, it is very common to find morphological and physiological adaptations to frequent fires, such as twisted trees, thick fruit skins and corky bark (Pivello 2011, Simon and Pennington 2012). Their presence confirms the role of fire in governing forest dynamics (Hoffmann et al. 2009, Pivello and Coutinho 1996). For example, fire causes top kill and often destroys the above ground biomass of saplings and smaller trees (Hoffmann et al. 2009). However, it also alters the forest composition, promotes regeneration and increases timber production (Certini 2005). Although mature trees often survive, fire stress affects their growth and fosters susceptibility to other stressors (Odhiambo et al. 2014). In particular, high fire frequency impairs the ability of trees to reach adult stages, accumulate bark and reach sufficient height to avoid top kill (Batalha et al. 2011, Hoffmann et al. 2003). Similarly, by altering soil properties (D. M. Silva et al. 2013), high fire frequency modifies the Cerrado physiognomies, reducing biodiversity (Bond et al. 2005, Lehmann et al. 2011, I. A. Silva and Batalha 2008).

In combatting wildfire, residents can play a crucial role in the conservation of natural resources by adopting risk mitigation strategies which have developed over the years and which currently represent the social memory regarding the ability of a local community to manage and cope with fire issues (Wilson et al. 2017). Such mitigation behaviour, also known as community resilience (Kelly et al. 2015), is the consequence of several dynamic factors (Champ et al. 2013), which interact with each other and influence people's perception of the risk. The relationship between risk perception and mitigation action has been a subject of studies across several disciplines (Beringer 2000, Dondo Bühler et al. 2013, Gounaridis et al. 2014, McCaffrey et al. 2013). Moreover, the exploration of stakeholders' perceptions has been increasingly adopted in the management and governance of forest resources (Pastorella et al. 2016, Santopuoli et al. 2016, Santopuoli et al. 2012). The main objective of this study is to explore local perceptions of wildfire risk and the mitigation behaviours in a fire-prone area of Brazil. Furthermore, since many authors agree that indigenous populations use fire in almost all of their traditional, ritual, cultural and daily activities, an additional aim of the study is to compare residents' perceptions among three municipalities that are contiguous with Bananal Island, where two important native populations live (Valente et al. 2013).

Methods

Study area

The present study was conducted in three municipalities (Dueré, Formoso do Araguaia and Lagoa da Confusão) located in the south-western part of the Tocantins of central Brazil (Fig. 1). Located along the western border of the state, Bananal Island represents the most important hot spot of biodiversity conservation in Tocantins, with Araguaia National Park in the north and the reservations of the Xavante and Javaés indigenous groups in the South (Valente et al. 2013). Particularly significant is the presence of Xavante group, which historically has been famous for its use of fire for management (Pivello 2011). The vegetation is of the Cerrado type, which represents one of the most important types of savannah in terms of species richness and level of endemism, (Forzza et al. 2012, Simon and Pennington 2012). Nevertheless, intensive human use has cleared more than 30% of the Cerrado biome, predominantly for pasture, intensive monoculture -e.g., soybean, rice and maize (Phalan et al. 2013) - and more recently for forest plantations of species such as eucalyptus and pine (Ceccon and Miramontes 2008, Klink et al. 2002).

According to the Koppen classification, the climate is seasonal: the wet season is from October to March and the dry season from April to September (Klink and Machado 2005). The annual mean temperatures range from 22°C to 27°C and the annual rainfall from 1'300 to 1'900 mm (Alvares et al. 2013). In this fire dependent/influenced ecosystem (Hard-

Figure 1 - Study area. The position of the three municipalities within the state of Tocantins and the border of the Bananal Island indigenous area on the left. The total area is 27,412 km^2, (3,424 km2 in Dueré, 13,423 km^2 in Formoso do Araguaia and 10,564 km^2 in Lagoa da Confusão), within which forest cover represents the 70% of the total area. The position of Tocantins within Brazil is on the right.

esty, Jeff and Myers, Ron and Fulks 2005), fire is an essential factor in conserving the native animal and plant species and maintaining ecological processes (Pivello 2011). The National Institute for Space Research (INPE 2015), reports that from 2003 to 2011, the annual average number of fires in Tocantins was 11'682, corresponding to almost 32'000 km^2 (11.5% of total surface) burned each year (Cachoeira 2015).

According to the Brazilian Statistics and Geography Institute database (Instituto Brasileiro de Geografia e Estatística), in 2014 the total human population was 35'352 (4'720 in Dueré, 18'773 in Formoso do Araguaia and 11'859 in Lagoa da Confusão).

Survey method

Data on the perception of fire were collected from February to September of 2014, during the development of the Forest Fire Prevention Plans (FFPPs) for the three municipalities, e.g. "*Plano Operativo de Prevenção e Combate aos Incêndios Florestais do municipio de Dueré*" (Giongo et al. 2014). In-person interviews were conducted with individuals over 16 years of age who inhabited the three municipalities of the area studied.

Respondents were mainly surveyed in private agroforestry enterprises and seldom in public locations such as local municipal offices, restaurants and market places. The main difficulty encountered for collecting information was the distance between forestry businesses, which affected the number of respondents. However, the final sample size consisted of 116 interviews, and considering the total population of the study area (35'352 inhabitants), the sampling error is estimated as ± 9.08% at the confidence level of 95%.

The interviewees were selected according to the combination of theoretical and snowball sampling for structured interviews. This approach allows collection of the maximum variety of concepts, ideas and practical experiences (López-Santiago et al. 2014, Paveglio et al. 2017). This strategy is designed to achieve both consistency and representativeness of the topic studied (Corbin and Strauss 1990, Strauss and Corbin 1994). It is important to highlight that the theoretical sampling strategy provides greater understanding of the representativeness of a slice of life such as individual acquaintances and practical experiences rather than prioritizing representativeness of population (Patton 1990, Strauss and Corbin 1994). The snowball sampling is a complimentary strategy that uses chain referral for the identification of additional informants from an initial sample (Paveglio et al. 2017).

The interviews were conducted through a semi-structured questionnaire based on the Ministerial guidance provided for developing the FFPPs (IBAMA 2009). The questionnaire contained 38 questions, including both open-ended and closed questions. There were 24 open-ended questions on socio-demographic characteristics such as age, race, gender and education, and open-ended questions were also used for explanations of the choices made with the closed questions. The 14 closed questions (Tab. 1) were designed to investigate the opinions of interviewees regarding two aspects:

(i) The use of fire for daily activities and its impact on the environment;
(ii) Knowledge about fire suppression techniques, their implementation and the interviewees personal capability.

The closed questions included two types of questions. The first consisted of 'Yes/No' answers, while the second consisted of giving a weight to the choices highlighted during the interview, ranking them from 1 "less important" to 9 "very important".

Table1 - Questions used to deliver the in-person interviews. The first group of questions was designed to investigate the daily use of fire among residents. The second group of questions addressed the mitigation behaviors of interviewees.

	Questions	Explanation
Wildfire risk perceptions	Fire opinion	To give a preference (positive or negative) about the usefulness of fire for land management, adding a justification of the choice.
	Fire use	To describe whether residents use fire for daily activities.
	Activities that use fire	To give at least one example of an activity (rural or domestic) for which fire is necessary and quantify its usefulness from 1 to 9.
	Problem for municipality	To evaluate whether fire represents a problem for the municipality where the interviewee live and to give the weight of its relevance from 1 to 9.
	Causes of fire ignition	To list the main causes of fire ignition, giving a weight to the frequency of each cause on a scale from 1 to 9.
	Risk for urban and rural areas	To indicate whether rural or urban areas are more affected by fire, giving weight to its importance on a scale from 1 to 9.
	Action to reduce risk of fire	To mention at least one potential action useful for reducing fire ignition or limiting fire impacts. For each action mentioned, the interviewee weighed its effectiveness from 1 to 9.
Fire mitigation behavior	Training course	To indicate whether the interviewee has taken part in a training course on firefighting.
	Voluntary activity	To indicate whether the interviewee has taken part in firefighting activities as a volunteer.
	Prescribed fire	To indicate whether the interviewee is familiar with techniques of prescribed fire.
	Example of prescribed fire	Give at least one example of prescribed fire techniques.
	Authorization for prescribed fire	To indicate whether the interviewee is familiar with institutions that authorize prescribed fires.
	Current fire suppressors	To indicate who currently takes part in fire suppression, giving a weight to the importance of each on a scale from 1 to 9.
	Expected fire suppressor	To list who should be expected to take part in fire suppression, giving the weight to the importance of each group on a scale from 1 to 9.

In this study, we use the term "wildfire risk perception" to mean understanding that fire can occur and damage natural resources, crops, domestic animals and human infrastructure. "Mitigation behaviours" are strategies that individual inhabitants are able to adopt or consider useful to firefighting, to reduce wildfire occurrence and to limit the impact on the environment.

Data analysis

Statistical analyses were carried out separately for: (i) classifying the social structure and the frequency of answers among municipality; (ii) testing whether the different socio-demographic variables affect the inhabitants' opinions; and (iii) the identification of common trends among municipalities.

Statistical analyses included an independent-sample t-test (p-value <0.05) and the Principal Component Analysis (PCA), using SPSS v 15.0.0 (2006). The t-test assessed whether the different socio demographic variables affect local opinions about wildfire risk and mitigation behaviour. By contrast, the PCA allows to identify the overall trend of investigated population about the awareness of risk perception and the preparedness to manage fire. Starting from the original variables considered in this study, the PCA identified the Principal Components (PCs) that allow us to assess the closeness and differences of perceptions among the three municipalities. Once the PCs were extracted, we displayed the score factors of the first two PCs through a scatterplot in order to show the variability among the interviewees as well as among the three municipalities. For the statistical analysis, the input data for the answers to the first type of closed questions ('Yes/No') was set as a value of 9 for 'Yes' and 1 for 'No', and we ranked the answers for the second type of closed questions from 1 to 9. "No opinion" and missing answers were ranked as 0. The open-ended questions were used to enrich the interpretation of the statistical findings.

Results

Social structure of population studied

The participatory approach involved a total of 116 local inhabitants, 25.0% female and 75.0% male, of the three municipalities (Tab. 2). Their ages ranged between 16 and 87 years with a median age of 42, and most of the interviewees (31.9%) were between 31 and 45. The people contacted from Formoso do Araguaia were younger than those in the other municipalities, with an average age of 36. Interviewees from Dueré were slightly older, with a median age of 46 years.

Most of interviewees were of mixed race, 56.0% of the overall total. This percentage reached 64.1% in Formoso do Araguaia probably due to the proximity of the indigenous reserves. White respondents (22.4%) were more frequent than black ones (18.1%). Finally, although Bananal Island was excluded from the study area, four native people (3.4% of total) took part in the interviews as well.

In terms of education, roughly a third of the interviewees (33.6%) declared that they had completed high school and 12.1% had more advanced education. Nevertheless, many interviewees (30.2%) did not complete the elementary school or were illiterate (7.8%), mainly in Lagoa da Confusão and in Dueré.

Table 2 - Population and social structure of the studied municipalities in the state of Tocantins. Elementary school inc. stands for elementary school incomplete.

Parameters	Municipalities						Total	
	Dueré		Formoso do Araguaia		Lagoa da Confusão			
	Num.	%	Num.	%	Num.	%	Num.	%
Num. Interview	**35**	**30.17**	**39**	**33.62**	**42**	**36.21**	**116**	**100**
Age								
16-30 years	7	20.00	17	43.59	9	21.43	33	28.45
31-45 years	11	31.43	10	25.64	16	38.10	37	31.90
46-60 years	12	34.29	11	28.21	8	19.05	31	26.72
61-75 years	4	11.43	1	2.56	8	19.05	13	11.21
76-87 years	1	2.86			1	2.38	2	1.72
Race								
Mixed race	19	54.29	25	64.10	21	50.00	65	56.03
White	7	20.00	9	23.08	10	23.81	26	22.41
Black	7	20.00	4	10.26	10	23.81	21	18.10
Indigenous	2	5.71	1	2.56	1	2.38	4	3.45
Gender								
Male	25	71.43	27	69.23	35	83.33	87	75.00
Female	10	28.57	12	30.77	7	16.67	29	25.00
Educational qualification								
Illiterate	2	5.71	-	-	7	16.67	9	7.76
Elementary school inc.	10	28.57	8	20.51	17	40.48	35	30.17
Elementary school	5	14.29	11	28.21	3	7.14	19	16.38
High school	12	34.29	18	46.15	9	21.43	39	33.62
Higher educational	6	17.14	2	5.13	6	14.29	14	12.07

Risk perception

The larger part of the interviewees (94.0%) agreed that fire represents a negative phenomenon, particularly for the rural environment (Tab. 3). Most explained their negative opinions about fire in terms of their awareness of the resulting environmental degradation (78.9%). According to the respondents, environmental degradation means degradation of soil, plants and animals, which alters the annual agricultural and hunting production. However, they also include the economic aspects such as the destruction of fences and infrastructure. The second most important explanation stressed by interviewees was the effect of fire on climate change. In particular, some explicitly referred to temperature increase and carbon dioxide emission, while others more generally referred to the emission of gases in the atmosphere with strong repercussions on human health. This was especially true of surveys from the municipality of Dueré, where the education levels among interviewees were higher. Finally, the lack of local firefighters was also noted. Though only one person mentioned this deficiency, it is significant given the high flammable index of Cerrado biome as well as the important role that fire plays for land management in these rural environments.

The study revealed that 50.0% of the interviewees used fire in their own activities, particularly in the municipality of Dueré. Although the overall use of fire in the study area was mostly for slash-and-burn practices (55.2%), in Dueré fire was used mostly for burning domestic waste. Furthermore, people also use fire for producing charcoal (5.2%) for cooking in their homes, along the river or in the field during the fishing and hunting expeditions (3.4%). Finally, people used fire for industrial activities (1.7%) such as soldering or ceramics and for bonfires (1.7%).

Most of interviewees (83.6%) perceived wildfire as a serious problem for the municipalities. They also highlighted three main types of damage: (i) environmental stress like destruction of plants, animals and soil; (ii) the adverse health effects in exposed humans; and (iii) the lack of preparedness of people to prevent and control the fires.

Dueré is the municipality where most interviewees (32 out of 35) described fire as a problem for the municipality and, additionally, it was the municipality with the most use of fire. Furthermore, the high rate of landowners and employees involved in the suppression activities, as a consequence of the lack of firefighters, underlines their perception of greater risk. The inhabitants were better acquainted with mitigation actions, even though a general lack of awareness about the causes of fire ignition remains one significant limitation highlighted by interviewees.

There was a wide range of confused perceptions about fire ignition, and heterogeneous points of view. Interviewees highlighted nine different causes of fire ignition, most of anthropogenic origin. The most often cited were cigarette butts (24.1%), intentional ignition (19.8%), mismanaged intentional fires in daily activities (18.9%), and agricultural practices (15.5%). The complexity of the inhabitants' perceptions was underscored by the other minor causes identified by interviewees and by those who "do not know".

Results showed that interviewees from Formoso do Araguaia considered the carelessness in the use of fire to be the most frequent cause of fire ignition. They also identified a prevalence of arsonists, and believed that improving the awareness of fire use among inhabitants represents the best solution for reducing fire impacts. Interviewees from Lagoa da Confusão highlighted the widest range of causes of fire ignition, including short-circuits, even though the cigarette butts and agricultural practices were the most commonly identified. Fire risk was barely noted, and it was mainly linked to the use of fire in the agricultural practices. The actions that could be useful for reducing fires include improving awareness and strictly limiting the use of fire to those activities for which fire is indispensable. In Dueré, interviewees declared that improving the awareness among residents is the most important solution for reducing fire risk.

Mitigation behaviours

Almost all the interviewees (98.2%) said they had taken part in fire suppression activities as a volunteer (Tab. 4). Nevertheless, only 30.2% of the interviewees had taken part in at least one training course on fire prevention and firefighting. However, several interviewees (24.1%) did not know what a prescribed fire is, nor did they know the procedure for its implementation. This was particularly evident in Formoso do Araguaia, where this value was 43.6% and the majority of the remaining interviewees (63.6%), who said they did know what prescribed fire is, did not mention any examples of prescribed fire. Furthermore, 31.8% recognized the firebreaks as a prerequisite to undertake prescribed fire and 4.5% mentioned backfires as a prescribed fire technique.

In contrast, interviewees from the other two municipalities were more confident about mitigation actions. In particular, in Lagoa da Confusão almost 98.0% of the interviewees were aware of at least one prescribed fire technique. They reported firebreaks to be the most frequent example of prescribed fire. Many interviewees (17.1%) associate prescribed fire with elements such as the season of the year and the time of day, saying that prescribed fires should

Table 3 - Perception of fire risk within three municipalities in the state of Tocantins.

Parameters	Municipalities						Total	
	Dueré		Formoso do Araguaia		Lagoa da Confusão			
	Num.	%	Num.	%	Num.	%	Num.	%
Fire opinion								
Negative	34	97.14	38	97.44	37	88.10	109	93.97
Positive/negative	-	-	1	2.56	3	7.14	4	3.45
Positive	1	2.86	-	-	2	4.76	3	2.59
Explanation of negative opinion								
Environmental degradation	23	67.65	33	84.62	34	82.93	90	78.95
Climate change	9	26.47	6	15.38	7	17.07	22	19.30
No local firefighters	1	2.94	-	-	-	-	1	0.88
Do not know	1	2.94	-	-	-	-	1	0.88
Personal use of fire								
Yes	23	65.71	13	33.33	22	52.38	58	50.00
No	12	34.29	26	66.67	20	47.62	58	50.00
Activities which use fire								
Slash and Burn	8	34.78	8	61.54	16	72.73	32	55.17
Burning domestic waste	13	56.52	3	23.08	2	9.09	18	31.03
Charcoal production	-	-	1	7.69	2	9.09	3	5.17
Cooking	1	4.35	-	-	1	4.55	2	3.45
Industrial activity	-	-	-	-	1	4.55	1	1.72
Prescribed fire	1	4.35	-	-	-	-	1	1.72
Bonfire	-	-	1	7.69	-	-	1	1.72
Problem for municipality								
Yes	32	91.43	29	74.36	36	85.71	97	83.62
No	3	8.57	10	25.64	6	14.29	19	16.38
Causes of fire ignition								
Cigarettes	10	28.57	5	12.82	13	30.95	28	24.14
Intentional	9	25.71	9	23.08	5	11.90	23	19.83
Unconscious	7	20.00	14	35.90	1	2.38	22	18.97
Slash-and-burn	6	17.14	3	7.69	9	21.43	18	15.52
Do not know	-	-	5	12.82	1	2.38	6	5.17
Glass bottom of bottles	1	2.86	-	-	4	9.52	5	4.31
Indigenous	-	-	1	2.56	4	9.52	5	4.31
Hunting/fishery	1	2.86	-	-	2	4.76	3	2.59
Short-circuit	-	-	-	-	3	7.14	3	2.59
High temperature	1	2.86	2	5.13	-	-	3	2.59
Environment at risk								
Urban environment	3	8.57	3	7.69	4	9.52	10	8.62
Both	3	8.57		0.00	15	35.71	18	15.52
Rural environment	29	82.86	36	92.31	23	54.76	88	75.86
How to reduce fire risk								
Awareness	21	60.00	18	46.15	22	52.38	61	52.59
Surveillance	4	11.43	5	12.82	6	14.29	15	12.93
Not use fire	3	8.57	5	12.82	7	16.67	15	12.93
Other	-	-	7	17.95	1	2.38	8	6.90
Do not know	3	8.57	2	5.13	2	4.76	7	6.03
Firebreak	2	5.71	-	-	3	7.14	5	4.31
Prevention	2	5.71	2	5.13	1	2.38	5	4.31

be scheduled at night and during the rainy season. Only 4.9% of interviewees mentioned backfire and 2.4% associated prescribed fire with large numbers of people involved in the suppression of fire.

Finally, most of interviewees in Dueré (71.4%) said they were aware of at least one prescribed fire technique. Firebreaks and equipment, such as fire swatters, backpack fire pumps and drip torches were the most frequent examples of prescribed fire tools, 60.0% and 12.0%, respectively. It was interesting to note that some of interviewees recognized the necessity of expertise (8.0%) in order to implement prescribed fires. Nevertheless, 12.0% of the interviewees were not able to provide any examples of prescribed fire.

Results showed that interviewees from Lagoa da Confusão were more familiar with the procedure for implementing prescribed fire. They were also aware of the institutions responsible for the prescribed fire authorization. In contrast, most of the interviewees from Formoso do Araguaia did not answer (43.6%) or did not know (20.5%) about this issue. Similarly, in Dueré, 28.6% of interviewees did not answer and 34.3% did not know.

The results showed that usually the main fire suppressors are landowners, employees and neighbors (40.5%). However, this is mainly evident in Dueré and Lagoa da Confusão, while in Formoso do Araguaia, the main fire suppressor is the National Centre for Fire Prevention (PREVFOGO), as stated by 59.0% of interviewees. Overall, often the people involved in fire suppression are volunteers (10.3%) who occasionally travel to the area where the fire occurs, followed by trained individuals and rural workers (9.5%). Finally, 6.9% of the interviewees said they did not know the answer to this question, especially in Formoso do Araguaia (15.4%).

Most of the interviewees (34.5%) believed that national public institutions and their firefighters are the most important of those expected to suppress fires. Furthermore, they believed that the party responsible for ignition (25.0%), landowners (16.4%),

and volunteers (13.8%) should participate in the fire suppression to speed the effort. Only 9.5% of the interviewees consider that trained people should participate in the fire suppression activities.

Table 4 - Personal opinions about fire mitigation strategies that interviewees consider useful to reduce fire impacts.

Parameters	Municipalities						Total	
	Dueré		Formoso do Araguaia		Lagoa da Confusão			
	Num.	%	Num.	%	Num.	%	Num.	%
Training course								
No	25	71.43	27	69.23	29	69.05	81	69.83
Yes	10	28.57	12	30.77	13	30.95	35	30.17
Voluntary activity								
Yes	29	97.75	32	97.63	39	99.15	100	98.25
No	6	2.25	7	2.37	3	0.85	16	1.75
Prescribed fire								
Yes	25	71.43	22	56.41	41	97.62	88	75.86
No	10	28.57	17	43.59	1	2.38	28	24.14
Prescribed fire example								
Firebreak	15	60.00	7	31.82	31	75.61	53	60.23
Any example	3	12.00	14	63.64	-	-	17	19.32
Season/time	-	-	-	-	7	17.07	7	7.95
Backfire	1	4.00	1	4.55	2	4.88	4	4.55
Equipment	3	12.00	-	-	-	-	3	3.41
Number of persons	1	4.00	-	-	1	2.44	2	2.27
Expertise	2	8.00	-	-	-	-	2	2.27
Authorization for prescribed fire								
Yes	13	37.14	14	35.90	27	64.29	54	46.55
Do not know	12	34.29	8	20.51	14	33.33	34	29.31
No Answer	10	28.57	17	43.59	1	2.38	28	24.14
Current fire suppressors								
Landowners/employees	23	65.71	2	5.13	22	52.38	47	40.52
Prevfogo	5	14.29	23	58.97	9	21.43	37	31.90
Volunteers	3	8.57	7	17.95	2	4.76	12	10.34
Trained/employees	3	8.57	-	-	8	19.05	11	9.48
Do not know	1	2.86	6	15.38	1	2.38	8	6.90
Arsonist	-	-	1	2.56	-	-	1	0.86
Expected fire suppressor								
Firefighter	8	22.86	20	51.28	12	28.57	40	34.48
Arsonist	7	20.00	11	28.21	11	26.19	29	25.00
Landowners	8	22.86	-	-	11	26.19	19	16.38
Volunteers	8	22.86	4	10.26	4	9.52	16	13.79
Trained	4	11.43	4	10.26	3	7.14	11	9.48
Do not know	-	-	-	-	1	2.38	1	0.86

Independent-sample t-test

The independent-samples t-test found few significant differences among interviewees (Fig. 2). Opinions did not differ by gender. Age and race had a stronger effect, though this was perhaps due to the sample sizes of certain age classes and races (e.g., only two people within the age range 76-87, and only four indigenous people took part in the interviews). The residence of interviewees and their education were the only variables that were associated with significant differences in responses.

Overall, the t-tests revealed more differences in mitigation behaviours than in wildfire risk perceptions. This demonstrates the widespread perceptions of wildfire risk among interviewees and highlights the heterogeneity of perceptions about the mitigation behaviours. Although most of interviewees had taken part in the suppression activities, they did not have adequate knowledge for wildfire prevention. Usually they acted on experiences and beliefs of the owner once a wildfire was ignited. Results confirmed that interviewees from Formoso do Araguaia were less familiar with mitigation behaviours (Tab. 5). In particular, there were significant differences about prescribed fire and prescribed fire examples between Formoso do Araguaia and Lagoa da Confusão.

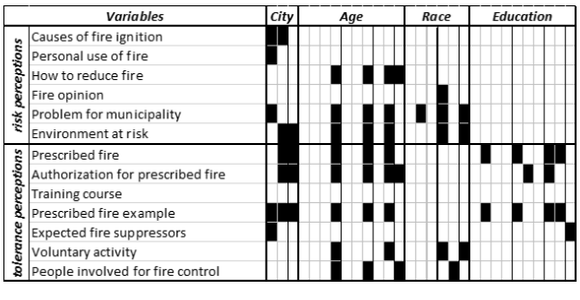

Figure 2 - Independent t-test. The figure shows the variables that presented statistically significant differences (black square), p-value <0.05. Gender is absent because it did not present any significant differences.

Furthermore, the results confirmed that high school and higher educational attainment positively affect awareness of wildfire mitigation behaviours (Tab. 6), even if the differences are not highly significant.

Principal Component Analysis

Since some variables did not have any significant correlations, the PCA combined only seven of the original variables, extracting four PCs that explained

Table 5 - Pairwise comparisons among municipalities (p-value is <0.05). The independent variables shown are only those that displayed significant differences. In the table, df stands for "Degrees of Freedom", M for "Mean" and SD for "Standard deviation". M and SD are given for the two municipalities of pairwise comparison.

			Dueré - Formoso do Araguaia				
	p-value	t	df	M	SD	M	SD
Causes of fire ignition	0.038	2.12	63.51	7.31	1.78	6.13	2.94
Personal use of fire	0.005	2.9	71.01	6.26	3.85	3.67	3.82
Problem for municipality	0.05	1.99	65.49	8.31	2.27	6.95	3.54
Prescribed fire example	0.001	3.63	68.56	6.09	4.06	2.82	3.61
Expected fire suppressors	0.014	2.52	71.45	5.40	2.69	7	2.75
			Dueré - Lagoa da Confução				
	p-value	t	df	M	SD	M	SD
Causes of fire ignition	0.048	2.01	73.35	7.31	1.78	6.33	2.49
Environment at risk	0.05	1.99	74.36	7.97	2.44	6.81	2.68
Prescribed fire	0.002	3.23	40.47	6.71	3.67	3.48	3.74
Authorization for prescribed fire	0.011	2.63	70.72	3.69	4.16	6.12	3.91
Prescribed fire example	0.001	3.75	40.63	6.09	4.06	8.79	1.39
			Formoso do Araguaia - Lagoa da Confução				
	p-value	t	df	M	SD	M	SD
Environment at risk	0.005	2.92	77.50	8.38	2.16	6.81	2.68
Prescribed fire	0.000	4.91	44.63	5.51	4.02	8.81	1.23
Authorization for prescribed fire	0.004	2.95	77.19	3.44	4.23	6.12	3.91
Prescribed fire example	0.000	9.67	48.30	2.82	3.61	8.79	1.39

Table 6 - Pairwise comparisons among educational attainment categories (p-value is <0.05). The independent variables shown are the only ones that displayed significant differences between fire mitigation behaviors. In the table, df stand for "Degrees of Freedom", M for "Mean" and SD for "Standard deviation". M and SD are given for the educational qualifications of the groups in each pairwise comparison.

			Prescribed fire				
Grouping variables	p-value	t	df	M	SD	M	SD
Illiterate - Elementary	0.017	2.56	23.10	8.11	2.67	4.79	4.10
Elementary incomplete - Elementary	0.023	2.39	30.45	7.40	3.25	4.79	4.10
Elementary - High	0.038	2.17	30.54	4.79	4.10	7.15	3.41
Elementary - Higher educational	0.003	3.30	28.37	4.79	4.10	8.43	2.14
			Authorization for prescribed fire				
Grouping variables	p-value	t	df	M	SD	M	SD
Elementary incomplete - High	0.048	2.02	71.84	3.54	4.02	5.49	4.28
Elementary - High	0.042	2.10	36.37	3	4.20	5.49	4.28
			Prescribed fire example				
Grouping variables	p-value	t	df	M	SD	M	SD
Illiterate - Elementary	0.003	3.30	21.43	8	3	3.42	4.18
Elementary incomplete - Elementary	0.012	2.64	35.63	6.51	3.99	3.42	4.18
Elementary - High	0.039	2.15	34.43	3.42	4.18	5.90	4.01
Elementary - Higher educational	0.010	2.73	30.93	3.42	4.18	6.93	3.2
			Expected fire suppressors				
Grouping variables	p-value	t	df	M	SD	M	SD
High - Higher educational	0.049	2.08	23.43	6.69	2.66	5	2.6

76.2% of the total variance. In order to represent the common trends of perceptions about wildfire risk and mitigation behaviours in the three municipalities, we used the factor scores obtained from the first two PCs to draw a scatterplot (Fig. 3). These two explained 20.5% (PC1) and 11.5% (PC2) of the variability. The variables that scored the highest values in PC1 were the authorization for prescribed fire and its implementation, reflecting the mitigation behaviours. The variables that yielded the highest values for PC2 were training courses, a current role as fire suppressor and the environment at risk reflecting the perceived risk.

In the scatterplot, the position of the symbols represents the interviewees' answers according to the two PC scores. Symbols on the far right reflect greater awareness of prescribed fire techniques and their implementation. The symbols at the top of the score plot reflect a perception of greater risk.

Interviewees from Formoso do Araguaia had

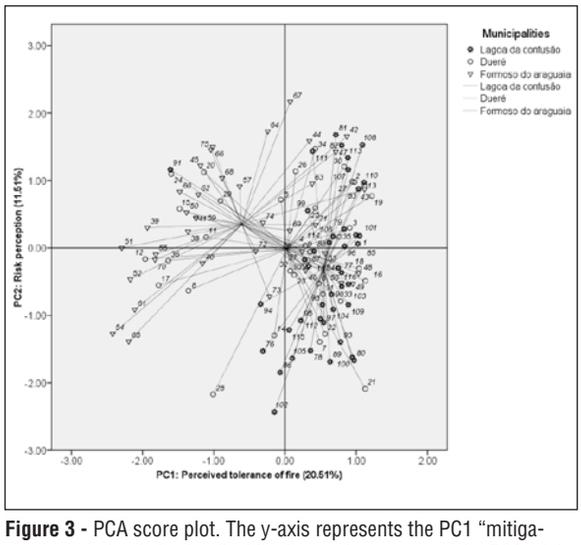

Figure 3 - PCA score plot. The y-axis represents the PC1 "mitigation behaviors" while the x-axis represents the PC2 "risk perception" among the citizens. The star indicates the municipalities of the Lagoa da Confusão, the circle Dueré and the triangle Formoso do Araguaia.

the most variability in mitigation behaviour, ranging from -2.65 (the lowest value) to 1.32, with more than 50.0% of negative score values positioned, for this reason, on the left side of the score plot. In contrast, in Dueré, the score values ranged from -2.34 to 1.32, but most of them presented positive values, reflecting the inhabitants' familiarity with mitigation behaviours. Finally, in Lagoa da Confusão, the score plot ranged from -1.17 to 1.32. Since most of them were positive, the interviewees from Lagoa da Confusão were overall the most aware of fire mitigation.

Risk perception increases along the vertical axis of the score plot. Results showed that those who participated in training courses had higher perceived risk of fire. In addition, interviewees who recognized the wildfire risk for the rural environment and those who declared the PREVFOGO as the most important current suppressor of fire are positioned at the top of the score plot. Interviewees from Dueré showed more variability in their scores, ranging from -2.15 (the lowest value) to 1.77. Within the municipality of Formoso do Araguaia, the results were largely positive, highlighting the higher risk perception by local inhabitants, with scores that ranged from -1.73 to 2.07. Finally, in Lagoa da Confusão, the variability was lowest, ranging from -1.98 to 1.36 with a negative trend.

The centroids of the score values for the three municipalities revealed the overall perceptions about wildfire risk and the mitigation behaviours. Formoso do Araguaia showed the highest level of risk perception and had the least capability in mitigation behaviours. This is likely due to the strong presence of firefighters who represented the most frequent suppressors of fire and to the high perception of fire risk for the rural environment. On the contrary, Lagoa da Confusão showed more familiarity with mitigation actions and perceived less risk. Finally, in Dueré the risk perception and the mitigation awareness were both intermediate amongst those of the other municipalities.

Discussion and conclusion

This study demonstrates that survey participants perceived wildfire risk as rather high, although the perceptions were complex and conflicting among interviewees. Interviewees felt that fire is a destructive phenomenon, but at the same time, they also highlighted its functionality in many activities. The most common use of fire was for traditional practices in agriculture and animal breeding (Klink and Machado 2005, Mistry 1998, Pereira Jr. et al. 2014, Pivello 2011), though the mismanagement of these practices represents one of the main causes of fires in this area. These findings stress the importance of disseminating knowledge about fire prevention and fire management among local inhabitants in limiting fire damage (Berkes 2004, Eriksen 2007, Mistry and Bizerril 2011). This represents a crucial challenge for policy decision makers because limiting fire impacts can strongly contribute to the reduction of land degradation (Kosmas et al. 2016) and halting the loss of biodiversity.

Furthermore, the interviewees perceived fire as a problem for the municipalities, not only in ecological aspects, such as soil degradation and biodiversity loss (Bond et al. 2005, Lehmann et al. 2011, I. A. Silva and Batalha 2008), but also for the administrative challenges of fire control. Although the second and third actions of the National Action Plan, developed by the State Committee for Forest Fire Fighting and Control of Fires, promote the mobilization, prevention, control and fighting of illegal fires by civilian individuals, this study reveals that only 30.2% of interviewees have taken part in training courses, and they rarely took part in suppression activities. Conversely, landowners, employees and rural inhabitants are the most frequent suppressors. Significant improvements would be needed to improve fire prevention activities and reduce the risk of fire. For example, promoting cooperation between trained people and landowners in order to schedule and implement prescribed fire would be useful. Likewise, it is important to enhance awareness regarding the causes of fire ignition, not only due to the main origin being Anthropogenic, but also in order to identify the main drivers of socio-ecological changes (Ferrara et al. 2016) and their impacts on the natural resources. The number of ignition causes listed by local respondents reflects, on one hand, the diversity of perceptions, and on the other hand a lack of knowledge among respondents. Cigarette butts were commonly identified as the main cause, but previous research has demonstrated the low probability of their causing fire ignition, given that they would require many favourable conditions such as wind and specific road surfaces (Xanthopoulos et al. 2006). Similarly, they referred to the bottom of a glass bottle, stating that bottles function as magnifying glasses and thereby enable fire ignition. Although this is another widespread opinion, experimental studies have demonstrated the low probability of fire ignition by glass fragments (Wittich and Müller 2009). Often respondents referred to the irresponsible use of fire, as well. Finally, there is a common bias that considers native people responsible for fires due to the pervasive use of fire in traditional customs. In contrast, some authors argue that indigenous practices reduce fire intensity because they maintain lower levels of fuel (Welch et al. 2013). However, the present study confirms that interview-

ees with high school diplomas recognized the high risk of fire in the area studied. They strongly agreed with the proposition that more awareness is necessary in order to reduce fire impacts. Although the social memory of local communities represents an important cultural heritage (Wilson et al. 2017), new efforts are necessary to improve the effectiveness of training activities and limiting fire impacts on land degradation and loss of ecosystem services. The social perceptions about the expected ecosystem services could represent an important starting point for a deeper evaluation of inhabitant behaviours.

Regarding fire mitigation behaviours, this study demonstrates that, although almost all the interviewees have taken part in fire suppression activities, most of them did not have an adequate level of competence. The participation in training activities was quite low as was the awareness of topics such as prescribed fire and its implementation. Most of the examples given for prescribed fire were rather vague and confusing. Most referred to the firebreaks as prescribed fire techniques. Only a few interviewees explicitly mentioned backfire as an example of prescribed fire, and even fewer recognized expertise as a prerequisite of implementing prescribed fires. Similarly, interviewees deemed the equipment and personnel sufficient for prescribed fire implementation. In a few cases, interviewees mentioned the burning season and mainly referred to tie of day and avoiding high temperatures (i.e. during the night and in November). Although they were not aware of the vegetative cover responses and phenology (Grace et al. 2006, Santos et al. 2003), early fire (May–June) favours woody plants, while later fire (September–October) favours grassy plants (Pivello and Coutinho 1996). These findings demonstrate the lack of awareness about forest fire control techniques and firefighting among local inhabitants, but also demonstrate the local experience in several voluntary efforts in fire suppression activities.

Finally, this study shows the variability of perceptions about wildfire issues among inhabitants in the three municipalities. Overall, interviewees that perceived higher risk were those from Formoso do Araguaia, followed by residents of Dueré and finally by those from Lagoa da Confusão. In contrast, interviewees from Formoso do Araguaia were less familiar with fire mitigation, followed by those from Dueré and then by residents from Lagoa da Confusão. Although fires were recognized as often induced by humans, inhabitants' perceptions were mostly focused on accidental rather than intentional fire. A general lack of awareness about the wildfire risk and fire mitigation behaviours has emerged from the study. Since the study area is fire dependent (Hardesty, Jeff and Myers, Ron and Fulks 2005, Pivello 2011), improving awareness about fire management represents the most suitable solution to reduce fire impacts. The role of local inhabitants is important in order to help strike the appropriate balance between developing and conserving natural resources and managing undesired fires. Based on their educational backgrounds, training in fire prevention, control and firefighting represent the most important tools for improving awareness. In conclusion, the study demonstrates that assessing inhabitant's perceptions offers a strong contribution to the evaluation of areas that are critically exposed to fire impacts due to the lack of preparedness of local inhabitants. Since fire issues are very common in Brazil as in other prone areas, this study can be further exploited to evaluate the perceptions among citizens elsewhere. The approach used highlights aspects of weakness in training activities and suggests an improvement of policy makers' efforts to overcome these challenges. Significant improvements could be achieved by a more interdisciplinary approach in order to increase the effectiveness of perceptions evaluation.

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