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Deliberation for wildfire risk management: Addressing conflicting views in the Chiquitania, Bolivia

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Wildfires are increasingly affecting forest landscapes around the world. In the Bolivian Chiquitania, southern Amazonia, large wildfires during recent droughts have intensified public debate around more systemic solutions to address the possible root causes. While the integration of different forms of fire knowledge is gaining acceptance as an approach to dealing with increasing wildfire risk, little attention has been given to this integration in the Amazonia. In fact, mismatches between policy, science and local realities have curtailed the success of fire risk strategies in the region. To address this challenge, we conducted interviews and focus group discussions with a wide range of actors in the Chiquitania to examine different forms of knowledge and views of fire, and the extent to which these were integrated in prevalent wildfire risk strategies. We found that the risk strategies were in tension between two conflicting understandings of fire. A conceptual framework was developed to capture the configuration of knowledge underpinning this tension. Adopting a more integrated and inclusive approach to manage wildfire risk will require overcoming first this tension through a more open deliberation process within a reflexive governance framework. We proposed three "deliberation arenas" to facilitate this process, which could ultimately support more systemic, inter-cultural fire management in the Chiquitania and other landscapes with conflicting views in the Amazonia.

KEYWORDS
Amazonia, climate change, conflict transformation, reflexive governance, traditional fire knowledge, wildfire risk management

1 | INTRODUCTION

Land cover conversion, biomass build up and climate change are increasing the risk of large wildfires worldwide (Food and Agriculture Organization [FAO], 2011; Stephens et al., 2014). Large wildfires have the potential to transform forest landscapes and convert net carbon sinks to net sources, thus further contributing to global climate change (Aragão et al., 2014; Barlow et al., 2012). Characterised by their large size and high intensity, these wildfires have resulted in major environmental and socio-economic disasters (FAO, 2011). Recent wildfires in Australia, Canada, the United States, Brazil, Indonesia, Botswana, Greece, Russia and South Africa have brought to global attention the need to better anticipate and prepare for future wildfire risk.

The wildfire upsurge in the Amazonia is a case in point. Over the past three decades, wildfires in the region have increased in size and frequency, causing major socio-ecological disturbance. In future, development trajectories and climate

change interactions are expected to amplify favourable conditions for increased wildfire risk in Amazonia (Malhi et al., 2008).

While affected Amazonian countries have widely recognised the need to approach wildfire risk in an anticipatory, adaptive manner, less attention has been given to the challenges linked to dealing with a wide range of worldviews and forms of knowledge in the process, not only from different disciplinary backgrounds, but also from different groups of people concerned (Norgaard, 2004; Van den Hove, 2006). This is not easy when views and interests are contentious. In fact, the politics of knowledge production and use tend to be considered deeply problematic because they can undermine collaboration and limit adaptive capacity (Leach et al., 2007). Carmenta et al. (2011) found that the lack of inter-disciplinary and inter-cultural approaches to fire research and management has limited the capacity to address wildfire risk in tropical forests worldwide.

A narrow approach to fire management, informed by a predominant worldview, neglects the historically different forms of knowledge that have influenced wildfire management across the world. Place-based understandings of wildfire dynamics have been gained through cumulative traditional fire knowledge (TFK), defined by Huffman (2013, p. 1) as "fire-related knowledge, beliefs and practices that have been developed and applied on specific landscapes for specific purposes by long-time inhabitants." This form of knowledge, which is common to Indigenous communities, functions differently from western or scientific ecological knowledge (SEK), which is based on objective documentation of natural phenomena resulting from observation, building on theories of general interest and applicability (Lake et al., 2017; Mason et al., 2012). In many countries, TFK-based fire management changed significantly after colonisation, being partially or completely replaced by an SEK-centric management approach (Christianson, 2015; Pyne, 1994).

Although TFK has been widely studied, and traditional burning practices have been documented (Huffman, 2013), little is known about how wildfire is currently managed in Indigenous communities worldwide (Christianson, 2015). At present, TFK is influenced by changes in demographics, unsupportive policy and climate change, which are affecting the traditional cues used by long-term inhabitants to make decisions (Huffman, 2013). It is also unknown whether contemporary wildfire risk management strategies are accepted in forest-dependent Indigenous communities, which are themselves becoming highly vulnerable to increased wildfires (Christianson, 2015).

Furthermore, little attention has been given to TFK and SEK integration as a potential approach to dealing with increasing wildfire risk in future. Emerging views that elements of TFK and SEK might be complementary to deal with wildfire risk are gaining acceptance in some countries, such as the United States and Australia (Lake et al., 2017; Mason et al., 2012; Russell-Smith et al., 2013), albeit slowly, and only as targeted experiments. In the Amazonia, such integration still seems far away. In Brazil, for instance, mismatches between policy, science and local-lived realities have curtailed the success of fire risk strategies and caused instead a widespread confusion around wildfires (Carmenta et al., 2013; Mistry & Bizerril, 2011).

To tackle the above integration challenge and improve understanding of contemporary TFK, we investigate different forms of fire knowledge in the Amazonia and ways in which a more inclusive approach to wildfire risk can be achieved. To this end, we first conduct a critical examination of different local perceptions and forms of knowledge around fire, and the extent to which these relate to prevalent wildfire risk strategies. Second, we discuss the application of a reflexive governance framework for the development of a wildfire risk management approach that takes into consideration different forms of knowledge and local understandings of fire.

We build on the concept of "reflexive governance," which was recently introduced to recognise the need to consider different meanings of nature and framings of problems in decision-making processes. Reflexive governance speaks to more inclusive and deliberative forms of knowledge production where different framings are openly and interactively negotiated under a more participatory framework (Leach et al., 2010). In this study, we use the concept of reflexive governance to explore ways in which different groups of people may have different understandings of fire, and hence experience risk and value trajectories of change in different ways. We further build on this concept to propose an inter-cultural approach that can help anticipate, and collectively adapt to, increased wildfire risk in future.

2 | BACKGROUND AND METHODS

2.1 | Wildfire risk in the case study

Instead of focusing on Brazil, which is one of the most common geographic targets for wildfire research in the Amazonia (Carmenta et al., 2011), we decided to conduct the study in the Bolivian Chiquitania, southern Amazonia. The Bolivian Chiquitania is particularly susceptible to wildfires because of a marked seasonality, with severe dry seasons affecting the region in recent years (Supporting Information S1). With a drier climate, conditions for wildfires are becoming more

favourable. The wildfire peaks experienced during the 2007 and 2010 droughts provide an example of extreme events (Supporting Information S1). Seasonality is projected to intensify in future, with less rainfall from July to November (Seiler et al., 2013) when most of the fires occur in the region (Devisscher et al., 2016).

Wildfire in the Chiquitania, and in the Amazonia in general, is not only associated with climate but also, and mainly, with human activity (Bush et al., 2008). Continued immigration and rapid expansion of the agricultural frontier are expected to interact with drier climatic conditions and further increase wildfire risk in future (Devisscher et al., 2016; Pacheco & Mertens, 2004; Redo et al., 2011).

While wildfire is not new to the region, the large wildfires that affected the Chiquitania during the 2010 drought served as a "wake-up call" that the fire regime is rapidly changing with potentially serious consequences for the environment, local livelihoods and the economy. The 2010 "wildfire crisis" intensified the public debate around wildfire, which had initially started in the late 1990s (McDaniel et al., 2005). Then, awareness-raising campaigns and sanctions were introduced by the national government, yet their efficacy to reduce risk proved limited in practice (Redo et al., 2011). At present, the government is looking for more systemic solutions to address the root causes of wildfire (Ibarnegaray et al., 2014).

2.2 | Current land cover, use and tenure

The Chiquitania spreads over Bolivia, Brazil and Paraguay, linking the Amazon rainforests to the north with the Gran Chaco shrublands to the south (Vides et al., 2007). The Bolivian Chiquitania covers more than 20 million ha in the Department of Santa Cruz (Figure 1). To study the region, we used the boundaries of the Chiquitano Model Forest. Most of the Chiquitania was designated a "Model Forest" in 2005 (Vides et al., 2007). More information about the Model Forest concept is provided in Supporting Information S2. Two representative sites in the Chiquitano Model Forest (hereafter "Chiquitania") were selected: (1) the Municipality of Concepción, in the transition zone between the Chiquitano forest and the Amazon rainforest, and (2) the Municipality of Roboré, in the transition between the dry forest and the Gran Chaco (Figure 1).

The predominant natural vegetation in the Chiquitania is tropical dry forest with semi-deciduous canopy trees, interspersed with grasslands and shrubbery of the woody savanna cerrado (Killeen et al., 1998). This dry forest covers about 54% of the region (UTNIT, 2011) and is managed as a source of timber and water, for hunting, construction material and harvest of non-timber forest products (PMOT, 2011). The closed canopy forests in the Chiquitania grow on relatively fertile soils where understory presence of C4 grasses is infrequent and natural fire is rare (Dexter et al., 2015; Pennington et al., 2009). On the contrary, fire in the grasslands of the savanna cerrado is more common. Because dry forests and grasslands occur as mosaics, it is necessary to consider their interconnections at the landscape level (Dexter et al., 2015).

Land tenure in the region is concentrated in the livestock sector. The livestock and forestry sectors contribute to about 90% of the regional economy (Vides et al., 2007). As a result, land used for cattle ranching, including mixed use with forested rangeland, covered about 80% of the Chiquitania by 2010, while land used for mixed and commercial agriculture covered only 3% (UTNIT, 2011).

2.3 | Current fire use in the case study

The Chiquitania is a dynamic frontier landscape with 162,000 inhabitants at the beginning of this century (Vides et al., 2007). Although there is an important presence of Chiquitano people, the largest ethnic group currently inhabiting the region (more than 60% of the local population), several waves of migrants coming from the Bolivian highlands since the 1950s have resulted in a contemporary mixed population and new settlements (Supporting Information S3).

The Chiquitania has a long history of traditional fire use among local Indigenous communities (McDaniel et al., 2005; Pinto & Vroomans, 2007). Fire use in these communities differs from practices in more recently established settlements called intercultural communities. While farmers in Indigenous communities practice mainly shifting cultivation for subsistence, clearing 1–2 ha every two years in communal land, recently settled farmers in the inter-cultural communities produce primarily for commerce, clearing 1–5 ha per household when they obtain a permit (see Supporting Information S4 for information on regulation). In both types of community, slash and burn agriculture, locally known as *chaqueo* (Figure 2), is predominant and the use of mechanisation is minimal due to higher operational costs. The difference is that Indigenous communities have accumulated experience using fire over generations, while inter-cultural communities use fire in larger clearings without necessarily building on local TFK. In Indigenous communities, fire is traditionally used to clear land for agriculture (i.e., "conversion fire"), but also to burn waste, to cook and to manage small-scale natural grasslands and cultivated pastures for cattle.

In the specific Municipalities of Concepción and Roboré, the area occupied by agriculture-focused communities is small compared with medium- and large-scale properties used for cattle ranching, where private landholdings vary in size from
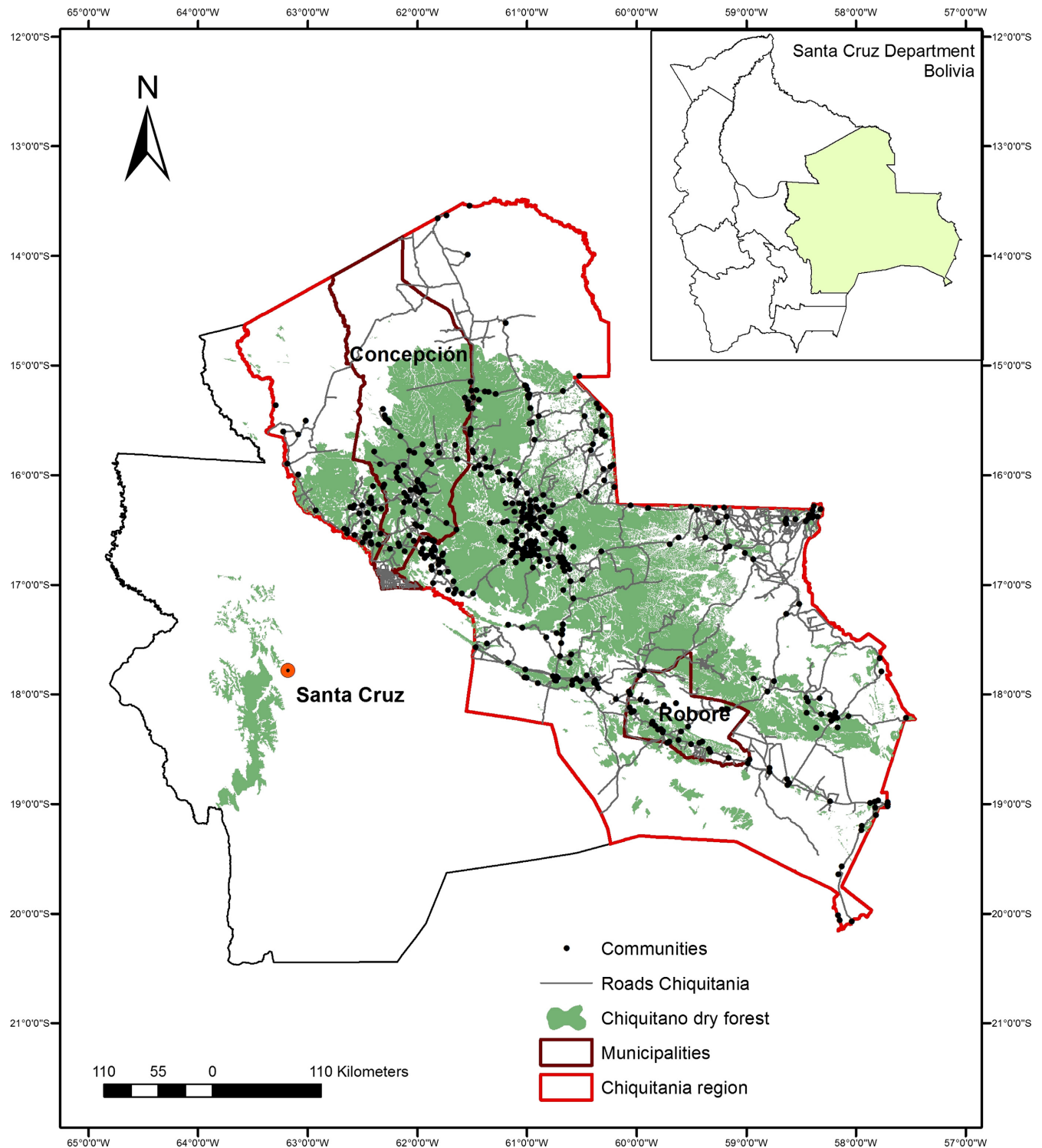
FIGURE 1 Our two study sites, Municipalities of Concepción and Roboré in the Chiquitania, Bolivia. The boundaries of the Chiquitania region are based on the Chiquitano Model Forest (Supporting Information S2). The semi-deciduous Chiquitano dry forest is defined by Navarro and Ferreira (2005). Roads and communities updated to 2008 (FCBC, 2011).

50 to 50,000 ha (Figure 2). Depending on their resource availability, private cattle ranchers may use manual or mechanised land clearing. To be cost effective, private landholders try to clear at least 20 ha if using machinery (see regulation in Supporting Information S4). In most instances, small and medium cattle ranchers hire manual labour to clear land for pastures using slash and burn. Private cattle ranchers traditionally use fire to maintain pastures (i.e., "maintenance fire"), facilitate grass regeneration, remove invasive species and eliminate pests on a periodic basis, ranging from one to five years.

FIGURE 2 Photos of characteristic landscape features in the Chiquitania region, communities and cattle. (a) Quitunukiña community (household in communal land), Roboré Municipality. (b) Middle-scale private cattle ranch (private landholding), Roboré Municipality. (c) Cleared land ready for burning (*chaqueo*) in San Andrés community, Concepción Municipality. (d) Wildfire by night, Concepción Municipality.

2.4 | Field methods

To study the different perceptions and forms of knowledge that shape the understanding of fire and ways to deal with wildfire risk, we combined in-depth, semi-structured interviews and focus group discussions with multiple actors, ranging from local fire users to municipal and national government authorities and fire researchers working in different institutes.

The interviews aimed at eliciting perceptions of fire management, including current understandings of local fire use, interests and considerations for burning. We also asked about fire accidents and views about wildfire, including causes and impacts. Interviews aimed to elicit views about wildfire risk strategies currently implemented in the region, as well as visions of the future for the Municipalities of Concepción and Roboré. Fieldwork was conducted from July to September 2013. Interviews were recorded in Spanish, and most were transcribed and translated into English using NVivo software (di Gregorio & Davidson, 2008).

Fire users we interviewed included Indigenous communities and private cattle ranchers, as presented in Table 1. We did not interview the inter-cultural communities because they were difficult to meet, as inhabitants were still constantly moving between the new settlements and their places of origin outside the region.

Semi-structured interviews were conducted in two Indigenous communities of each Municipality selected on pre-defined criteria (Table 1). While similar in terms of selection criteria, the communities showed distinct experiences with fire: San Andrés had been affected by a large wildfire in 2007; in Quitunukiña and Limoncito, a local conservation NGO was piloting activities to improve fire management since 2011; and San Fermín had not yet engaged in any formal training on fire

management. In each community, we first organised a community gathering to construct a historical profile and a community map. Households were located on the community map, and we identified clusters for spatial sampling. Ten households in each community evenly distributed across the different clusters were randomly selected for interviews.

Private cattle ranchers were categorised by size according to the number of cattle they own. We conducted interviews with 10 private cattle ranchers in each Municipality according to the proportion in each category (Table 1). The private cattle ranchers we interviewed were first identified through the local cattle rancher associations and then using snowball sampling.

Interviews were also conducted with representatives of the government and fire research and practitioner community working in the municipalities and in Santa Cruz (Table 1). In addition, we conducted participant observation (Bryman, 2012) during six local workshops and training relevant to wildfire in the study sites and Santa Cruz. These included training of fire fighters conducted by the regional government and volunteers, meetings between authorities and communities or cattle ranchers, internal community meetings and a convention to launch the Regional Fire Platform.

Finally, we facilitated focus group discussions with homogeneous groups by actor type in each municipality, selecting participants from the pool of interviewees based on pre-defined criteria (Table 1). In Santa Cruz, we conducted an additional focus group with regional authorities and research institutes. In each session, we discussed the main causes of wildfire and the different strategies envisaged or implemented to deal with wildfire risk in the region.

3 | RESULTS

3.1 | Local traditional knowledge of fire use and perceptions about wildfire

The interviews with Indigenous communities and traditional cattle ranchers revealed that fire was considered a means of life and subsistence central to the identity, culture and production systems in the Chiquitania. For them, fire had positive connotations associated with "cleaning" and "renewal." *Chaqueo* was considered a common practice and often the only affordable one. When asked about fire use, many community farmers responded, "how else are we going to produce?"

TABLE 1 Interviews and focus group discussions in Santa Cruz and the Municipalities of Roboré and Concepción

Actor group	Sampling strategy	Criteria
Indigenous communities: Limoncito (48 hh[a], Roboré) Quitunukiña (27 hh, Roboré) San Andrés (38 hh, Concepción) San Fermín (22 hh, Concepción)	Spatial sampling: 10 households per community ($n = 40$)	Representativeness of the Chiquitano Indigenous group Consolidated and recognised by the state Road accessibility during the fieldwork period Subsistence agriculture as the main livelihood complemented with other activities such as cattle ranching, forestry and cash crop
Private cattle ranchers: Large, middle and small cattle ranchers in Roboré and Concepción	Stratified and snowball sampling: 10 cattle ranchers per site ($n = 20$)	Roboré: 5% large cattle ranchers, 35% middle sized cattle ranchers, 60% small cattle ranchers Concepción: 10% large cattle ranchers, 60% middle sized cattle ranchers, 30% small cattle ranchers
Authorities and fire researchers: Representatives of government authorities and fire research community	Purposive sampling: Representatives of the government in Concepción (8), in Roboré (5), and in Santa Cruz (3), Cattle Rancher Federation (1), and practitioners/researchers (3) working on wildfire in the Chiquitania ($n = 20$)	Government entity influencing wildfire risk management decisions Research/practitioner community directly involved in studying, or influencing, local fire management
Focus groups in each case study municipality: Local authorities, communities and cattle ranchers Focus group in Santa Cruz: Regional authorities and fire practitioners/researchers	Selection of 5 persons per homogenous actor group 3 focus groups per municipality (6 in total) 1 focus group in Santa Cruz ($n = 35$)	Knowledge of the local social and ecological dynamics of wildfire Expertise with fire management Knowledge of land management systems in the region Time (greater than 10 years) working on or living in the sites

[a]Households with permanent residence in the community between 2005 and 2010. Source: PMOT (2011).
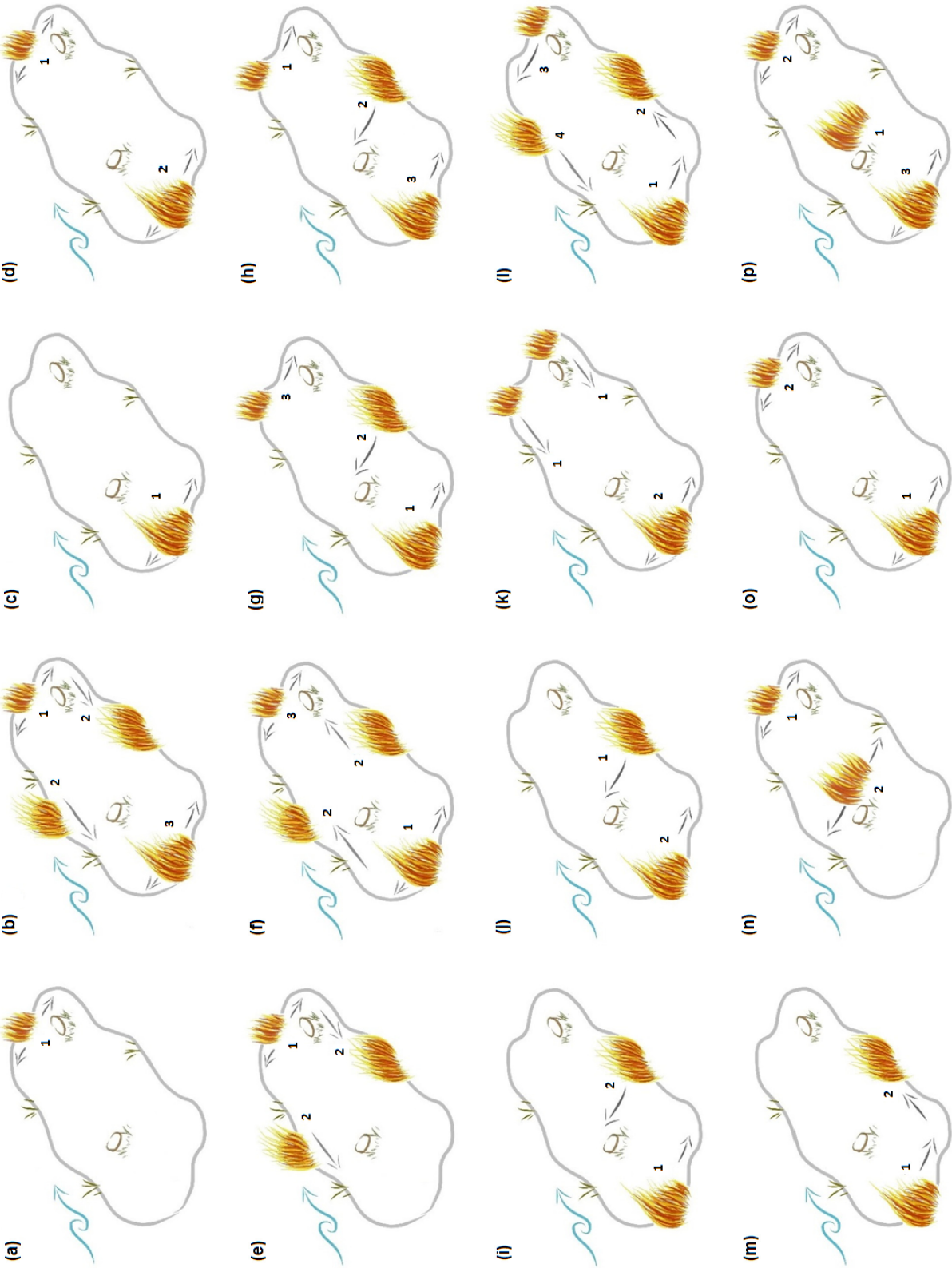
FIGURE 3 Graphical representation of different burning techniques in cleared forest plots (1–3 ha) practised by community farmers in the Municipalities of Concepción and Roboré in the Chiquitania, Bolivia. The first three graphs depict practices described more commonly in (a) San Andrés, which was affected by a large wildfire in 2007, (b) Quitunukiña, which was involved in training on controlled burning, and (c) San Fermín, which has not engaged in any training yet. Burning techniques (d) to (p) were used by farmers in different communities on different occasions, but were less common. The blue arrow represents the wind direction. Numbers next to fire ignitions show the order in which farmers would ignite different points in the plot. Grey arrows next to the numbers represent the direction in which farmers would move with the fire torch. Tree stumps represent vegetation that was slashed prior to burning.

Local farmers preferred "conversion fire" in forests (i.e., clearing of old growth forest for subsistence agriculture) to clearing in fallow land, because the former provided them access to more fertile soils and required less maintenance labour afterwards.

The practice of *chaqueo* had been passed through generations, yet burning techniques differed between and within Indigenous communities (Figure 3). Fire management knowledge was not necessarily shared as a community collective, but instead within families. A farmer in Quitunukiña explained, "The technique I use is a technique of my family … I do not know if other community people apply the same technique, each family has its own criteria."

"Maintenance fire" was used to renew and maintain pastures, and remove weeds and pests. By tradition, maintenance fire was used mainly in native grasslands, but at the time of the study, it was also observed in cultivated pastures. Cattle ranchers would practice seasonal patch mosaic burning of grass and pasture to ensure regrowth throughout the year. Although maintenance fire was commonly used among Indigenous communities and small–medium private cattle ranchers, some interviewed private ranchers criticised it for nutrient loss due to post-burn erosion.

The practice and timing of *chaqueo* were embedded in local cultural beliefs. For example, farmers explained that people who believed in the "Virgin of Fire" (associated to Saint Rose of Lima in the Christian doctrine) would burn on 30 August in hope of a good result. Most farmers would burn at the end of the dry season. While some burning happened after the first rain, most burning was planned just before the start of the rainy season when conditions would become favourable for seeding. In the case of "maintenance fire" in pastures, small private cattle ranchers indicated they burned early in the dry season. A small cattle rancher in Roboré explained the reason: "the surrounding forest is still green and there is less risk for fire to get out of control and burn the forest."

Considerations of the local biophysical environment informed burning decisions. In general, local fire users mentioned wind, solar radiation, biomass accumulation and soil conditions as important factors to consider when burning. Most farmers tended to burn between 10 a.m. and 2 p.m. with high solar radiation. They indicated that moderate wind was necessary for a good burn, otherwise vegetation would need to be cleared manually afterwards – an activity they called *chafreo* and considered resource and time intensive.

Depending on the size of the plot, local farmers would burn alone or with family members; rarely, they would ask neighbours for help. Most interviewees used some form of controlled burning. Many Indigenous farmers and private cattle ranchers used backburn (i.e., fire set downwind of the main fire for controlled fuel clearing), although this was more commonly practiced among communities that had been impacted by wildfires in the past or participated in training on improved burning (Figure 3). Due to labour constraints, most farmers opened 1–3 m wide firebreaks around the plot, despite government recommendations to open 5 m wide breaks.

In recent years, the timing of *chaqueo* has been affected by a prolonged dry period (*seca*). Farmers perceive that the onset of rains has shifted by one or sometimes even two months, significantly delaying the burning calendar and affecting production. A farmer in San Andrés explained, "Since 2000 we have had dry years, we felt the *seca* more … Then the rain would start only in December … These have been difficult years for agriculture". The burning calendar was also affected by the bureaucracy and time involved in obtaining forest-clearing permits, which have been enforced more tightly by the government since 2010. Indigenous farmers explained that delays have forced them to burn under less favourable conditions, having to invest in additional labour and resources in *chafreo*, or to completely postpone burning until the following year.

Although fire was at the core of their livelihoods, Indigenous communities and private cattle ranchers recognised that fire was multifaceted and could be detrimental when not properly managed. In general, forest fires were only considered a problem if people were affected. Indigenous farmers in Roboré and Concepción mentioned indirect negative impacts, such as affected wildlife, which in turn had an impact on their hunting and production. A farmer in Quitunukiña noted, "When pests come to eat our production it is because they have lost their own food in the forest, because of wildfires. We have seen more of this in the years with large wildfires". Forest fires also impacted human health, causing visual and respiratory problems.

Interviews revealed that "accidental fires" (i.e., when fires get out of human control and burn the forest) were experienced both during "conversion fire" and "maintenance fire". Interviewees identified human and natural causes for these accidents. Human factors included insufficient labour (i.e., farmers burning on their own or with few members), careless behaviour, lack of or inadequate firebreaks, plot size becoming larger over time and poor post-burn monitoring. Accidental fire was also attributed to poor collaboration between neighbours to burn together. Hunting and "intentional fire" (e.g., starting forest fires as a leisure activity) were also mentioned, although not all farmers shared this opinion. In an important way, interviewees recognised that human-induced accidents could be prevented.

In addition to human causes, fire users perceived that wildfire was also driven by natural factors that were impossible to control, such as a change in the wind direction or recent severe droughts. Although new roads and a higher population density were human forces, they were also perceived as drivers "out of their control". A farmer in Limoncito reflected:

> Before, like 10 years ago, we were able to burn without a firebreak, but it was not so dry like it is now. Now it is necessary to have firebreaks. Also, before we did not use to have neighbours around, so if the fire would go across it was not dangerous.

3.2 | Regional perceptions about wildfire risk

Among government agencies and regional fire researchers, the common perception is that wildfires have increased in size and intensity over time. Fire researchers/practitioners perceived that the current fire regime of the Chiquitania was characterised by a fire return interval of three to five years, which was closely linked to biomass accumulation. Representatives of the regional and national government stated that contemporary wildfires were almost entirely anthropogenic in nature. Accidental fires from *chaqueo* and pasture maintenance were perceived as the main causes of wildfire, but not the only ones. Regional government representatives and researchers also mentioned road development, more frequent droughts, and intentional fires as main drivers. Hunting was mentioned by local authorities, but the regional agencies gave it less importance.

Local authorities in Concepción and Roboré perceived that the livestock sector and the new inter-cultural communities played an increasingly important role in spreading the use of fire and increasing the overall wildfire risk in the region. An expansion in cattle ranching was expected partially because of investment from Argentina and Brazil, but also as an indirect result of stricter enforcement of forestry regulation. Increased on-the-ground inspection of environmentally responsible forestry operations was expected to shift investment from forestry towards a more lucrative livestock sector. Authorities in Concepción expressed their concern about using "maintenance fire" in increasingly large areas of grassland and pasture, as it was perceived to be more difficult to control.

Authorities also foresaw an increase in land endowment from the national government, leading to more inter-cultural communities settling in the region and accelerating deforestation and fire use. Despite migrants coming from highland areas where *chaqueo* was not used as a traditional production practice, inter-cultural communities tended to use fire to clear new land in the forest because it was considered more economic. In Concepción, a local authority manager voiced his concern, "Inter-cultural communities burn more than Indigenous communities, because they manually work larger fields for agriculture. They produce both for subsistence and commerce". Concerns about new settlements raised by local authorities in Concepción and Roboré also revealed emerging tensions around land and political power in the region.

3.3 | Wildfire risk strategies playing out in the Chiquitania

The large wildfires that affected the Chiquitania in 2010 stirred the interest of different government agencies and the public at large to work on new strategies to better address the root causes of wildfire. We found several strategies envisaged in the region, as briefly described in Table 2. Some entailed intensifying the top-down measures introduced in the late 1990s.

TABLE 2 List of wildfire risk strategies introduced in the Chiquitania, Bolivia

Strategies	Approach	Coordination agency	Operationalisation
Fire management	Bottom-up	Regional and local governments, local NGO, regional fire researchers and practitioners	Pilot actions in communities of the region
Awareness raising	Top-down	National and regional governments	National coverage through media
Regulation and monitoring	Top-down	National and regional governments Local NGO (early warning system)	National coverage, regional systems and on-the-ground operations
Fire suppression	Top-down	National government	Pilot actions (demo sites) in the region
Regional Fire Platform	Mixed	Regional government, local NGOs and regional fire researchers and practitioners	Regional coverage through meetings

Others involved new strategies that were piloted in some Indigenous communities to be up-scaled eventually as part of a new 10-year fire management programme. We considered strategies introduced at the local, regional and national levels to understand the extent to which they integrated different views and understandings of fire.

At the local level, bottom-up pilot strategies focused on improving fire management among Indigenous farmers and private cattle ranchers. In 2011, a local conservation NGO called Fundación Amigos de la Naturaleza (FAN) initiated a pilot project in the Municipality of Roboré to establish "fire committees". The Indigenous communities that were part of a fire committee were trained in improved burning techniques. Each community also had a delegate responsible for weather monitoring, a system that informed a decentralised early warning system for wildfire risk.

Through interviews with Indigenous farmers in Roboré, we found that this fire management strategy recognised the importance of fire for local producers and provided the opportunity to integrate TFK into capacity-building activities. Fire practitioners from FAN explained that "some of the traditional knowledge has to be 'updated' given the drier conditions that are increasing wildfire risk." For instance, instead of burning at noon, practitioners would recommend burning earlier in the morning or late afternoon when solar radiation and relative humidity would be less conducive to intense fires, hence reducing the likelihood of accidents. This initiative was backed up by the regional government of Santa Cruz. In Concepción, the local government tried to coordinate similar training in Indigenous communities, but this process was ad hoc and dependent on the support of a group of volunteers in the Fundación de Salvamento Ayuda y Rescate (FUNSAR).[1]

Some suggestions to modify traditional burning practices met with resistance in the Indigenous communities of Roboré. Some farmers indicated their preference to work according to their own experience and argued that some recommendations in the training (e.g., wider firebreaks) would require time and labour they could not afford. Other farmers demonstrated a lack of trust in theoretically "improved" practices, explaining that to adopt new practices they would prefer to learn by doing. A key factor that made farmers "modify" their practices (e.g., use backburn) were one-to-one exchanges with FAN technicians visiting their plots.

In an interesting manner, most significant changes in fire risk management were observed in the Indigenous community of San Andrés, which was impacted by a large wildfire in 2007. The community leader explained that his community adopted internal rules to prevent accidental fires after this serious incident:

> We did not initiate the large wildfire that affected the community and the neighbouring cattle ranch that year, but we did not like to be blamed by other communities and the Municipal authority . . . The fire that year was very large and affected our agriculture fields and pastures . . . Later, in a community gathering we decided to sign a community agreement. We set up internal rules and even an internal sanction for those who are not compliant . . . Now we notify the community leaders and our neighbours when we burn. We open firebreaks and we take water bag packs, and if there is an accident we use the bell to call the community for help. (SAA01, San Andrés, 6 September 2013)

At the regional level, the government has revised and intensified media campaigns and regulation. Most farmers and cattle ranchers we interviewed had been exposed to media campaigns through the radio, television or printed material. According to them, these campaigns had increased awareness about the negative impacts of wildfires and the need to be more careful when burning. Regulation, on the other hand, involved sanctioning and burning permits, as well as increased monitoring activities. Local authorities pointed out that, "People are more scared to burn, also because there is more presence of the state to monitor on-the-ground activities". Although this regulative strategy depended on third-party notification, many fire users admitted they were afraid of being denounced and sent to prison.

Monitoring activities also included the use of remote sensing to monitor fire occurrence. Regional fire monitoring was led by the government of Santa Cruz, with national monitoring by the Forest and Land Authority (ABT). This activity was complemented by a third monitoring system "SATRIFO" developed by FAN, which also served as an early warning system. We observed that monitoring activities were carried out independently, and the information was not always consistent across the three systems. Interviews with the ABT, FAN and the regional government revealed that there was no intention to develop an integrated monitoring system.

At the national level, the government envisaged a new strategy to suppress the use of fire with alternative, modern techniques expected to boost agricultural productivity. To this end, a programme called "Amazonia Without Fire" was launched in 2011 with funds and technical support from Brazil and Italy. The programme recognised that *chaqueo* was part of the cultural tradition in the region, but considered it an "inadequate practice and an uncontrolled phenomenon, which resulted in large forest fires in recent years" (PASF-II, 2012, p. 1). The vision of modernisation linked to

increased agriculture production was encouraged by national interests for food security and sovereignty (Law N337, 2013; Law N650, 2015).

In the Chiquitania, the "Amazonia Without Fire" programme mainly targeted the livestock sector, which could benefit from alternative techniques to increase productivity. Efforts focused on replacing traditional fire-dependent cattle ranching with mechanised intensive systems. Although private cattle ranchers in Concepción and Roboré expressed their interest in capacity building and their ambition to grow, they felt that adoption of new technology would only be possible with external financial and technical assistance. Interviews with local authorities revealed that the mechanism to introduce fire-free technology was still unclear. In a first instance, demonstrative fields were planned with support from the Municipal governments.

Finally, a recently introduced strategy was the Regional Fire Platform (RFP). Launched in 2013, the platform aimed to facilitate dialogue and coordination among all actors, regional to local, who can make a significant contribution to managing wildfire risk in the Department of Santa Cruz. The platform was endorsed by the regional government and created with support from FAN and other regional fire practitioners. Although we noticed that the RFP was well received by both public entities and civil society organisations, the focus group discussion with regional government representatives and fire researchers revealed that it had been relatively inactive since its inception due to internal politics, weak leadership and inter-institutional collaboration, and unclear operational and financial procedures.

3.4 | Tensions around wildfire

The examination above of diverse perceptions and fire risk strategies introduced at different scales has revealed that contrasting meanings attached to fire were playing out in the Chiquitania. These meanings were embedded in different worldviews of the present and the future of the region. More specifically, we found that wildfire risk strategies were subjected to two conflicting understandings of fire, as illustrated in Figure 4.

On the one hand, fire suppression strategies like the "Amazonia Without Fire" and the enforced regulation consider fire as an uncontrolled phenomenon. These strategies were built on the notion that wildfire is a threat that must be controlled, and they identified wildfire as a negative phenomenon driven by multiple causes that are highly unpredictable and difficult to manage. As a result, these strategies aimed to reduce or eradicate fire. Strategies underpinned by this narrative seem to rely heavily on formal knowledge, codified in models, maps, fire-free technological packages, remote sensing and other systems perceived to be reliable and objective by government agencies. Usually, these strategies adopted a top-down approach (Figure 4).
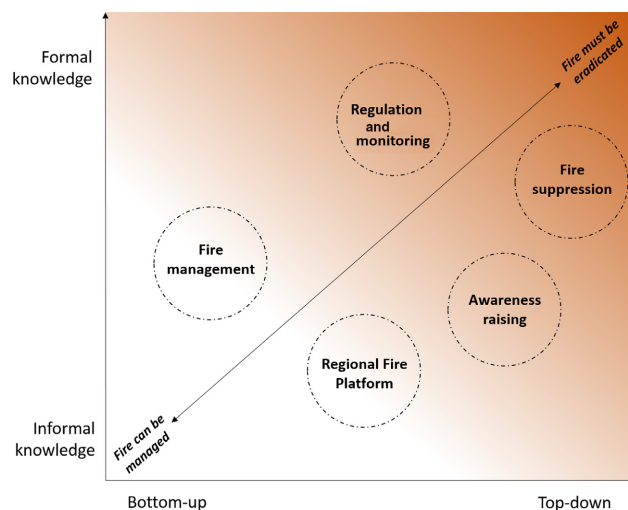

FIGURE 4 Conceptual framework developed based on the analysis of wildfire risk strategies in the Chiquitania. Strategies are mapped according to (x-axis) the approach used in their development and implementation, and (y-axis) the different forms of knowledge and perceptions of fire they consider and support. The diagonal line shows two opposing understandings of fire underpinning the risk strategies. On one extreme of the diagonal, the narrative "fire can be managed" is more closely related to bottom-up processes and informal knowledge. Some strategies, like "fire management" and the "Regional Fire Platform," build on this narrative. On the other extreme of the diagonal, the narrative "fire must be controlled" is more closely associated with top-down approaches and formalised knowledge. The "fire suppression" strategy builds more strongly on this understanding.

On the other hand, there were strategies that considered fire as necessary and manageable, and embraced the need to integrate different forms of knowledge and understandings of fire to collectively address increasing wildfire risk. The narrative underpinning these strategies recognised fire as part of the cultural identity, production force and subsistence in the Chiquitania, as well as part of the natural disturbance regime of the region. The need to improve fire management was emphasised to reduce wildfire risk in the context of drier climatic conditions, and this improvement relied strongly on a bottom-up approach where local TFK was "updated" and combined with forms of SEK through more informal and flexible processes of exchange and learning (Figure 4).

4 | DISCUSSION

4.1 | Recognising diverse forms of knowledge and ways of managing fire

This study has provided insights into contemporary TFK among traditional fire users in southern Amazonia. As in other studies of TFK (Huffman, 2013), fire users in the Chiquitania had accumulated knowledge about local burning conditions and timing, the fire regime and the consequences of not burning. Nonetheless, this knowledge was challenged by changing climatic conditions, new settlement of immigrants and command-and-control strategies more tightly enforced by the government.

Unlike other post-colonisation regions, traditional burning practices in Chiquitania have not yet lost as a result of enforced fire suppression (Huffman, 2013). However, TFK is not integrated in most of the prevalent wildfire risk strategies. In fact, the different wildfire risk strategies in the region were disconnected, and in latent tension. Strategies that built on the notion that fire must be controlled seemed particularly to widen the gap between different forms of knowledge and understandings of fire. Top-down strategies like "fire suppression," "regulation and monitoring" and "awareness raising" mainly reflected command-and-control views of the government responding to increased risk and promoting negative meanings attached to fire.

These top-down strategies favoured forms of formal SEK or "organised knowledge" (Vink et al., 2013) that would inform decisions, often building on a singular notion of "sound science" and a technocentric approach. Carmenta et al. (2011) found, for example, that remote sensing techniques were favoured by policy-makers because of their replicability and representation of a seemingly objective reality. However, these strategies increased the invisibility of the TFK of marginalised fire user groups, which became "hidden" evidence unused in policy decisions. In fact, traditional burning was viewed as a backward and inadequate practice that must be replaced. In many ways, this approach resonated with past colonial fire policies, which have extinguished traditional burning practices in Europe and many parts of the colonial world (Pyne, 1994). Huffman (2013) highlighted that central governments tend to adopt such command-and-control response during times of increased fire risk. This approach could eventually lead to an irreversible loss of TFK (Christianson, 2015), when the opposite is needed to improve congruence between fire risk strategies and the local social–ecological wildfire dynamics.

Recent evidence shows that fire suppression is not always an effective solution. Stephens et al. (2014) cautioned that it is in fact leading to increased vulnerability to larger wildfires as biomass accumulates. This was observed, for example, in fire-prone forest–grassland landscapes of Venezuela when traditional burning was forbidden (Bilbao et al., 2010; Sletto & Rodriguez, 2013). The grassland in the Chiquitania is also fire prone, and eradicating the current patch mosaic burning practices (Parr & Brockett, 1999) could result in similar perverse outcomes.

The only strategy that has explicitly tried to combine TFK and SEK is the "fire management" strategy. This strategy acknowledged the value of TFK and recognised the complex fire-mediated relationship between humans and the local environment. Although TFK was highly valued, this approach also emphasised the need to "update it," anticipating the changing conditions driven by climate change. We observed that traditional fire users were not only highly vulnerable to increased wildfire risk, they were also aware of increased climatic variation and the human-related factors that lead to fire accidents. Traditional burning practices seemed vulnerable to factors perceived as "out of control" by local fire users, with droughts particularly recognised as problematic.

Christianson (2015) pointed out the need to study the social acceptance of contemporary wildfire risk strategies among forest-dependent Indigenous communities. In our study, Indigenous communities were not able to conceive of production without the use of fire, while traditional cattle ranchers were open to fire-free technologies if support was provided. However, Indigenous communities were open to learn about new techniques for controlled burning, but their approach to learning was based on experience. They emphasised that some modification of their traditional practice would only be possible if they can see effective results, within their time and resource limitations. We also observed

that modifications were initiated by the Indigenous communities themselves, such as the case of San Andres after being affected by a large wildfire.

Pilot activities under the "fire management" strategy showed that updating TFK is feasible in ways that may enhance resilience to climate change. Such insights contribute to an incipient area of research interested in reintroducing traditional fire use to maintain cultural landscapes in the context of climate change (Huffman, 2013; Lake et al., 2017). Intentional, prescribed burning was not yet a fire risk strategy considered by the government in the Chiquitania. However, controlled burning by Indigenous farmers and traditional cattle ranchers could be considered a form of prescribed burning, particularly in fire-prone grasslands and forest edges. Much research is needed to understand the best way to make use of TFK-based prescribed burning given specific landscape configurations.

By using TFK and empowering local producers to manage their own vulnerability, the "fire management" strategy gave explanatory value to the agency of even apparently marginal actors and people at risk. Atwell et al. (2008) noted this type of agency is a key condition for successful participatory risk management. This process required catalysers, such as the local NGO FAN and the regional government, who played an important role in integrating local TFK and SEK. This flexible process exhibited the qualities of "unorganised knowledge" (Vink et al., 2013) where the focus is on learning and deliberating over the problem and solutions.

4.2 | Building on reflexive governance to manage wildfire risk

If possible, nesting the different fire risk strategies in the Chiquitania and addressing actors' specificities would help achieve more effective risk management and build "bridges of understanding" (Mason et al., 2012, p. 192) between diverse fire knowledge systems. We suggest this could be facilitated through active deliberation.

Deliberation is central to reflexive governance, which can facilitate collective solutions "not intended to reduce complexity, but to help learn better how to live with it" (Leach et al., 2007, p. 29). The main objective is to value hidden traditional, informal knowledge equally with the dominant, formal knowledge so that the former also counts as "evidence" in the decision-making. Rodriguez et al. (2013) emphasised that such a process requires deliberation about different views of fire to develop a plural approach to fire risk management. In the case of the Chiquitania, some conditions for this deliberation process are already in place, but reflexive capacity needs to be further developed. This capacity could be built through three proposed "deliberation arenas," which can reinforce each other through a cyclic process (Figure 5).

The first deliberation arena, "general awareness," involves mindfulness among the people concerned about the need for some form of change to improve risk management. This awareness may come from the realisation that the fire regime is rapidly changing, that future climatic conditions will increase risk or that incongruence between fire management policies
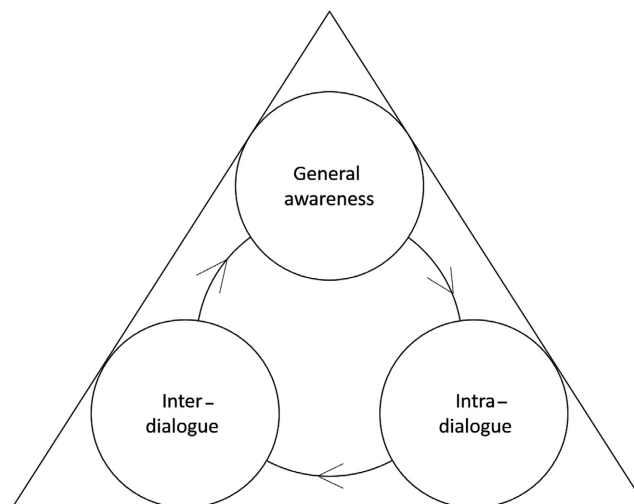

FIGURE 5 Deliberation process to overcome the latent tension created by conflicting views of fire. The process includes three deliberation arenas: general awareness (about the need for change), intra-dialogue (deliberation within a social group) and inter-dialogue (open deliberation between different social groups). These arenas are interconnected and can reinforce each other through a cyclic process (i.e., deliberation may increase awareness, which in turn may foster further deliberation).

and local-lived realities is resulting in undesirable outcomes for different groups of people affected. In the Chiquitania, the urgency to anticipate future impacts ranked fire risk management high in the 2010 political agenda and opened space for debate. The recent droughts generated enough evidence that the state alone does not have the capability to address increasingly large wildfires with conventional approaches, thus creating the need for alternative approaches and for non-state actors to be more involved in risk management.

According to Hajer and Wagenaar (2003), spaces for deliberation open in situations where there is an opportunity emerging in an institutional vacuum. In the Chiquitania, local NGOs such as FAN, which operates based on SEK but with a deep understanding of local TFK, helped raise awareness among government agencies about the need to reframe wildfire risk management and pay more attention to local social–ecological conditions and other forms of fire knowledge.

The second deliberation arena, "intra dialogue," refers to dialogue within a social group related to wildfire risk management, for example within Indigenous communities. Each group holds a different understanding of fire, but there are also conflicting views within a group. A dialogue within a group can build capacity for subsequent productive, open deliberations with other groups of actors. For example, in the Gran Sabana in Venezuela, Rodriguez et al. (2013) found that dialogue within Indigenous groups helped overcome existing struggle with conflicting intergenerational differences within the group and prepared them to engage afterwards in constructive deliberation about fire with state agencies and park rangers.

In the Chiquitania, we noticed that Indigenous people had different takes on fire risk management. One reason may be that burning practices were inherited only within families and not by community collectives, thus resulting in different practices coexisting within each community. We also observed varying appreciation for training opportunities on control burning. These diverging views would need to be first negotiated within the social group to explore common ground before joining a more open debate with other groups. Perhaps the "fire committees" could help facilitate this deliberation within Indigenous communities. The local cattle rancher associations could also help in the case of cattle ranchers.

The third deliberation arena, "inter dialogue," relates to negotiation between different social groups. According to Hajer and Wagenaar (2003), the number of perceptions and framings that are negotiated has an important bearing on the construction of collective solutions that are more just and equitable. Leach et al. (2007) argued that deliberative spaces have the potential to transform latent conflicts into circumstances where more inclusive decisions are made. Such a process could lead to what Sletto and Rodriguez (2013) termed "inter-cultural fire management". In the Chiquitania, the recently launched RFP could provide a space for open deliberation between diverse groups of actors. This in turn would increase general awareness of the issue and possible solutions (Figure 5).

Although the RFP was not fully operational at the time of this study, it was endorsed by the regional government and supported by NGOs, academia and regional fire practitioners. The platform provided the basic conditions for a more integrated and inclusive wildfire risk-management approach under a reflexive governance framework, including the ability to (1) facilitate learning, transdisciplinary research and coproduction of knowledge in an environment where different forms of knowledge are equally valued; (2) strengthen social networks and catalyse commitment to mobilise support; and (3) develop collective risk strategies that have the support of the government, as well as non-state actors.

The main challenge affecting the deliberation process outlined above will be to maintain the momentum for dialogue. It is not easy to keep the deliberation on wildfire risk high on the political agenda when economic and public focus shift to other developmental priorities. The political cycle is another limiting factor hindering the continuity required for a deliberation process that requires governmental support. Another main challenge, which calls for further research is the implication of new immigrant settlements in the region. The consequential demographic change will inevitably spread the use of fire into new forest frontiers and influence the politics of knowledge playing out in decision-making.

5 | CONCLUSIONS

In the Chiquitania region, as well as in many other forest landscapes around the world, TFK could be better used to inform and improve prevalent wildfire risk strategies. Indeed, it is ironic that TFK remains poorly integrated in contemporary risk strategies when traditional fire users have played a central role in shaping fire regimes in these landscapes. While traditional fire use in the Chiquitania is recognised, central government has favoured the adoption of command-and-control responses in the face of increased wildfire risk. Only pilot, bottom-up strategies focused on combining TFK and SEK have developed a more participatory fire risk management system adapted to local ecological and social conditions.

To facilitate a more integrated, inclusive fire risk management approach, we have first revealed the existing tension between conflicting understandings of fire in the region. We have then suggested three deliberation arenas to facilitate this process within a reflexive governance framework. Transdisciplinary research involving traditional fire users could help further expand this work. An assessment of new immigrants settling in the region and their role in influencing the politics of knowledge would also complement this study. Valuing and integrating different forms of knowledge, and understanding locally lived realities, are prerequisites for a more systemic approach to anticipate, and collectively adapt to, increased wildfire risk in future.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

ENDNOTE

[1] Observation on capacity building activity based on interviews with representatives of the regional government, local authority managers in Concepción and the leader of FUNSAR in Concepción, complemented by participant observation during fire fighter training in Roboré and Concepción.

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REFERENCES

Aragão, L. E. O. C., Poulter, B., Barlow, J. B., Anderson, L. O., Malhi, Y., Saatchi, S., Phillips, O. L., & Gloor, E. (2014). Environmental change and the carbon balance of Amazonian forests. *Biological Reviews*, 89, 913–931. https://doi.org/10.1111/brv.12088

Atwell, R. C., Schulte, L. A., & Westphal, L. M. (2008). Linking resilience theory and diffusion of innovations theory to understand the potential for perennials in the U.S. Corn Belt. *Ecology and Society*, 14, 30.

Barlow, J., Parry, L., Gardner, T. A., Ferreira, J., Aragão, L. E. O., Carmenta, R., Berenguer, E., Vieira, I. C. G., Souza, C., & Cochrane, M. A. (2012). The critical importance of considering fire in REDD+ programs. *Biological Conservation*, 154, 1–8. https://doi.org/10.1016/j.biocon.2012.03.034

Bilbao, B., Leal, A., & Mendez, C. (2010). Indigenous use of fire and forest loss in Canaima National Park, Venezuela: Assessment of and tools for alternative strategies of fire management in Pemon Indigenous lands. *Human Ecology*, 38, 663–673. https://doi.org/10.1007/s10745-010-9344-0

Bolivia Law N337 2013 Ley de Apoyo a la Produccion de alimentos y restitucion de bosques. La Asamblea Legislativa Plurinacional (2013). Retrieved from http://www.lexivox.org/norms/BO-L-N337.xhtml

Bolivia Law N650 2015 Agenda Patriótica del Bicenternario 2025. Ministerio de Autonomías. (2015). Retrieved from http://www.lexivox.org/norms/BO-L-N650.xhtml

Bryman, A. (2012). *Social research methods*. Oxford, UK: Oxford University Press.

Bush, M. B., Silman, M. R., McMichael, C., & Saatchi, S. (2008). Fire, climate change, and biodiversity in Amazonia: A late-Holocene perspective. *Philosophical Transactions of the Royal Society B*, 363, 1795–1802. https://doi.org/10.1098/rstb.2007.0014

Carmenta, R., Parry, L., Blackburn, A., Vermeylen, S., & Barlow, J. (2011). Understanding human-fire interactions in tropical forest regions: A case for interdisciplinary research across the natural and social sciences. *Ecology and Society*, 16, 53. https://doi.org/10.5751/es-03950-160153

Carmenta, R., Vermeylen, S., Parry, L., & Barlow, J. (2013). Shifting cultivation and fire policy: Insights from the Brazilian Amazon. *Human Ecology*, 41, 603–614. https://doi.org/10.1007/s10745-013-9600-1

Christianson, A. (2015). Social science research on Indigenous wildfire management in the 21st century and future research needs. *International Journal of Wildland Fire*, *24*, 190–200. https://doi.org/10.1071/WF13048

Devisscher, T., Anderson, L. O., Aragão, L. E., Galván, L., & Malhi, Y. (2016). Increased wildfire risk driven by climate and development interactions in the Bolivian Chiquitania, Southern Amazonia. *PLoS ONE*, *11*, 0161323. https://doi.org/10.1371/journal.pone.0161323

Dexter, K., Smart, B., Baldauf, C., Baker, T. R., Balinga, M. P., Brienen, R. J. W., Fauset, S., Feldpausch, T. R., Ferreira-da Silva, L., Muledi, J. I., Lewis, S. L., Lopez-Gonzalez, G., Marimon-Junior, B. H., Marimon, B. S., Meerts, P., Page, N., Parthasarathy, N., Phillips, O. L., Sunderland, T. C. H., Theilade, I., Weintritt, J., Affum-Baffoe, K., Araujo, A., Arroyo, L., Begne, S. K., Neves, E. C-. D., Collins, M., Cuni-Sanchez, A., Djuikouo, K. M-N., Elias, F., Foli, E. G., Jeffery, K. J., Killeen, T., Malhi, Y., Maracahipes, L., Mendoza, C., Morandi, P., Santos, C. O.-D., Parada-Gutierrez, A., Pardo, G., Peh, K. S. H., Salomão, R. P., Silveira, M., Sinatora Miranda, H., Silk, J. W. F., Sonke, B., Taedoumg, H. E., Toledo, M., Umetsu, R. K., Villaroel, R. G., Vos, V., White, L. J. T., & Pennington, R. T. (2015). Floristics and biogeography of vegetation in seasonally dry tropical regions. *International Forestry Review*, *17*, 10–32 https://doi.org/10.1505/146554815815834859

FCBC (2011). Dataset shared by the organisation under a Memorandum of Understanding Fundación para la Conservación del Bosque Chiquitano. Retrieved from http://www.fcbc.org.bo

Food and Agriculture Organization (FAO) (2011). *Findings and implications from a coarse-scale global assessment of recent selected mega-fires*. Paper presented at the 5th International Wildland Fire Conference, 9-13 May, Sun City.

di Gregorio, S., & Davidson, J. (2008). *Qualitative research design for software users*. New York, NY: Open University Press.

Hajer, M., & Wagenaar, H. (2003). Introduction. In: M. Hajer & H. Wagenaar (Eds.), *Deliberative policy analysis: Understanding governance in the network society*. (pp. 1–30). Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/CBO9780511490934.002

Huffman, M. R. (2013). The many elements of traditional fire knowledge: Synthesis, classification, and aids to cross-cultural problem solving in fire-dependent systems around the world. *Ecology and Society*, *18*, 3. https://doi.org/10.5751/es-05843-180403

Ibarnegaray, V., Pinto, C., & Rodriguez-Montellano, A. (2014). *El manejo comunitario del fuego: un enfoque participativo para la gestión de incendios forestales en Bolivia* (FAN Policy Brief). Retrieved from www.fan-bo.org/wp-content/files/policybriefMCF.pdf

Killeen, T., Jardim, A., Manami, F., Saravia, P., & Rojas, N. (1998). Diversity, composition, and structure of a tropical deciduous forest in the Chiquitania region of Santa Cruz, Bolivia. *Journal of Tropical Ecology*, *14*, 803–827. https://doi.org/10.1017/s0266467498000583

Lake, F. K., Wright, V., Morgan, P., McFadzen, M., McWethy, D., & Stevens-Rumann, C. (2017). Returning fire to the land: Celebrating traditional knowledge and fire. *Journal of Forestry*, *115*, 343–353. https://doi.org/10.5849/jof.2016-043r2

Leach, M., Bloom, G., Ely, A., Nightingale, P., Scoones, I., Shah, E., & Smith, A. (2007). Understanding Governance: Pathways to Sustainability (STEPS Working Paper). Brighton, UK: 2 STEPS Centre.

Leach, M., Scoones, I., & Stirling, A. (2010). *Dynamic sustainabilities. Technology, environment, social justice*. London, UK: Earthscan.

Malhi, Y., Roberts, J. T., Betts, R. A., Killeen, T. J., Li, W., & Nobre, C. (2008). Climate change, deforestation, and the fate of the Amazon. *Science*, *319*, 169. https://doi.org/10.1126/science.1146961

Mason, L., White, G., Morishima, G., Alvarado, E., Andrew, L., Clark, F., Durglo, M., Durglo, J., Eneas, J., Erickson, J., & Friedlander, M. (2012). Listening and learning from traditional knowledge and Western science: A dialogue on contemporary challenges of forest health and wildfire. *Journal of Forestry*, *110*, 187–193. https://doi.org/10.5849/jof.11-006

McDaniel, J., Kennard, D., & Fuentes, A. (2005). Smokey the tapir: Traditional fire knowledge and fire prevention campaigns in lowland Bolivia. *Society and Natural Resources: An International Journal*, *18*, 921–931. https://doi.org/10.1080/08941920500248921

Mistry, J., & Bizerril, M. (2011). Why it is important to understand the relationship between people, fire and protected areas. *Biodiversidade Brasiliera*, *2*, 40–49.

Navarro, G., & Ferreira, W. (2005). *Caracterización de complejos de vegetación y unidades puras del bosque seco Chiquitano*. Santa Cruz, Bolivia: Fundación para la Conservación del Bosque Chiquitano.

Norgaard, R. B. (2004). Learning and knowing collectively. *Ecological Economics*, *49*, 231–241. https://doi.org/10.1016/j.ecolecon.2004.03.021

Pacheco, P., & Mertens, B. (2004). Land use change and agricultural development in Santa Cruz, Bolivia. *Bois et Forêts des Tropiques*, *280*, 30–40.

Parr, C. L., & Brockett, B. H. (1999). Patch-mosaic burning: A new paradigm for savanna fire management in protected areas? *Koedoe*, *42*, 117–130. https://doi.org/10.4102/koedoe.v42i2.237

PASF-II (2012). Programa 'Amazonia sin Fuego FASE II' (PASF-II). Retrieved from http://www.cooperazioneallosviluppo.esteri.it/pdgcs/Documentazione/BandiAvvisi/2012-07-04_Amazonia_programma.pdf

Pennington, R. T., Lavin, M., & Oliveira-Filho, A. T. (2009). Woody plant diversity, evolution, and ecology in the tropics: Perspectives from seasonally dry tropical forests. *Annual Review of Ecology, Evolution, and Systematic*, *40*, 437–457. https://doi.org/10.1146/annurev.ecolsys.110308.120327

Pinto, C., & Vroomans, V. (2007). *Chaqueos e Incendios Forestales en Bolivia*. Santa Cruz, CA: Instituto Boliviano de Investigación Forestal.

PMOT (2011). *Plan Municipal de Ordenamiento Territorial (PMOT) 2011–2021 del Municipio de Concepción*. Santa Cruz, Bolivia: Gobierno Municipal de Concepción.

Pyne, S. (1994). Maintaining focus: An introduction to anthropogenic fire. *Chemosphere*, *29*, 889–911. https://doi.org/10.1016/0045-6535(94)90159-7

Redo, D., Millington, A. C., & Hindery, D. (2011). Deforestation dynamics and policy changes in Bolivia's post-neoliberal era. *Land Use Policy*, *28*, 227–241. https://doi.org/10.1016/j.landusepol.2010.06.004

Rodriguez, I., Sletto, B., Bilbao, B., & Leal, A. (2013). *'Opening up' fire conflicts: Reflexive governance and transformative knowledge networks in culturally fragile indigenous landscapes* (STEPS Working Paper 54). Brighton, UK: STEPS Centre.

Russell-Smith, J., Cook, G. D., Cooke, P. M., Edwards, A. C., Lendrum, M., Meyer, C. P., & Whitehead, P. J. (2013). Managing fire regimes in north Australian savannas: Applying Aboriginal approaches to contemporary global problems. *Frontiers in Ecology and the Environment*, *11*, https://doi.org/10.1890/120251

Seiler, C., Hutjes, R. W., & Kabat, P. (2013). Likely ranges of climate change in Bolivia. *American Meteorology Society*, *52*, 1303–1317. https://doi.org/10.1175/jamc-d-12-0224.1

Sletto, B., & Rodriguez, J. (2013). Burning, fire prevention and landscape productions among the Pemon, Gran Sabana, Venezuela: Toward an intercultural approach to wildland fire management in Neotropical Savannas. *Journal of Environmental Management*, *115*, 155–166. https://doi.org/10.1016/j.jenvman.2012.10.041

Stephens, S. L., Burrows, N., Buyantuyev, A., Gray, R. W., Keane, R. E., Kubian, R., Liu, S., Seijo, F., Shu, L., Tolhurst, K. G., & van Wagtendonk, J. W. (2014). Temperate and boreal forest mega-fires: Characteristics and challenges. *Frontiers in Ecology and the Environment*, *12*, 115–122. https://doi.org/10.1890/120332

UTNIT (2011). Mapa de cobertura y uso actual de la tierra, Bolivia. COBUSO 2010. Unidad Técnica Nacional de Información de la Tierra. Retreived from http://cdrnbolivia.org/geografia-fisica-nacional.htm

Van den Hove, S. (2006). Between consensus and compromise: Acknowledging the negotiation dimension in participatory approaches. *Land Use Policy*, *23*, 10–17. https://doi.org/10.1016/j.landusepol.2004.09.001

Vides, R., Reichle, S., & Padilla, F. (2007). *Planificación ecorregional del Bosque Seco Chiquitano*. Santa Cruz, Bolivia: Fundación para la Conservación del Bosque Chiquitano (FCBC).

Vink, M. J., Dewulf, A., & Termeer, C. (2013). The role of knowledge and power in climate change adaptation governance: A systematic literature review. *Ecology and Society*, *18*, 46. https://doi.org/10.5751/es-05897-180446

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Supporting Information S1. Climate in the Chiquitania.

Supporting Information S2. The concept of Model Forest.

Supporting Information S3. Past land occupation and migration to the Chiquitania.

Supporting Information S4. Bolivian regulation on forestland clearing.