Burning perceptions that integrate wellbeing and ecosystem services to inform fire governance in the Peruvian Andes

Abstract

Fire is an essential tool enabling tropical subsistence agriculture, but can escape beyond its intended borders when not adequately controlled. Indeed this risk may be increasing under changing ecological and climatic shifts with implications for what constitutes adequate fire management. Understanding the perceptions of key actors about the role of fire and effective management is a crucial step in fire governance because it exposes views and can facilitate transparent decision-making and conflict management. Drawing on frameworks of wellbeing and ecosystem services, we conducted Q methodology with 56 fire users and managers, including subsistence-based Quechua farmers, firefighters, researchers, nonprofit staff, and government agents. Factor analysis revealed three distinct viewpoints on the role of fire, ranging from emphasizing the negative impacts of escaped fires on ecosystem services (e.g., on biodiversity and climate change impacts) to acknowledging benefits of intentional fires for rural wellbeing (e.g., that agricultural burns open new farmland or fire as the most accessible way to work the farm). We also found three viewpoints regarding fire management deemed effective: top-down fire suppression, community-based fire suppression, and community-based fire management. Integrating these diverse perspectives, actionable insights for decision making should include: legal recognition of traditional controlled burns, training programs that support volunteer community fire brigades, and the integration of integrated fire management solutions at multiple scales (community, district, regional, and national). Our analysis, grounded in the Peruvian Andes, suggests pathways for effective fire governance that can reconcile the different needs, uses, and types of fire.

Keywords: fire governance, community-based fire management, wellbeing, ecosystem services, Q methodology.

Highlights:

- Some actors emphasized the burdens of fire and others acknowledged its benefits.
- Viewpoints ranged from top-down fire suppression to community-based management.
- Some actors advocated for promoting safe use of agricultural burns.
- Effective fire governance requires reconciling the different needs of key actors.

1. Introduction

Wildfires are a growing global environmental concern and are considered a rising threat in many nations. Intense wildfires influenced by droughts and strong winds, create serious harm to local communities, economies, ecosystems, and public health (Barlow et al., 2020; Johnson & Dearden, 2009; Reid et al., 2016; Sorrensen, 2009). At the same time, intentional fire use is essential to numerous Indigenous Peoples and local communities practicing tropical subsistence agriculture and is a longstanding intergenerational, and accessible way of releasing nutrients, controlling pests and weeds, and thereby preparing new farmland (Bowman et al., 2011; Padoch & Pinedo-Vasquez, 2010; Sorrensen, 2004). Crucially, small-scale traditional farmers have been historically and often still are condemned for their use of fire in land preparation (Carmenta et al., 2021; Dressler et al., 2021; Moura et al., 2019). In more recent years, agricultural burns and other ignition sources have increasingly affected fire regimes - described as the frequency, intensity, severity, and seasonality of fire- in all tropical ecosystems (Armenteras et al., 2020; Johansson et al., 2020; Shlisky et al., 2009). Further, the risk that intentional

agricultural burns may result in escaped or 'wild' fires is likely increasing due to externally driven changes in global and regional climate and socioecological conditions (Bowman et al., 2011; Chen et al., 2011; Herawati & Santoso, 2011; IPCC, 2021).

Globally, societies have responded to the threat of escaped fire with varying levels of fire suppression and prevention strategies (Cochrane & Bowman, 2021; Moore, 2019). Numerous failures of fire prohibition responses are documented, while the harms of blanket condemnation of traditional fire use have been recognized alongside the clear benefits of intentional fire (Croker et al., 2024; Martinez et al., 2023; Moura et al., 2019). Calls have increased for new practices and paradigms on fire management, which is the process of planning, controlling, and monitoring fires to prevent destructive wildfires, support ecological health, and balance safety with sustainable land-use practices (Myers, 2006). New approaches should incorporate Indigenous and local ecological knowledge (McKemey et al., 2020; Mistry et al., 2016; Perry et al., 2018; Rodríguez et al., 2011; Welch, 2015), avoid overcriminalization of fire-related practices (Carmenta et al., 2019; Moura et al., 2019), target specific fire types and users (Barlow et al., 2020; Carmenta et al., 2017; Jefferson et al., 2020), and promote bottom-up fire management (Cammelli et al., 2019; Martinez-Torres et al., 2018; Monzón-Alvarado & Keys, 2016). For example, Indigenous and traditional fire practices and knowledge have been incorporated into national fire management, particularly in northern Australia, southern Africa, and Brazil (Moura et al., 2019; Ockwell, 2008; Oliveira et al., 2022). These practices are also increasingly recognized across the world through a number of international networks of knowledge exchange, such as the integrated fire management network (FIRE-ADAPT) and the FAO's global fire management hub.

Fire governance involves diverse layers of decision-makers and key actors to determine both the social and ecological role of fire and how to manage it (Moore, 2019; Scott et al., 2014). Fire governance has tended to be polarized and politically embedded in heavily divergent views on the role of fire types and uneven distribution of the benefits and negative impacts of both intentional and escaped fires (Brenkert-Smith et al., 2017; Cammelli et al., 2019; Carmenta et al., 2017). The distribution of impacts experienced by stakeholders in relation to fire types influences what management decisions they support and find acceptable. Understanding actor perceptions is a crucial step in unlocking effective and just fire governance with the goal of enhancing the positive contributions of fire and reducing their negative impacts. It has proven effective in a number of environmental governance arenas including understanding policy context and facilitating communication and transparent decision-making (Brugha & Varvasovszky, 2000; Prell et al., 2009; Reed et al., 2009).

In the southern Peruvian Andes particularly, a considerable extent of the land is collectively owned and managed by Quechua communities with high levels of collective participation in natural resource management (Diez, 2012; SICCAM, 2017). As in many tropical countries, agricultural burns are currently prohibited because of the perceived problems they generate when not adequately controlled (Law-29263, 2008; MINAGRI, 2012). As a result, there is a prevailing narrative among government officials and the general public that small-scale farmers engage in inappropriate or ineffective use of fire. Various government entities, often with scarce resources, are charged with wildfire prevention and control actions. These include the Peruvian Forest Service, the Peruvian Protected Natural Areas Service, and risk management offices at different government levels. Official firefighting efforts are carried out by the Peruvian Firefighter Company, a civil society institution that tackles urban (structural) as well as wildland fires. However, escaped fires are generally fought and brought under control by rural communities, due to a lack of government resources and the remoteness dictated by Andean topography. A few environmental nonprofit organizations have begun working in the last decade with local communities on wildfire prevention and control, particularly in Andean communities that harbor native forests within their territories and are proximate to natural protected areas.

We aim to shed light on how key actors (from Indigenous Quechua farmers to government officials) prioritize the benefits and negative impacts of fire types employing complementary frameworks of wellbeing and ecosystem services. This approach offers a novel way to examine the role of fire within livelihoods and ecosystems by assessing how key social actors weigh its positive and negative impacts. We also aim to identify which of the various fire management strategies are considered more effective by these actors and where agreement lies between them. We use the southern Peruvian Andes as a case study because, even though the ecological role of fire has increasingly garnered research attention (Oliveras et al., 2017; Román-Cuesta et al., 2014), how humans interact with fire has rarely been investigated. The following research questions guided our contribution:

- How do different actors perceive and prioritize the benefits and negative impacts of fire types?
- What are the distinctions and similarities in preferences for current and potential fire management strategies?
- What is the relationship between how actors prioritize the benefits and negative impacts of fire types and their preferred management strategies?

2. Theoretical foundations

2.1. Wellbeing and Ecosystem Services Frameworks to evaluate perceptions of the role of fire types

Jointly, wellbeing and ecosystem services frameworks can be used to understand differentiated viewpoints on the role of fire in rural ecosystems and livelihoods. For all rural communities, human wellbeing is inescapably connected with the land and its ecosystem services (Russell et al., 2013). How diverse key actors prioritize both the benefits and negative impacts of fire types can inform their preferred fire management strategies. Our study distinguishes between two types of fires: agricultural burns and escaped fires, noting that agricultural burns are the primary source of uncontrolled or 'wild' fires in tropical regions (Cochrane, 2009).

While the use of wellbeing frameworks is relatively common in social and development policy and practice (White, 2010), they have recently been embraced in the realm of biodiversity conservation (Biedenweg & Gross-Camp, 2018; Mbaru et al., 2021; Milner-Gulland et al., 2014; Woodhouse & McCabe, 2018). Within these frameworks, relying solely on the material dimension of wellbeing has shifted to also include subjective and relational dimensions. Such multidimensional approaches include the evaluation of i) material assets and standards of living, ii) relational elements such as social relations, access to public services, and personal relationships, and iii) subjective indicators such as their perceptions, values, ideologies, and beliefs (Gough & McGregor, 2007; White, 2010).

Intentional fires can offer benefits across all dimensions of human wellbeing and, in fire-adapted systems, they are necessary for ecosystem function and renewal. For example, material benefits of agricultural burns are related to opening up farmland, enhancing nutrient availability to crops, and reducing weeds and pests that damage production (Bowman et al., 2011; Padoch & Pinedo-Vasquez, 2010; Sorrensen, 2004). Some relational benefits include that burning can be a traditional, sometimes collective activity, and that fire-based agriculture is foundational to the persistence and autonomy of Indigenous and local communities across the tropics (Nikolakis et al., 2020). In the subjective dimension, using fire, versus more costly fire-free alternatives, makes agricultural production more feasible and can be part of a farmer's identity (Huffman, 2013). Yet, intentional fires can escape and incur harms such as economic loss (material), forced out-migration and social conflict (relational), and fear related to the risk that fires may escape or that there may be related sanctions and blame (subjective) (Carmenta et al., 2021; Dressler et al., 2021).

The Millennium Ecosystem Assessment determined four ecosystem services types to understand how their changes affect human wellbeing (Millennium Ecosystem Assessment, 2005). Provisioning services are associated with the supply of material goods; regulating services, with the regulation of natural processes; cultural services, with the nonmaterial benefits that humans might experience from their natural environment; and supporting services, with the underlying ecological functions that sustain all others. In either fire-sensitive or fire-dependent ecosystems, changes in fire frequency, intensity, and seasonality can negatively impact ecosystem services: Escaped fires can destroy crops, livestock forage, timber, and water sources (provisioning), and disrupt water cycling and soil stability, leading to erosion, sedimentation in rivers, and increased carbon emissions that drive climate change (regulating). Fires can also damage sacred sites, and recreational spaces (cultural), while also degrade soil health and biodiversity, impairing nutrient cycling and long-term ecosystem resilience (supporting) (Carmenta et al., 2021; Cochrane & Bowman, 2021; Gillson et al., 2019; McLauchlan et al., 2020; Pausas & Keeley, 2009; Shlisky et al., 2009).

When different actors consider fire's impact, there is often tension between those who prioritize ecosystem services and those who emphasize the positive effects of fire on human wellbeing. Advocates focused on ecosystem services may stress regulating services, like climate stability, air quality, and erosion control; viewing uncontrolled fire as a threat that disrupts natural processes and reduces biodiversity, ultimately endangering long-term environmental resilience (Keating, 2007; Martin et al., 2016). In contrast, others could see fire as integral to wellbeing, particularly its positive impacts on material and relational aspects of life. These actors, including for example fire users, might emphasize that controlled burns can provide immediate, tangible benefits, such as increased crop yields and pest control, which are essential for material wellbeing (Bilbao et al., 2019; Carmenta et al., 2013; Huffman, 2010; Mistry et al., 2016). Moreover, for many, fire is tied to cultural identity and traditional land management practices that strengthen community bonds and uphold relational wellbeing (Daeli et al., 2021; Greenler et al., 2024; Hoffman et al., 2022; Martinez et al., 2023).

2.2.Top-Down Fire Suppression versus Community-based or Integrated Fire Management

Top-down fire suppression typically involves fire bans dictated by higher levels of government and efforts to rapidly detect, control, and extinguish wildfires. Current suppression policies were initiated during colonial rule, intended to modernize traditional land management and to protect standing stocks of natural resources that were seen as the possession of the state (Humphrey et al., 2021; Keating, 2007; Martinez et al., 2023; Moura et al., 2019). In some contexts, fire suppression has resulted in changed vegetation loads that fuel very intense fires worldwide (Bowman et al., 2011). In other regions, especially in tropical countries, people have continued to use fire for small-scale traditional agriculture, even though it has been broadly prohibited by central governments (Carmenta et al., 2019; Cochrane & Bowman, 2021; Daeli et al., 2021; Moura et al., 2019).

Both integrated and community-based fire management have been promoted as solutions to complex isses related with fire. Integrated fire management (IFM) is a holistic approach to managing fire that combines fire prevention, preparedness, suppression, and recovery strategies. Unlike traditional fire suppression alone, IFM aims to balance the ecological role of fire with the need to protect communities, natural resources, and biodiversity (Lotan, 1979; Myers, 2006; Rego et al., 2010). Integrated solutions to the wildfire issue require appropriate assessment of the ecological role and plural impacts of different fire types; the social, cultural, and economic context in which fire occurs; and the reasons for and practices of burning (Moore, 2019; Myers, 2006). At its core is an emphasis on the local context, from which management strategies can then be articulated at higher levels of governance (Gillson et al., 2019; Moore, 2019).

Community-based fire management (CBFiM) consists of any community-based efforts to use fire in safe and effective ways as part of their livelihoods, sometimes with the use of traditional fire knowledge (FAO, 2011). IFM and CBFiM are closely related approaches that complement each other, with CBFiM often acting as a fundamental component of IFM. CBFiM is centered around local community participation and it prioritizes empowering communities to manage fires using their knowledge, practices, and resources (Huffman, 2013; Mistry et al., 2016; Schmidt et al., 2018). We refer here to a type of community-based fire management related to local communities in the Global South, that are characterized by small-scale subsistence production and often significant rights over the management of natural resources (RRI, 2014).

3. Case study: southern Peruvian Andes

Fire suppression is the dominant government response to wildfires in the Peruvian Andes, including firefighting efforts and the prohibition of fire use (SERFOR, 2017). Since 2008, burns of agricultural residue and escaped fires are both prohibited under current agrarian and forestry laws (Law-29263, 2008; MINAGRI, 2012). On paper, the forestry law punishes people who let fires escape with huge fines and jail penalties (up to 7 years), though these sanctions are rarely enforced. In addition to sanctions, various government entities work on wildfire prevention and control actions, such as firefighting and educational activities, albeit with scarce resources. These entities include SERFOR (Peruvian Forest Service), SERNANP (Peruvian Protected Natural Areas Service), and risk management offices at different government levels (district, provincial, and regional). Coordination between these entities is limited to when wildfires reach such a magnitude as to affect areas within various jurisdictions, especially protected areas or archaeological sites. In general, fire awareness campaigns that discourage both agricultural burns and escaped fires are widely applied by most government and other external (to rural communities) actors interested in wildfire prevention and control.

The Peruvian Firefighter Company (‘*compañía de bomberos*,’ in Spanish), a civil society institution, has traditionally fought urban and wildland fires. A small number of others trained in wildfire fighting are found in some municipalities and protected areas. The limited support from the government has pushed the Firefighter Company, in the last few years, to seek collaboration with nonprofit organizations and international cooperation, such as the US Forest Service, to receive specialized training on wildland firefighting. Even so, escaped fires are fought back mainly by rural people, due to a lack of government resources and remoteness dictated by Andean topography. Since 2021, the regional government in Cusco has trained several firefighting brigades in campesino communities, which is the first regional-based effort to strengthen local capacity in fire control.

Peru has more than nine thousand legally recognized rural communities, which include over three million Indigenous Peoples and mestizos involved in small-scale farming (National Institute of Statistics and Informatics-INEI, 2018). Rural communities located in the Andes are termed *‘comunidades campesinas’* and are important suppliers of food consumed in the country (Diez, 2012). According to the Peruvian Law of Campesino Communities - Law No. 24656 (El Peruano 1987), these communities are organizations composed of families inhabiting territories linked by social, economic and cultural ties, which are expressed in the communal property of the land, mutual aid, and democratic governance. Recognized community lands are owned and managed collectively, but some portions (parcels) can be allocated to individual community members whereby a property title is in the name of the community, but individuals receive a non-transferable ‘possession certificate.’ Other portions of the communal land are used jointly by all members, such as highland pastures for livestock grazing and exotic tree plantations (Diez, 2012; Eguren et al., 2009).

Most Peruvian wildfires occur in the high Andes, in elevations between 1500 and 4000 meters (Zubieta et al., 2023). Annual fire frequency is highly influenced by changes in cumulative precipitation and drought parameters, which are strongly related to El Niño events (All et al., 2017; Bradley & Millington, 2006; Oliveras et al., 2014; Zubieta et al., 2023; Zubieta et al., 2021). Small-scale agricultural burns are the main source of escaped fires in this area (SERFOR, 2017). Agricultural fields are embedded in landscapes of puna grassland and scattered shrubland. High Andean communities located on the eastern slope of the Andes hold some patches of montane cloud forests, which contain fire-sensitive species (Oliveras et al., 2017).

4. Methods

To identify viewpoints of relevant actors about the role of fire types and effective fire management, we applied Q methodology, which gathers specific and quantifiable information about respondents' opinions through ranking of a set of fixed statements (Addams & Proops, 2000; Brown, 1996; Dasgupta & Vira, 2005; Ramlo, 2016). It provides a systematic and rigorous semi-quantitative method for examining human subjectivity that helps identify and understand similarities and differences in key actor positions (Brown, 1996). Q methodology does not provide generalizable results to an entire population because it relies on purposeful samples, but it does give an approximation of the diversity of viewpoints existing in a particular set of key actors, in this case, within the southern Peruvian Andes.

4.1.Preliminary entry

We identified two campesino communities and their related sets of external institutions from two regions, Apurimac and Cusco, with similar landscape, socioeconomic, and wildfire risk characteristics (Figure 1). Both communities were located between 2300 and 3800 meters above sea level and adjacent to a natural protected area: Manu National Park (in Cusco) and Ampay National Sanctuary (in Apurimac), respectively. Each was composed of 200 to 300 farm families that relied on small-scale agriculture mainly the cultivation of maize (*Zea mays*), potatoes (*Solanum tuberosum*), barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), fava beans (*Vicia faba*), oats (*Avena sativa*), olluco (*Ullucus tuberosus*), alfalfa (*Medicago sativa*), quinoa (*Chenopodium quinoa*), beans (*Phaseolus vulgaris*), and tarwi (*Lupinus mutabilis*), in addition to extensive cattle and sheep ranching. Farmers used fire to expand farmland (Figure 1, a & d) and, within cultivated fields, to clear agricultural residue and unwanted vegetation (Figure 1, b & c) (Luna-Celino & Kainer, 2024). Each community was embedded in landscapes of puna grassland, montane cloud forests, and scattered shrubland. Each community had been collaborating on fire-related actions for about 15 years with external institutions such as environmental nonprofit organizations and agents from protected areas and local government. These partner nonprofit organizations have implemented various forest conservation and climate change adaptation programs over the years, including training of communal firefighting brigades and native trees restoration in areas affected by wildfires.

Prior to data collection we conducted scoping activities to engage communities of interest, build relationships, and gather pilot data. First, in 2021, we conducted in-depth individual interviews with seven community members and 14 external actors (agents from government and nonprofit organizations, and one researcher) with two main questions: What is the role of fire? and What are the solutions to the wildfire issue in the region? This information served to identify key actors and explore potential viewpoints. Most of these preliminary respondents agreed that campesino communities were on the front-lines of fire response in the Peruvian Andes. Second, as part of our early community engagement, we intentionally spent at least two months in each community in 2022, to become acquainted with resident families and learn about their livelihoods, agricultural systems, and interactions with external actors. We sought to

build trusting relationships, discuss our desire to learn about their livelihoods including fire use, and express that we were not opposed to agricultural burning. In this phase we also pilot-tested our Q methodology with six individuals, who were not included as final study participants, to verify the appropriateness of the number, language, and framing of statements. Finally, we preliminarily observed that farmers conducted controlled agricultural burns for the following two reasons: 1) Within the farmland, to burn either agricultural residue before a new farm cycle or grass to improve the regeneration and quality of pasture for livestock, or shrubs growing in the farm that provided refuge to animals damaging crops. 2) To expand farmland on areas dominated by forest and shrubland (slash and burn) or by native high Andean grassland (on higher elevations). During this preliminary entry phase, we also recognized that most community members were active farmers and fire users.

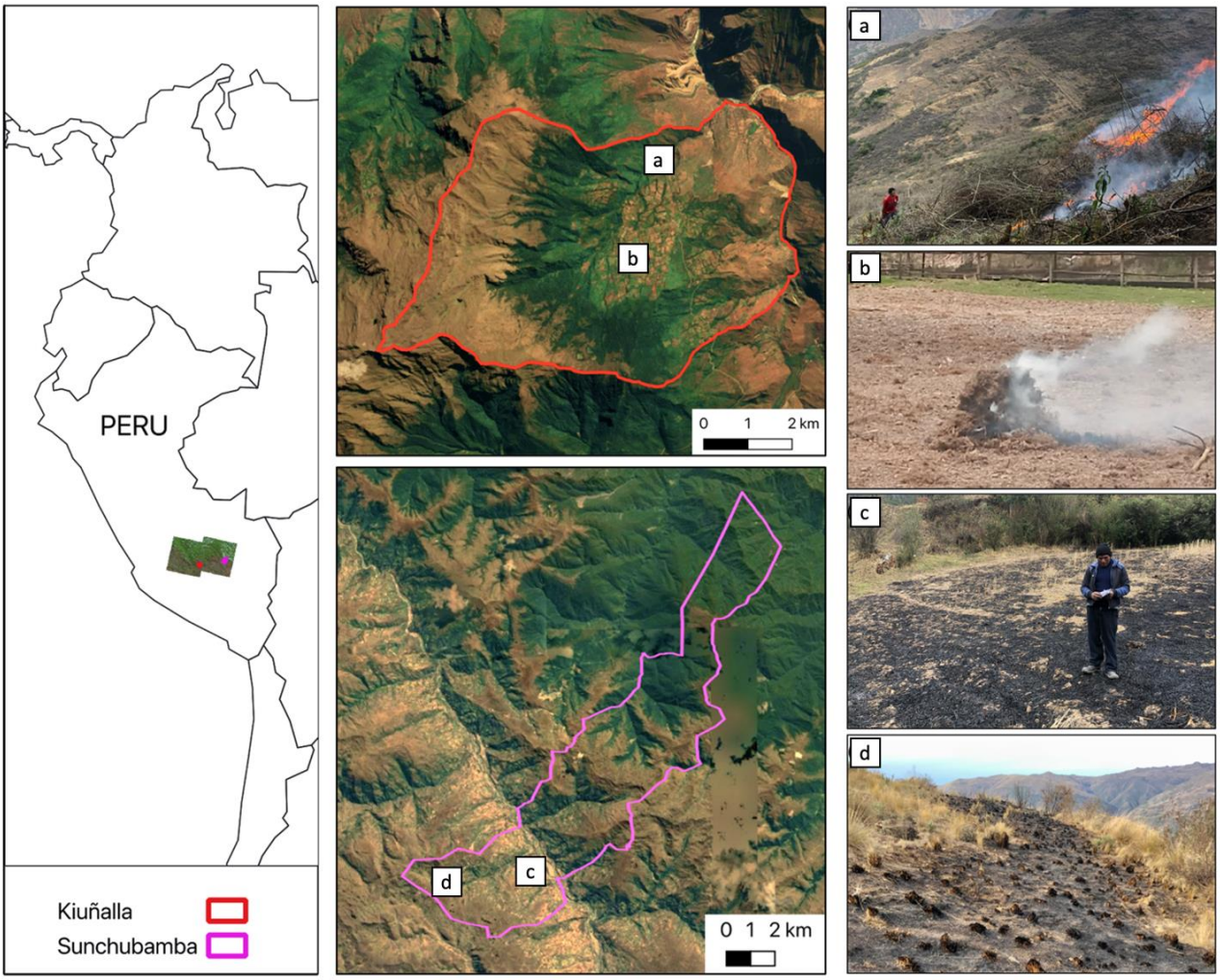

Figure 1. Location of campesino communities Kiuñalla and Sunchubamba in the southern Peruvian Andes and major burn types: to expand farmland in the cloud forest (a) and in the puna grassland (d); within cultivated fields, to clear agricultural waste and unwanted vegetation, such as invasive weeds (b) and wheat residue (c). Adapted from Luna-Celino & Kainer (2024).

4.2.Sampling effort

We evaluated responses from 56 Q sorters, female (n = 17, 30.4%) and male (n = 39, 69.6%), located in Apurimac (n = 27), Cusco (n = 26), and Lima (n = 3) regions. We used snowball sampling to

identify key internal and external actors related to community fire actions (Table 1). Key actors for this research are those who have a say in the decision-making process or influence a policy or action (Sterling et al., 2017; Vogler et al., 2017). Internal actors refer to the community residents and leaders who have participated to varying degrees in decision-making about fire use, prevention, and firefighting in their communities. External actors, all residing in urban locations, refer to agents of organizations/institutions who have supported fire management efforts in one of the focal communities. These included regional or district government, protected areas, nonprofit organizations, and firefighters. Finally, to integrate an academic perspective, our sample included four researchers who had not worked specifically in the focal communities but had published findings on agricultural burns and escaped fire prevention in the broader Andean region. A sample size of 56 participants was defined by saturation in identifying key actors; thus, it was a purposeful selection (Brick, 2011; Brown, 1996; Heckathorn, 2011).

Table 1. Description of key actors and sample effort.

Key actors	Description
Community members (n = 16)	(C) Community residents and leaders who have participated to varying degrees in decision-making about fire use, prevention, and firefighting in their communities.
Firefighters (n = 11)	(F) These actors operate in the province or region where communities are located, mainly in cities, only assisting in fighting escaped fires in rural areas when they are severe. Selected participants typically espoused high levels of experience on wildland firefighting, either with more than 25 years of service or were certified as wildland firefighting trainers.
Government (n = 14)	(G) Agents of 1) the district, province, or regional risk management office; or 2) the regional natural resource management office. These offices deal with fire risk and prevention at some level.
Nonprofit organization (n = 4)	(N) Two Q sorters from each of the couple of nonprofit organizations that have actively supported communal fire management efforts, including fire prevention and control. The sample included the director of the organization and the project coordinator actively working with the campesino community.
Protected area (n = 7)	(P) Four agents from Ampay National Sanctuary (Apurimac) and three agents from Manu National Park (Cusco) who have been involved in direct firefighting and training of communal fire brigades.
Researchers (n = 4)	(R) Based in Lima and Cusco, these actors have published research on agricultural fire use (two Q sorters) and escaped fire prevention (two Q sorters). They account for most fire-related researchers in the country.

4.3.Data collection

In June and July 2023, we implemented Q methodology with the 56 key actors identified to capture and contrast their perceptions of the role of fire types (first research question) and fire management strategies (second research question). We developed 23 statements for each of these two research questions following a review of primary and secondary information. Primary sources comprised in-depth individual interviews and observations on agricultural burns conducted in 2021 and 2022, while secondary information included a review of existing literature that addressed similar research questions in tropical regions (Cammelli et al., 2019; Carmenta et al., 2017). The selection of statements reflected structured and naturalistic criteria, because statements came from a balanced assignation within theoretical

frameworks and emerged from in-depth individual interviews, respectively (Dasgupta & Vira, 2005). Statements on the role of fire reflected benefits and negative impacts of fire on human wellbeing (benefits = 12 statements, negative impacts = six statements) and ecosystem services (negative impacts = five statements) (Supplementary Table 1). Statements on fire management reflected either top-down suppression (eight statements), integrated fire management (seven statements), or community-based (eight statements) strategies (Supplementary Table 2). All top-down suppression and community-based statements reflected current strategies with varying degrees of application. Integrated statements reflected strategies that had not yet been applied in the Peruvian context, such as the promotion of safe use of fire and landscape management.

Following an introduction to study objectives and obtaining informed consent (IRB202202315), research participants (hereafter also termed Q sorters) sequentially considered statements written on 4x5-inch cards and sorted them out into two Q boards, one on the role of fire and another on fire management. The Q boards were two posterboards, each with a pyramid-shaped grid and a 7-step scale, from 'least -3' to 'most +3' (Supplementary Figure 1). We explained that, in our research, we considered fire to have two forms: agricultural burns (*'quemas agricolas'*) and, when it gets out of control, escaped fires (*'incendios'*). We did this because the term *'quemar'* (to burn) in Spanish, in the context of the study, is used indiscriminately to refer to carry out agricultural burns as well as escaped fires (or start of wildfires).

We instructed participants to sort the 23 statements on agricultural burns and escaped fires, following four steps. First, we asked them to carefully read all statements and respond to the prompt question 'To what extent do you agree with the following statements?' by placing each into one of three piles: 'most agree' on the right; neutral or undecided on the center; and 'least agree' on the left. We counted the number of statements within each pile to locate the point of neutrality (whether the majority of the statements were preliminarily distributed to the right or left section of the board). Second, from the pile on the right, participants sorted the cards further into the Q board, based on the extent to which they most agreed with the statements. Then, from the pile on the left, participants sorted cards based on the extent to which they least agreed with the statements. Statements on the neutral pile were then allocated in the center. This procedure forced participants to place each of the 23 statements into a single box within the constrained 7-step scale. Third, once all statements were placed on the board, participants were asked to look again and move statements until they were satisfied with each statement's final location. Fourth, a semi-structured interview followed to gather more information on the reasons behind placing statements on the 'least agree -3' and 'most agree +3' boxes.

For the second Q board, we followed the same steps, and asked participants to sort the second set of 23 statements specific to fire management. Because 'fire management' was not a familiar term among most key actors, we explained our meaning as 'strategies for wildfire ('*incendios'*) prevention and control and what to do with agricultural burns.' Participants were first asked to sort statements responding to the specific question 'How effective do you consider the following statement?' and again were asked to place the 23 statements into three piles: 'most effective' on the right; neutral or undecided on the center; and 'least effective' on the left. Secondly, participants further sorted the cards from the right and left pile responding to what level they considered those statements the most or least effective. Another brief semi-structured interview followed to gather more information on the reasons behind placing statements on the 'least effective -3' and 'most effective +3' boxes. We also collected additional information on each Q sorter, such as age, gender, actor type, and experience with fire. Each Q evaluation lasted on average 70 minutes.

4.4.Data analysis

The goal of our Q data analysis was to identify factors, or viewpoints, among Q sorters to explain perceptions and their variations among actors. Our numerical data were aggregated into average factors

by applying factor analysis and varimax rotation (Brown, 1996; Watts & Stenner, 2005), using KenQ desktop 1.2.1 software. Each factor was the average viewpoint of Q sorters with similar views. The number of factors on each Q evaluation was selected on the basis of three criteria: Factors having eigenvalues greater than 1.0, the maximum number of defining Q sorters, and explanatory power. The software provided the following information for each factor: 1) Composite Q sort: represents how a hypothetical Q sorter with 100% loading would have ordered all the statements. 2) Salient statements: statements placed on the 'most' and 'least' boxes. 3) Distinguishing statements: statements placed significantly differently between factors. 4) Consensus statements: statements placed similarly in all factors. 5) Factor membership: the percent of defining Q sorters, which are respondents with high factor loading. We illustrated each viewpoint for its salient and distinguishing statements and exemplified them with selected quotes (full quotes and their original Spanish versions are in Supplementary Table 3 and 4) from the follow-up interviews with the Q defining sorters of that factor. No significant difference was found among factors resulting from the analysis of responses solely from the Apurimac or Cusco regions. Furthermore, to respond to the third research question (relationship between actors' perceptions on the role of fire and their preferred management strategies), we jointly analyzed the actor type distribution for each viewpoint on the role of fire and fire management.

5. Results

5.1. Viewpoints on the role of fire types on rural livelihoods and ecosystems

Three distinct factors, or viewpoints on the role of fire types (RF1, RF2, RF3), were extracted from the analysis and defined by factor correlations, level of variance explained, and membership for each factor (Table 2). Out of the 56 Q sorters, 46 (the defining Q sorters) significantly loaded in one of the three factors (Supplementary Table 5). All factors were correlated (Table 2), and factor membership was higher in RF1 (54.3%), followed by RF2 (30.4%), and RF3 (15.2%).

Table 2. Factor correlations, explained variance, and membership on perceptions of the role of fire (RF).

Factor	RF1	RF2	RF3	Explained variance	Number of defining Q sorters and factor membership[a]
RF1	1			43%	25 (54.3%)
RF2	0.5576	1		9%	14 (30.4%)
RF3	0.6426	0.6508	1	4%	7 (15.2%)

[a]Percentage of Q sorters significantly loading in only one factor ($p<0.05$).

Commonalities and differences between the three viewpoints emerged. In general, respondents highly agreed with most of the 23 statements as evidenced by the point of neutrality, which skewed towards the left side of the Q board at the first sorting step. On average cards were placed on the left (less agreed) = 5.62 cards (SD = 2.82), middle = 5.86 cards (SD = 3.07), and right (more agreed) = 11.5 cards (SD = 3.3). There were four consensus statements across all three factors ($p<0.05$), that were placed similarly on the Q board: i) escaped fires pollute the air (+2,+1,+2); ii) agricultural burns get rid of agricultural residues from past harvests (0,0,0), iii) agricultural burns are a traditional practice (+1,+1,0); and iv) agricultural burns allow maize to grow more easily (-3,-1,-1). Differences between viewpoints were illustrated by key actor membership and by all salient (rated either +3 or -3) and some distinguishing statements were shown on composite Q sort for each factor (Figure 2 and Table 3).

Table 3. Perceptions on the role of fire for rural ecosystems and livelihoods. Salient and distinguishing statements for each of three factors at $p<0.05$ (*) and $p<0.01$ (**) on perceptions of the role of fire, which considered both agricultural burns (AB) and escaped fires (EF).

Factor name	Least agree (-3):	Most agree (+3):	Factor membership[a]
RF1: Escaped fires negatively impact ecosystem services	AB bring nutrients to the soil**	EF promote global warming**	C=30.8%, **F=70%, G=84.6%**, N=50%, P=40%, R=0%
	AB allow maize to grow more easily*	EF reduce biodiversity	
RF2: Agricultural burns open up more land for agriculture, but escaped fires impact ecosystem services	EF especially impact pine and eucalyptus plantations**	AB open up more land for agriculture**	**C=38.5%**, F=20%, G=7.7%, N=50%, P=40%, **R=100%**
	EF encourage impacted farmers to leave their community	EF reduce biodiversity	
RF3: Agricultural burns facilitate some farm activities, but escaped fires reduce water availability	AB are a social activity that encourages reciprocity in farm work	EF reduce water availability**	C=30.8%, F=10%, G=7.7%, N=0%, P=20%, R=0%
	AB bring nutrients to the soil**	AB are the easiest way to work the farm	

C = community member, F = firefighter, R = researcher, G = government agent, N = nonprofit organization agent, and P = protected area agent. In bold are highest factor membership for each actor type.
[a]Percentage of Q sorters of a specific actor type significantly loading in only one factor ($p<0.05$).

Viewpoint RF1: Escaped fires negatively impact ecosystem services.

This viewpoint was the most representative among government agents (84.6%) and firefighters (70%), and a few other key actors (Table 3). It highlighted the negative impacts of escaped fires on ecosystem services. The most agreed upon statements (+3) were that escaped fires reduce biodiversity and promote global warming, as articulated by a firefighter and a protected area agent, respectively, saying that '*fire kills all living beings in the area'* (F6), and that '*because of escaped fires, there is a very strong variation here in the mountains in the heat, and the seasons of the year are no longer as before'* (P4). This viewpoint also included some agreement (+1) that agricultural burns are traditional, but also pointed to negative impacts of escaped fires on material wellbeing, such as causing farm damage and economic losses (+2). A government agent said that, in Apurimac, *'the loss of pines and eucalyptus does imply a huge economic loss'* (G8); however, *'escaped fires also damage native plants, which are a little more difficult to recover*,' again, emphasizing harm to ecosystem services.

This viewpoint agreed less with any benefits of agricultural burns. The least agreed upon statements (-3) were that agricultural burns bring nutrients to the soil and allows maize to grow more easily. A government agent reported the following: '*the same year [of the burning] maize plants will grow well, but not the following year. The soil contains microorganisms that strengthen the soil. By burning, you are killing them and over time this land will no longer produce maize well'* (G2), acknowledging some benefits of agricultural burns, but only in the short term.

Viewpoint RF2: Agricultural burns open up more land for agriculture, but escaped fires impact ecosystem services.

This viewpoint was held by all researchers and half of nonprofit organization agents. It was also held by slightly more community members than the other two factors (38.5%). It appeared to recognize

the distinction between the utility of agricultural burns and the destructive impacts of escaped fires, especially on ecosystem services. The two most agreed statements (+3) were that escaped fires reduce biodiversity and agricultural burns open up more land for agriculture. A government agent explained that fires *'have definitely reduced native high Andean species, such as forests of q'euñas and chachacomos; also, there were spectacled bears in places with native vegetation, and due to the burning they are migrating to other areas or are disappearing*' (G6). In contrast, a community member articulated the benefits of agricultural burns for opening more land for agriculture, noting that '*when a farmer has small land, they burn because it the easiest way to open up more farmland'* (C15). Similarly, another agreed upon statement (+2) was that agricultural burns are the easiest way to work the farm. A protected areas agent recognized that '*no matter how much technical assistance trains them [farmers] to make compost or biol, they balance all the effort they have to put in their farm and find that burning is more convenient*' (P7).

The least agreed upon statements (-3) were two negative impacts of escaped fires on material and relational dimensions of wellbeing, respectively: that they especially impact pine and eucalyptus plantations and that they encourage farmers to leave their community. Capturing the essence of both statements, a researcher reported that escaped fires *'affect native shrublands, puna grassland, especially native trees, more than pine and eucalyptus plantations,'* and also that, when impacted by escaped fires, *'farmers do not leave their homes; however, when fire impacts are much stronger, even their homes are destroyed, they could leave, but it doesn't always happen'* (R1).

RF1: Escaped fires negatively impact ecosystem services

-3	-2	-1	0	+1	+2	+3
**AB bring nutrients to the soil	**AB are the cheapest way to work the farm	**AB are the easiest way to work the farm	EF especially impact pine and eucalyptus plantations	EF reduce water availability	*EF cause farm damage and economic loss	EF reduce biodiversity (native plants & animals)
*AB allow maize to grow more easily	AB reduce pests and animals that damage agricultural production	**AB open up more land for agriculture	AB get ride of agricultural residues from past harvests	EF bring lots of social conflict	EF pollute the air	**EF promote global warming
	EF encourage impacted farmers to leave their community	AB are part of farmer identity	**The magnitude of EF nowadays discourages farmers to burn	**EF affect ecotourism	**EF impoverish the soil	
		*AB are a social activity that encourages reciprocity in farm work	**AB promote regeneration of new grasses for livestock	AB are a tradicional practice		
			AB reduce weeds that damage agricultural production			

RF2: Agricultural burns open up more land for agriculture, but escaped fires impact ecosystem services

-3	-2	-1	0	+1	+2	+3
**EF especially impact pine and eucalyptus plantations	AB are part of farmer identity	**AB reduce pests and animals that damage agricultural production	AB get ride of agricultural residues from past harvests	EF promote global warming	EF pollute the air	EF reduce biodiversity (native plants & animals)
EF encourage impacted farmers to leave their community	*The magnitude of EF nowadays discourages farmers to burn	**EF bring lots of social conflict	**AB promote regeneration of new grasses for livestock	EF reduce water availability	*EF cause farm damage and economic loss	**AB open up more land for agriculture
	AB are a social activity that encourages reciprocity in farm work	**AB bring nutrients to the soil	**AB reduce weeds that damage agricultural production	AB are the cheapest way to work the farm	AB are the easiest way to work the farm	
		AB allow maize to grow more easily	AB are a tradicional practice	EF impoverish the soil		
			EF affect ecotourism			

RF3: Agricultural burns facilitate some farm activities, but escaped fires reduce water availability

-3	-2	-1	0	+1	+2	+3
AB are a social activity that encourages reciprocity in farm work	**AB promote regeneration of new grasses for livestock	EF affect ecotourism	EF impoverish the soil	EF pollute the air	EF promote global warming	**EF reduce water availability
**AB bring nutrients to the soil	AB reduce pests and animals that damage agricultural production	AB reduce weeds that damage agricultural production	**EF cause farm damage and economic loss	AB are the cheapest way to work the farm	EF reduce biodiversity (native plants & animals)	AB are the easiest way to work the farm
	EF encourage impacted farmers to leave their community	AB allow maize to grow more easily	EF especially impact pine and eucalyptus plantations	AB are part of farmer identity	**AB are a tradicional practice	
		*The magnitude of EF nowadays discourages farmers to burn	AB get ride of agricultural residues from past harvests	EF bring lots of social conflict		
			**AB open up more land for agriculture			

Figure 2. Composite Q sorts for the three factors on perceptions of the role of fire types on human wellbeing and ecosystem services, showing distinguishing statements at $p<0.05$ (*) and $p<0.01$ (**). Statement colors: blue = agricultural burns (AB), orange = escaped fires (EF).

Viewpoint RF3: Agricultural burns facilitate some farm activities, but escaped fires reduce water availability.

This viewpoint was not clearly representative of any particular group. It was held by 30.8% of community members, and very few other external key actors. It agreed more with all negative impacts of escaped fires on ecosystem services, focusing on decreased water availability (+3). A community member explained that water *'comes from vegetation, so when you burn the forest, water is reduced because the vegetation no longer filters it'* (C14). This viewpoint also most agreed (+3) with agricultural burns being the easiest way to work the farm, which is a benefit of subjective wellbeing, as was articulated by a protected area agent: *'farmers use fire to get rid of agricultural residue. Some do controlled burning, and some don't. They burn instead of hiring people because it's easier'* (P6).

The two least agreed statements (-3) were benefits of agricultural burns on relational and material dimensions of wellbeing, respectively: it encourages reciprocity in farm work and delivers nutrients to the soil. A government agent disputed any reciprocity benefit by explaining that '*each farmer burns individually without assistance from other people'* (G14). Similar to the previous viewpoint and responding to the notion that fire enhances soil nutrient availability, a community member explained that agricultural burns '*bring nutrients for one or two years, but then the land becomes poor because fire kills soil beneficial microorganisms and insects*' (C1).

5.2. Viewpoints on current and potential fire management strategies

Three distinct factors, or viewpoints of fire management (FM1, FM2, FM3), were extracted from the analysis and were defined by factor correlations, level of variance explained, and membership (Table 4). Out the 56 Q sorters, 43 significantly loaded in one of the three factors (Supplementary Table 5). There was limited correlation between factors, except for FM2 and FM3 (Table 4), and factor membership was higher in FM2 (44.2%), followed by FM1 (27.9%) and FM3 (27.9%).

Table 4. Factor correlations, explained variance, and membership on perceptions of fire management (FM) strategies.

Factors	FM1	FM2	FM3	Explained variance	Number of defining Q sorters and factor membership[a]
FM1	1			8%	12 (27.9%)
FM2	0.3539	1		26%	19 (44.2%)
FM3	0.2965	0.5678	1	7%	12 (27.9%)

[a]Percentage of Q sorters significantly loading in only one factor ($p<0.05$).

A commonality between the three factors was that respondents considered most statements as highly effective in managing fires, as evidenced by the point of neutrality, which skewed towards the left side of the Q board. Sorted cards were placed in the first sorting step as follows, on average: left (less effective) = 4.25 cards (SD = 2.54), middle = 6.62 cards (SD = 3.01), right (more effective) = 12.13 cards (SD = 3.99). There were three consensus statements across all three factors ($p<0.05$), that were placed similarly on the Q board: i) coordination between different sectors and levels of government to prevent and extinguish fires (1,1,1); ii) reforestation of native vegetation after wildfires (1,0,0); and iii) use of prescribed burns to defend priority areas where we do not want escaped fires (-2,-2,-2). Differences between viewpoints were illustrated by key actor membership and by all salient and some distinguishing statements of the composite Q sort for each factor (Figure 3 and Table 5).

Table 5. Salient and distinguishing statements for each of three factors at $p<0.05$ (*) and $p<0.01$ (**)

on perceptions of fire management (FM) strategies.

Factor name	Least effective (-3):	Most effective (+3):	Factor membership (%)[a]
FM1: Top-down fire suppression	Territorial zoning to avoid agricultural burns in headwaters, forests, and tree plantations **	More funding for firefighters (better equipment and training)**	C=0%, F=40%, **G=60%**, N=0%, P=25%, R=33.3%
	Avoid planting flammable vegetation in the landscape (such as pine or eucalyptus)	Legal sanctions for those who let fires escape*	
FM2: Community-based fire suppression	Campesino communities grant local permits to carry out agricultural burns*	Create, train and equip community fire brigades**	**C=75%**, **F=50%**, G=20%, N=50%, P=25%, R=0%
	Avoid planting flammable vegetation in the landscape (such as pine or eucalyptus)	Promote better organization in rural communities to prevent and control fires	
FM3: Community-based fire management	Better water management in the landscape to prevent fires (reservoirs and canals)**	Create, train and equip community fire brigades**	C=25%, F=10%, G=20%, N=50%, **P=50%, R=66.7%**
	Use of drones, aircraft and satellite technology to detect and extinguish fires	Promote better organization in rural communities to prevent and control fires	

C = community member, F = firefighter, R = researcher, G = government agent, N = nonprofit organization agent, and P = protected area agent. In bold are the highest factor membership for each actor type.
[a]Percentage of Q sorters of a specific actor type significantly loading in only one factor ($p<0.05$). Forty-three out of 56 Q sorters were significantly represented in one factor.

Viewpoint FM1: Top-down fire suppression.

This top-down fire suppression viewpoint was held by 60% of government agents, but not by a majority of any other actors (Table 5). The most effective strategies (+3) were funding for firefighters and legal sanctions for those who start a fire that escapes. One firefighter reported they need more equipment and resources and expressed the need for '*specialized brigades dedicated solely and exclusively to wildland firefighting'* (F10), which is not yet a reality in the Peruvian context. A government agent articulated that legal sanctions for those who start a fire that escapes are effective because their existence makes people *'alert and afraid to carry out their burnings'* (G12). However, all Q sorters in favor of this strategy also said that legal sanctions need to be reinforced, as confirmed by a protected area agent who said that '*of so many escaped fires that have been evaluated by the prosecutor's office, none has proceeded'* (P5). Another strategy considered as highly effective (+2) was funding for local government actions to fight fires. As articulated by a firefighter and a government agent, respectively, explaining its effectiveness because local governments *'are located close to campesino communities, where burning occurs*' (F10) and this funding would allow them to '*provide adequate support to volunteer firefighters coming to their jurisdiction*' (G13). While a few actors holding this viewpoint considered it effective to train farmers on how to safely conduct their burns, this strategy was not as important as fire suppression (thus, this statement was placed in neutral in the composite). On the contrary, a couple of government agents stated that controlled burns are not possible because all agricultural burns lead to escaped fires.

Those who loaded onto this viewpoint considered land management strategies such as territorial zoning on communal lands and avoiding planting pine and eucalyptus trees to be least effective (-3) strategies. A protected area agent explained that these two strategies could be effective but are '*not practical because rural people would not implement them'* (P5). Regarding the latter strategy, a firefighter and a government agent, respectively, explained that these plantations are *'resources highly appreciated by locals for their wood*' (G13) and *'have become a native feature in Andean landscape'* (P5). Another strategy considered least effective (-2) was campesino communities granting local permits to carry out burns because it means '*accepting that agricultural burns are the right thing to do and that it is wrong,'* a firefighter noted (F9).

Viewpoint FM2: Community-based fire suppression.

This viewpoint was held by 75% of community members, by half the firefighters and nonprofit organization agents, and few other actors (Table 5). The most effective strategies (+3) were to promote better communal organization and to create, train, and equip fire brigades, both bottom-up efforts to be led by local communities in collaboration with external actors. Two farmers (C12 and C14) highlighted that better communal organization would help firefighting when '*fire is still easy to control.*' Corroborating our 2021 preliminary findings that campesino communities were on the front-lines of fire response in the Peruvian Andes, a nonprofit organization agent added that campesino communities and local fire brigades provide the *'first response to fires when they have not yet gotten stronger, and while volunteer firefighters and risk specialists are mobilizing to the rural area'* (N2). For this nonprofit agent, communal brigades can also prevent escaped fires '*by training others in their communities on what they have learned and remind them to burn carefully*' (N2).

This viewpoint, however, also considered not only communal sanctions effective (+2), but also legal sanctions (+2) for those who let fires escape. A couple of community members explained legal sanctions '*elicit fear among farmers regarding the possibility of getting fined for letting fires to escape'* and *'would make farmers to burn less'* (C12 and C14). One of these community members considered both communal and legal sanctions to be equally effective in promoting farmers to burn carefully (C12). Indeed, one of our study communities had been implementing graduated sanctions for letting fires escape, fining responsible parties 500 soles (USD $140) or more, based on the magnitude of fire damage. In contrast, this viewpoint also highlighted farmer training on how to safely carry out burns (+2) to be highly effective.

This viewpoint considered two statements to be the least effective (-3): to avoid planting flammable vegetation and campesino communities granting local permits to burn. Similar to the previous viewpoint, one firefighter thought that avoiding eucalyptus and pine plantations was '*unrealistic because they are the trees that grow faster and are more abundant than other types of trees in the Andean region'* (F11). Two agents from different nonprofit organizations explained that local burn permits could be *'problematic*' because, in case a fire escapes, farmers would say their community had given them permission, clearing themselves of any individual accountability (N2 and N3). Another strategy considered as least effective (-2) in this viewpoint was legal sanctions for those who use agricultural burns. One non-profit agent expressed that '*even though burning is prohibited, farmers will continue to do it*' and that the current law is a reason why external actors '*cannot train farmers on how to carry out their burns safely'* (N3), which was a claim shared with few other actors.

Viewpoint FM3: Community-based fire management.

This viewpoint suggests that farmers should be the main actors in carrying out fire management strategies, including safe use of fire, with support from external agents. This viewpoint was held by half

of the agents of nonprofit organizations and protected areas, 66.7% of researchers, and a minority of other key actors. Similar to the previous viewpoint, the promotion of communal organization and fire brigades to prevent and control escaped fires were considered to be the most effective strategies (+3). One non-profit agent mentioned that external actors '*should work closer with farmers, from bottom to top… and promote communities to update their statutes, creating new functional committees such as forest committees and fire brigades'* (N1). A community member explained that farmers *'already know about firefighting but need constant training and appropriate equipment*' (C3). Similarly, a protected area manager stated that these trainings should be '*constant and empowering by letting everyone know what a brigade member is and their responsibilities and benefits'* (P7) as a way to encourage greater farmer membership.

This viewpoint also considered two mechanisms related to safe use of fire as effective (+2): training farmers and community rules that inform how to safely carry out agricultural burns. From one researcher's perspective, community rules could indicate *'to avoid burning when risk is higher, such as in the afternoons, or promote burning with the company of other people*' (R2). A nonprofit agent argued that campesino communities '*must update their statutes, to indicate that farmers should report to the community board every time they burn and ask for help from other farmers to burn together with them'* (N1). Regarding training farmers on how to safely carry out agricultural burns, a protected area agent, as well as a few other external actors, indicated the need to first *'repeal the law prohibiting agricultural burns, otherwise you cannot train on safe burning'* (P7).

The least effective statements (-3) were the use of technology (drones, aircraft, satellite images) and water management to prevent and fight fires, mainly because respondents found these strategies to be '*difficult*,' '*unrealistic*,' or '*requiring nonexistent economic resources*' (C2 and N1). Another less effective strategy (-2) within this viewpoint was the implementation of legal sanctions on the use of agricultural burning and for those who let fires escape. Respondents said that neither law was enforced because '*they are trapped in bureaucracy and there are not enough specialists to take care of the process in the prosecutor's office*' (N1). Regarding the law prohibiting agricultural burns, a researcher said that *'even if the farmers are trained on fire-free alternatives, they will continue to use fire'* (R1). This researcher explained further that *'there is a prohibition approach that does not work… It only changes the perspective of fire users, forcing them to see fire in a negative way and burn with great fear'* (R1). Throughout the first author's four-month stay in both communities, no farmer mentioned knowing of prohibitions on agricultural burns; however, everyone seemed to be aware of the potential sanctions for those who let a fire escape. This explains the low awareness about the fire use prohibition law among fire users, but also why it impedes the promotion of safe fire use by external actors.

FM1: Top-down fire suppression

-3	-2	-1	0	+1	+2	+3
Avoid planting flammable vegetation in the landscape (such as pine or eucalyptus)	Coordination between neighboring communities to manage conflicts when fire escapes their borders	**Community rules on how to safely carry out agricultural burns	**Create, train and equip community fire brigades	**Promote better organization in rural communities to prevent and control fires	**More funding for local government actions to fight fires	**More funding for firefighters (better equipment and training.)
**Territorial zoning to avoid agricultural burning in headwaters, forests, and tree plantations	Use of prescribed burns to defend priority areas where we do not want escaped fires	Communal sanctions for those who let fires escape	** Legal sanctions for those who use agricultural burning	Training and incentives for farmers to avoid burning (compost and improved pastures)	**Use of drones, aircraft and satellite technology to detect and extinguish fires	*Legal sanctions for those who start a fire that escapes
	*Campesino communities grant local permits to carry out agricultural burns	Better water management in the landscape to prevent fires (reservoirs and canals)	**Farmer training on how to safely carry out burns	Reforestation of native vegetation after wildfires	Include farmers in multisectoral fire prevention coordination	
		**Regulated and careful fire use, avoiding burns in very dry seasons and during strong winds	Raise awareness to avoid accidental fires by cooking outside or children playing	Coordination between different sectors and levels of government to prevent and extinguish fires		
			Awareness campaigns on the dangers of agricultural burning			

FM2: Community-based fire suppression

-3	-2	-1	0	+1	+2	+3
Avoid planting flammable vegetation in the landscape (such as pine or eucalyptus)	Use of prescribed burns to defend priority areas where we do not want escaped fires	**More funding for firefighters (better equipment and training)	*Include farmers in multisectoral fire prevention coordination	*Community rules on how to safely carry out agricultural burns	Farmer training on how to safely carry out burns	Promote better organization in rural communities to prevent and control fires
*Campesino communities grant local permits to carry out agricultural burns	Use of drones, aircraft and satellite technology to detect and extinguish fires	*Territorial zoning to avoid agricultural burning in headwaters, forests, and tree plantations	Reforestation of native vegetation after wildfires	**Awareness campaigns on the dangers of agricultural burning	*Legal sanctions for those who let fires escape	**Create, train and equip community fire brigades
	*Legal sanctions for those who use agricultural burning	*More funding for local government actions to fight fires	*Regulated and careful fire use, avoiding burns in very dry seasons and during strong winds	**Coordination between neighboring communities to manage conflicts when fire escapes their borders	**Communal sanctions for those who let fires escape	
		Better water management in the landscape to prevent fires (reservoirs and canals)	Raise awareness to avoid accidental fires by cooking outside or children playing	Coordination between different sectors and levels of government to prevent and extinguish fires		
			**Training and incentives for farmers to avoid burning (compost and improved pastures)			

FM3: Community-based fire management

-3	-2	-1	0	+1	+2	+3
Use of drones, aircraft and satellite technology to detect and extinguish fires	**Legal sanctions for those who start a fire that escapes	Coordination between neighboring communities to manage conflicts when fire escapes their borders	Reforestation of native vegetation after wildfires	**More funding for firefighters (better equipment and training)	Farmer training on how to safely carry out burns	**Create, train and equip community fire brigades
**Better water management in the landscape to prevent fires (reservoirs and canals)	* Legal sanctions for those who use agricultural burning	**Raise awareness to avoid accidental fires by cooking outside or children playing	Awareness campaigns on the dangers of agricultural burning	Training and incentives for farmers to avoid burning (compost and improved pastures)	*Community rules on how to safely carry out agricultural burns	Promote better organization in rural communities to prevent and control fires
	Use of prescribed burns to defend priority areas where we do not want escaped fires	*Territorial zoning to avoid agricultural burning in headwaters, forests, and tree plantations	*More funding for local government actions to fight fires	Coordination between different sectors and levels of government to prevent and extinguish fires	Include farmers in multisectoral fire prevention coordination	
		**Avoid planting flammable vegetation in the landscape (such as pine or eucalyptus)	*Regulated and careful fire use, avoiding burns in very dry seasons and during strong winds	**Campesino communities grant local permits to carry out agricultural burns		
			Communal sanctions for those who let fires escape			

Figure 3. Composite Q sorts for the three factors on perceptions of fire management strategies, showing distinguishing statements at $p<0.05$ (*) and $p<0.01$ (**). Statement colors: red = top-down fire suppression; blue = integrated fire management; green = community-based fire management.

5.3.Relationship between participants' perceptions of fire roles and effective fire management

We found three main results of concurrent factors on 'role of fire' (RF) and 'fire management' (FM) from the two distinct Q boards: First, 45.7% of defining sorters on RF and FM (16 of the 35 Q sorters) held viewpoints with the same factor number in both Q boards. In other words, Q sorters that adhered to RF1 also adhered to FM1, RF2 with FM2, and RF3 with FM3, respectively. Second, almost all Q sorters who prioritized the negative role of fire on ecosystem services (RF1) also considered fire suppression strategies to be more effective, either top-down (10 Q sorters: four firefighters and six government agents) or community-based (8 Q sorters, half of them were community members). Third, a varied portion of respondents representing community members, researchers, and nonprofit organizations highlighted that agricultural burns have benefits but hurt ecosystem services (RF2 and RF3). These respondents considered that communities should be in charge of either fire suppression or management (FM2 and FM3) rather than top-down suppression (Figure 4).

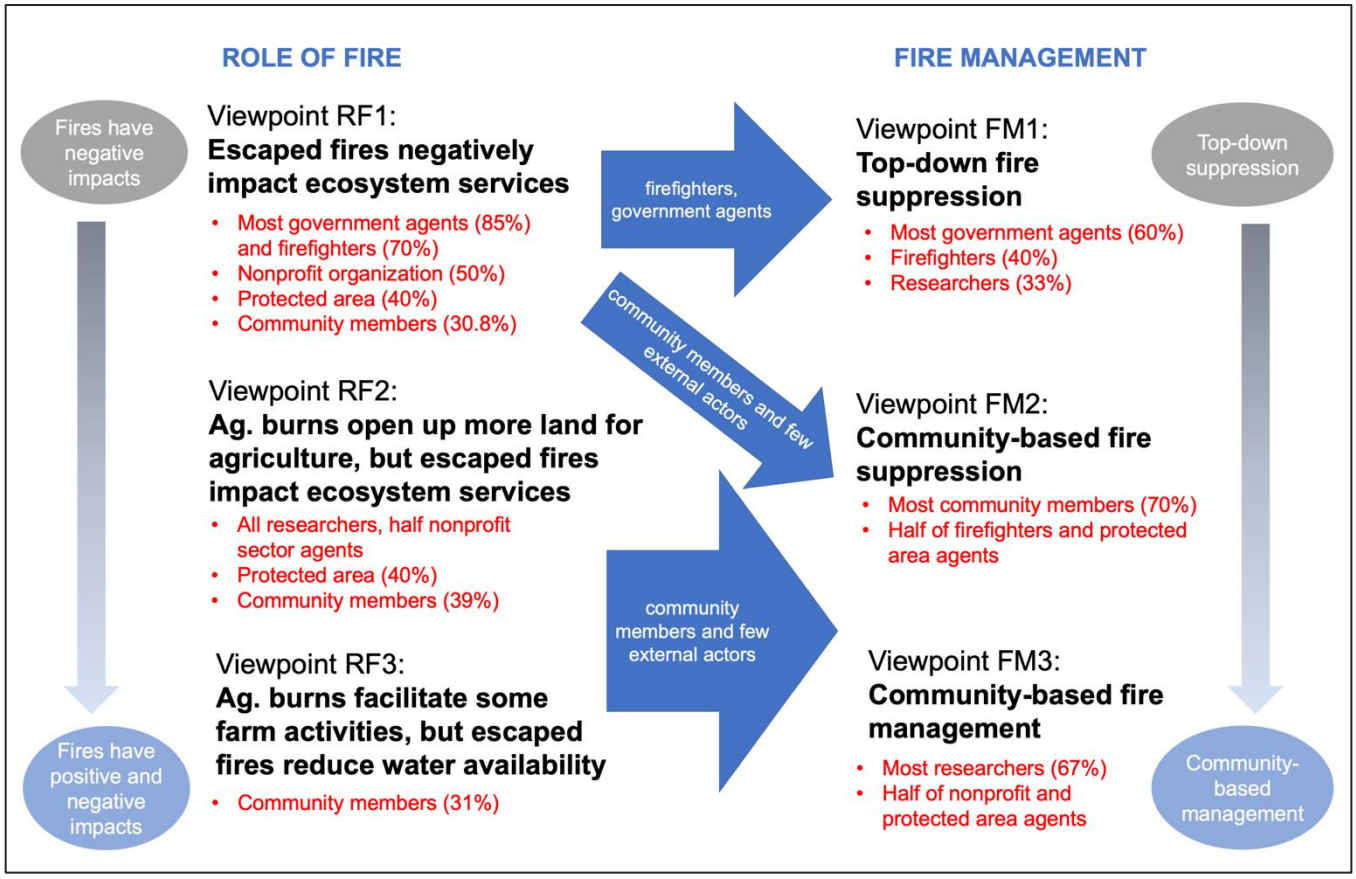

Figure 4. Concurrence between viewpoints on the role of fire types (RF) and viewpoints on effective fire management (FM) strategies. In red letters, key actors with more than 30% per each factor.

6. Discussion

Viewpoints on the role of fire types ranged from emphasizing the negative impacts of escaped fires on ecosystem services to acknowledging some benefits of agricultural burns for rural livelihoods. Regarding fire management, three viewpoints emerged: one emphasizing top-down fire suppression, another on community-based fire suppression, and the third one favoring community-based fire management. Most government agents and firefighters, holding an emphasis on the negative impacts of escaped fires, advocated for the continuation of top-down fire suppression policies; whereas community

members and other external actors with a more balanced perception of fire advocated for community-based actions, either suppression or management. The recognition of diverse opinions on the role of fire and what to do with it suggests a need for fire governance that reconciles the different needs of various key actors, especially those of impoverished fire users.

6.1. Ecosystem services and wellbeing: two sides of the same coin

Ecosystem services and wellbeing frameworks can help understand the diversity of fire viewpoints. Government agents and firefighters in our study emphasized that fire negatively impacts ecosystem services such as soil, air, biodiversity, water availability and catalyzes climate change -a vision widely shared globally by the general public (Fidelis, 2020). These respondents focused on escaped fires in the Peruvian Andes and their contribution to global warming; however, this emphasis is exaggerated. For example, countrywide Peruvian emissions account for less than 1% of global emissions, while energy consumption in the Global North is the most significant global source (Ge et al., 2020). And while this unjust viewpoint blames smallholders for climate change, they, in turn, are becoming increasingly vulnerable to droughts and rising temperatures (Carmenta et al., 2021).

In contrast, we found that small-scale farmers, compared to other key actors, better recognized the benefits of fire in agriculture, as reported for other regions (Carmenta et al., 2017; Pereira et al., 2016). They highlighted that agricultural burns are considered a traditional practice, part of a farmer's identity, and the cheapest and easiest way to work the farm, which are benefits of fire in the relational and subjective dimensions of wellbeing. These type of fire benefits have not been uncovered much in the literature, except for findings about Indigenous perceptions of fire use strengthening cultural connection and wellbeing in Canada (Nikolakis et al., 2020). A biased focus on only the material dimensions of wellbeing leaves aside the importance of fire users' beliefs, knowledge and collective value (Cooper & Kainer, 2018; McKinnon et al., 2016).

Furthermore, considering ecosystem services and wellbeing frameworks together could leverage the expectations that rural communities serve as stewards of biodiversity conservation at the expense of sacrificing their wellbeing (Agarwala et al., 2014; Martin et al., 2016). Unjust expectations by key urban actors arise because small-scale farmers and Indigenous communities often intersect with expanding regional economies and well-preserved landscapes that provide ecosystem services to far reaching populations (Kohler & Brondizio, 2017). Rural communities of the high Andes are unfairly charged with the great responsibility of maintaining intact forest and water resources for the benefit of urban centers in the lowlands (de Francisco & Boelens, 2014; Mercado-Garcia et al., 2023). They are also expected to provide diverse and affordable agricultural products, galvanizing their reliance on agricultural burns to keep production costs low.

6.2. Top-down or bottom-up?

Our results suggested divergent opinions about who should lead fire suppression and fire management efforts. We found a clear division among preferences for top-down and community-based fire-related actions, which is partly explained by actor prioritization of the benefits or negative impacts of fire. Actors prioritizing the negative impacts of fire on ecosystem services also considered fire suppression measures to be more effective, either top-down or bottom-up. The top-down fire suppression viewpoint, held mostly by government agents, highlighted funding for firefighting efforts and legal sanctions. In contrast, the actors that acknowledged some benefits of burns for agriculture, placed emphasis on community-based efforts, either to suppress or manage fire. This reflects each group's level of action: government agents tend to advocate for top-down, while community members favor local solutions. Compared to other external actors, protected area agents and researchers have a

history of greater collaboration with campesino communities and international actors, such as international nonprofit organizations and other researchers, all of whom endorse a fire management approach. Both local and international influences could explain why they recognized the benefits of agricultural burning and their willingness to promote bottom-up fire management.

Contrasting perceptions among small-scale farmers in prioritizing the benefits or negative impacts of fire suggest something crucial about the challenge of fire use in tropical agriculture. Small-scale farmers are between a rock and a hard place: on the one hand, they face the negative impacts of escaped fires, exacerbated by climate change, and on the other, they need to use fire to support their livelihoods, but confront unfavorable fire policies (Carmenta et al., 2021). Farmers agree that fire has negative impacts because it harms biodiversity and water and drives climate change. In their voices, these consequences and drivers are interrelated and impact their agricultural production: fire reduces the native vegetation that filters and provides the water used in agriculture, while climate change alters rain availability and increases unexpected droughts and frosts - impacts highly evidenced throughout the Tropical Andes (Drenkhan et al., 2019; Gonzales-Valero, 2018; Lasage et al., 2015; Lynch, 2012; Vidal-Merino et al., 2019). Farmers' contrasting opinions about fire in the Brazilian Amazon were explained by their level of involvement with agricultural practices and their history with wildfire damage. Some considered fire use to be a farmer's right and firefighting a collective and not too-risky activity, while others expressed positive sentiments about technological advances that could promote fire-free agriculture (Cammelli et al., 2019). Both in our study and Cammelli et al.'s (2019), most farmers agreed that they had significant incentives to fight wildfires because they could always be affected by fires spreading from adjacent farms. This logic may explain why most small-scale farmers in the Peruvian Andes consider community-based fire suppression among the most effective strategies.

Some external actors and community members expressed interest in promoting locally-based safe use of fire, which is part of an IFM approach. However, the current law prohibiting agricultural burns prevents external actors from training farmers to conduct burns safely. Around the world, laws governing access to natural resources and controlling traditional practices, such as agricultural burns, have been broadly designed without incorporating local and Indigenous people's perspectives (Duffy, 2010; Larson et al., 2021). Consequentially, informal practices persist and local people are criminalized (Dressler et al., 2021). Some efforts to reduce the emphasis on law enforcement for fire regulation have been forthcoming in other Latin American countries, although with some misfit challenges, such as overly detailed and inflexible burn requirements that are difficult to achieve in practice (Carmenta et al., 2013; Monzón-Alvarado & Keys, 2016). In Peru, the regional government of Cusco, in collaboration with the U.S. Agency for International Development and U.S. Forest Services offices in Peru, recently has inserted IFM into the national and regional debate.

Considering that fire suppression could lead to fuel accumulation in the long term, it is urgent to actively manage fires as part of preventive measures, which includes not only safe use of fire but also proactive landscape planning (Armenteras & de la Barrera, 2023; Cochrane & Bowman, 2021). No landscape planning strategies, such as avoiding flammable exotic tree plantations, prescribed burning, territorial zoning, or improving water management, were considered effective by our study participants. This was partly because they have not been applied in the Peruvian Andes and/or actors do not recognize them as potential measures to prevent wildfires. For example, the statement on avoiding the plantation of pines and eucalyptus was considered ineffective, perhaps because these trees are highly valued by community members for their rapid wood production. Eucalyptus trees particularly, which have been planted since Spanish colonization, are considered an intrinsic feature in Andean landscape and culture. These highly flammable species actively promoted by government projects in the Peruvian Andes for the last few decades, are fueling mega fires in other South American regions (Ammerman, 2022; Armenteras

& de la Barrera, 2023; Farley, 2007; Toy-Opazo et al., 2024). Similarly, a broad consensus among all participants was that prescribed burns are ineffective, mainly because this strategy is not yet known in the country. Prescribed burns are controlled fire applications usually on fire-dependent ecosystems conducted by a certified team of professionals in specific weather conditions to meet management objectives (Scott et al., 2014; Waldrop & Goodrick, 2012). Thus, it demonstrates the need for key actors to actively evaluate drivers that increase wildfire risk and to consider landscape management strategies suitable to the Andean region.

Integrated and adaptive fire management should incorporate perceptions and knowledge about the benefits and negative impact of fire on both ecosystem services and human wellbeing. IFM involves similar prioritization on both suppression and effective use of fire at different levels of governance. Adaptive management should guide plans and actions based on existing knowledge and perception analysis, monitor subsequent results and new knowledge, and inform future management actions. Thus, integrated and adaptive fire management should aim to bring together organizations, local communities, and agencies to address the multiple uses of fire with a holistic and resilient approach (Gillson et al., 2019; Myers, 2006; Rego et al., 2010; Shlisky et al., 2009). It means that rather than top-down or bottom-up approaches, integrated and adaptive fire management should account for both types of processes, where actors can coordinate effectively and transfer funding and resources across actors to accomplish work (Kelly et al., 2019).

IFM strategies across tropical regions combine community participation, traditional knowledge, and modern tools to reduce wildfire risks and support reforestation. For example, in the tropical savannas of northern Australia, southern Africa, and South America, governments have promoted the implementation of prescribed burnings early in the dry season in collaboration with rural and Indigenous communities (Mistry et al., 2019; Moura et al., 2019). In Ecuador, a recently implemented pilot project with an IFM approach is training communal firefighting brigades in prescribed burning, pasture regeneration, and farmland protection (Bustos & Duce, 2022). While in Mexico, IFM processes implemented in the Selva El Ocote Biosphere Reserve prevented adverse wildfire events by engaging with local communities, but faced challenges from budget cuts, shifting government priorities, and weakened rule of law (Neger et al., 2024). In general, the transition from top-down fire suppression policies to local and inclusive approaches in tropical regions often has been challenged by unfavorable legal frameworks and centralized governments (Mistry et al., 2016; Moura et al., 2019; Schmidt et al., 2018).

6.3.Recommendations for effective fire governance in the Peruvian Andes

Heeding the urgent call for transformative and just actions to deal with pressing environmental issues (Larson et al., 2021), we argue that fire governance needs to take into account the diversity of perceptions about fire types to support evidence-based decision-making and comprehensive fire management strategies (Bennett, 2016; Lockwood et al., 2010). In particular, fire governance should center the voices of fire users, fostering reflection on how power relationships and broader processes and institutions influence local management. This position also considers the uncovered middle-ground viewpoint, which is stimulating communities to adopt effective fire-related actions, either safe use of fire, firefighting, or both. As most respondents agreed, national fire policy should recognize that rural communities are on the front lines because those who use fire also provide the first (and sometimes only) firefighting response to escape fires.

Effective community-based fire management promotes community participation in policy design and prioritizes locally crafted rules, monitoring, and sanctioning processes (FAO, 2003; Moore, 2019). It comes with the understanding that communities' capacity to fight fires should be utilized on initial stages of fire control due to the intrinsic risks of firefighting (FAO, 2011). Advocates of communal fire brigades

in the Peruvian Andes articulate this position, given that every year farmers are killed or injured trying to put out fires (Telesur, 2023). Since communities often lack equipment and skills in analyzing, planning, and monitoring their fire management actions, cooperation with external actors is critical, especially from governments who can provide adequate legal and policy frameworks and allow decentralized participation in planning and decision-making (Sattler et al., 2016).

Language also matters in the process of promoting effective fire governance. We recognized early on in our study that the term *'quemar'* (to burn) was used indiscriminately to refer to both fire types discussed here, agricultural burns and escaped fires, reflecting colonial roots of fire use prohibition and discrimination against rural practices (Moura et al., 2019). When conducting the Q methodology, we explained to both farmers and external actor respondents that the term '*quemas agricolas'* (agricultural burns) was distinctly different than the term *'incendios'* (escaped fires). This lack of differentiation between two different fire types diminishes the agency of fire users. Recognition of farmer agency to actively control their burns involves understanding traditional fire knowledge as sophisticated and based on long-term exposure and observations of weather, climate, vegetation, ecology, landscape, human needs, and the risks and benefits of fire (Huffman, 2013; Moore, 2019; Rodríguez-Trejo et al., 2011).

Efforts to promote IFM in the Peruvian Andes should focus on balancing traditional fire practices with modern fire prevention and management techniques, building community capacity, and supporting sustainable livelihoods. Adapted from FAO (2011) and Myers (2006), possible policy measures include:

- Legal recognition of traditional controlled burns by implementing a permit system that respects Indigenous knowledge and sets clear, seasonal guidelines to prevent fires during high-risk periods.
- Capacity building is essential, and training programs should be established to support volunteer community fire brigades and integrate fire management into agricultural extension services with guidance on safe burn practices, fire prevention, and soil restoration.
- Traditional knowledge should be incorporated into IFM plans by creating knowledge exchange platforms and creating advisory councils with Indigenous leaders to inform local and regional policies.
- Technological tools can further support these efforts; satellite and drone monitoring systems should be used to provide real-time fire data to community brigades and local authorities, while a mobile app or WhatsApp-based reporting system could enable rapid reporting and response to potential fires.
- Financial incentives, such as subsidies for fire-safe land management practices and a recovery fund for fire-related damages, can support sustainable land use.
- Education and outreach initiatives are also key, with public awareness campaigns about the risks of uncontrolled burns and fire education integrated into school curricula on fire safety, prevention, and ecology.

Lastly, regional fire management centers can be established to coordinate efforts across local governments, community leaders, non-profits, and environmental and agricultural agencies, promoting a well-supported, inclusive IFM strategy in the Andes.

7. Conclusion

Overall, our study brings insights into how key actors think about fire and fire management and promotes conversations on fire governance and local community empowerment. The southern Peruvian Andes is used here as a case study to explore the varied perspectives of key actors involved in fire-related decision-making. This case highlights a setting where escaped fires have only recently drawn significant attention, contrasting with the minimal concern they posed two decades ago. It also represents a context where numerous rural communities are already empowered and exercise a degree of autonomy in natural

resource governance and decision-making. With some implications to other tropical regions, this study found how contrasted opinions about the role of fire can lead to a range of preferred fire solutions, from top-down suppression to community-based fire management. This divergence reflects an underlying debate over whether fire should be banned or embraced. Reconciling these perspectives demands an integrated fire management approach that balances the ecological and social role of fire with solutions at multiple scales. Furthermore, fire-related actions have been historically addressed from a top-down conservationist approach when they should also be integrated into discussions of rural development. Ideally, such a shift could strengthen local and traditional institutions for adequate fire prevention and control and provide a better fit to the local context of the actors implementing them.

8. References

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