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"No One Is Safe": Agricultural Burnings, Wildfires and Risk Perception in Two Agropastoral Communities in the Puna of Cusco, Peru

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Abstract: By developing a conceptual framework that integrates the use of fire in agricultural activities, the occurrence of wildfires, and the perception of wildfire risk, this article examines the interplay among these three elements within both wet and dry Puna grasslands. The analysis focuses on two peasant and agropastoral communities, Vilcabamba and Apachaco, both located in the Cusco region—an area with the highest incidence of wildfires in Peru. This study highlights the sociocultural significance and persistence of agricultural burnings within Puna agropastoral communities and the necessity of considering changes in agricultural activity, mutual aid systems, and communal institutions—particularly regarding land ownership—to understand the factors contributing to wildfire occurrence. Furthermore, it reveals the widespread recognition of wildfire risk among community members, who are acutely aware of both the likelihood and potential severity of wildfire events, while governmental policies aimed at addressing this hazard predominantly focus on raising awareness and enforcing bans on agricultural burning, with limited consideration of these complex sociocultural dynamics.

Keywords: land tenure; burnings; wildfires; risk perception; Andes

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1. Introduction

Wildfires have increasingly been recognized as a critical concern due to their rising frequency and magnitude [1–3]. In Latin American, this trend has raised pressing questions regarding the underlying causes of what is predominantly an anthropogenic hazard, disproportionately affecting already vulnerable populations such as indigenous or peasant communities as well as small-scale farmers. The academic literature highlights a strong connection between fire usage and agricultural practices, particularly through controlled burning, with the loss of control being identified as the primary driver of wildfires across various ecosystems [4–13]. In Peru, official monitoring data indicate a significant increase in wildfire occurrences over the past five years [14], with Puna grassland ecosystems—home to agropastoral systems and peasant communities—being particularly affected.

Pastoral systems, understood as adaptive networks of biophysical and social interactions, are predominantly shaped by socioeconomic and political factors that influence their capacity to sustain and create habitats [15]. In Peru, agropastoral activities are concentrated in the vulnerable Puna region, where ecosystem services are increasingly threatened by climate change, agricultural intensification, overgrazing, and mining [16]. Studies on

Peruvian pastoral systems [17,18] underscores the significant influence of agricultural technification, urbanization, investment, and climate variability in driving these changes. Moreover, the transition towards individual land tenure and the erosion of communal organizations have played a crucial role, though peasant communities continue to defend their resources [18].

In medium- and small-scale agriculture, which forms a component of pastoral systems, agricultural burning remains a widely practiced, cost-effective, and deeply ingrained sociocultural method for multiple purposes, including clearing agricultural residues, expanding arable land, enhancing soil nutrients, and mitigating climate-related risk [7–9,19], despite regulatory prohibitions issued by the Agricultural Ministry (MINAGRI or AG) (Article 207 of the Forestry Management Regulation—Supreme Decree No. 018-2015-MINAGRI, Article 27 of the Solid Waste Management Regulation of the Agricultural Sector—Supreme Decree No. 016-2012-AG, Article 310 of Legislative Decree No. 1237 of 2015 amending the Penal Code) and widespread awareness of the associated risks of wildfires [19].

This article examines the relationship between the use of fire in agricultural activities, the occurrence of wildfires, and the perception of fire risk in wet and dry Puna grasslands, focusing on two agropastoral communities (Apachaco and Vilcabamba) located in the Cusco region of Peru. The analysis seeks to integrate sociocultural and ecological processes at both local and broader scales. In doing so, the article highlights how changes in land tenure and management practices contribute to the occurrence of wildfires, linking these phenomena to broader shifts in land use and technological advancements.

While some studies focus on the physical factors influencing wildfires [1,20], research on the social and cultural dimensions remains limited. This gap is particularly significant given that over 90% of wildfires in Peru are anthropogenic in origin [7] and primarily associated with agricultural activities in grasslands and pastures of the Peruvian Andes, which are identified as highly combustible in wildfire risk assessments [21].

1.1. Background

1.1.1. Livestock Activity and Social Changes in the Puna

The Puna ecoregion, comprising wet and dry (xerophytic) Puna, holds considerable significance due to its rich biological and agricultural biodiversity, as well as the essential ecosystem services it provides, including food and fiber production, carbon sequestration, and water regulation [16]. In Peru, high Andean grasslands, or *pajonales*, cover 14.2% of the national territory and support 73% of the country's cattle population [22]. Moreover, natural pastures—both managed and unmanaged—constitute 85% of the agricultural land within the Puna altitudinal zone [23] and are predominantly used by peasant families for extensive livestock farming.

Historically, livestock farming in Peru has been predominantly concentrated in the Sierra, with grazing serving as a central activity. Pastoral communities were traditionally characterized by their mobility, which enabled them to maintain autonomy [24] and manage risks more effectively [15,25], given the mobility of their primary resource—livestock. While agriculture has often been considered a risky activity due to its vulnerability to market and climate conditions, it is common for Puna communities to combine farming and agriculture, thereby forming agropastoral systems [16].

Flores Ochoa's study [26] identifies three key characteristics of high Puna societies (located above 4200 m.a.s.l.): seasonal transhumance, which involves relocating residences to access adequate pastures for livestock; dispersed settlement patterns without urban centers; and social organization rooted in kinship ties. In the middle Puna (4000 to 4200 m.a.s.l.), societies primarily engage in mixed farming, with a particular focus on tuber cultivation. These features, while reflecting both historical continuities and recent transformations,

remain central to understanding the dynamics of agropastoral systems, especially within middle Puna societies.

Livestock production systems involving native and *criollo* animals are predominantly traditional and managed by small-scale, often economically disadvantaged peasant producers who prioritize farming over breeding, particularly with non-native (introduced) livestock ([27], p. 274). These systems are oriented toward savings and characterized by minimal investment and an emphasis on risk avoidance rather than maximizing productivity. They rely primarily on natural pastures or limited seasonal forage and make extensive use of communal grazing areas ([27], pp. 274, 275). Thus, peasant livestock farming has historically been geared toward subsistence or local markets, where quantity often took precedence over quality, as it conferred social prestige. While pastures were communally owned and managed through communal institutions, livestock ownership remained private or confined to family units [28].

Earlier studies have characterized livestock farming in the Puna as being closely tied to mobility, low levels of technological advancement, minimal investment, and heavy reliance on natural pastures and communal management. However, recent research [16–18,29–32] has revealed significant changes: increased specialization in livestock farming, a shift from extensive to semi-intensive production systems, a heightened emphasis on market-oriented crops, a diminished redistributive capacity of peasant communities due to the rise of private-family management, and the gradual abandonment of both cultivated lands and natural pastures.

The transition from extensive to semi-intensive livestock farming has been driven by early 20th century political projects that introduced purebred livestock like the Brown Swiss, adaptable up to 4000 m.a.s.l. [17]. These efforts aimed to enhance livestock quality to support the production of dairy products for commercial markets [33]. In response, families have expanded cultivated pasture areas and invested in infrastructure, including irrigation systems and fencing, reflecting increased specialization and a greater commitment to livestock management.

Suarez [17] identifies several factors that have facilitated the adoption of the Brown-Swiss breed, including land subdivision, irrigation systems, stables, and fenced enclosures. The transition from extensive to semi-intensive livestock farming is marked by delineated grazing lands managed by individual families aiming to establish micro-enterprises, focused on improving livestock quality and its derivatives. This shift entails that the new livestock—now Brown Swiss—fulfils its technological and ecological functions within the delimited plot rather than grazing on the natural pastures of the highland areas. In other contexts, such as in Huamantanga in the Lima highlands, the increase in "improved" livestock over *chusco* or *criollo* breeds and the privatization of communal land are linked to the construction of a road connecting Huamantanga to Lima [32]. To mitigate livestock feed risks, the Peruvian state and NGOs have promoted pasture cultivation to address climate-related hazards [34,35]. Meanwhile, in other areas of the Puna, market-oriented crops like maca and quinoa are becoming more prominent due to growing demand, leading to intensified agricultural practices, shorter fallow periods, and a reduction in grazing areas [16].

Changes within Puna livestock communities are characterized by shifts in pasture use and management. Studies [31,36,37] highlight a combination of communal and private or family-based tenure, with private tenure becoming increasingly dominant through land subdivision. While livestock farming remains largely subsistence-oriented, there is a growing trend toward specialization and economic investment, as evidenced by the adoption of "improved" livestock breeds and the cultivation of managed pastures, which is gradually resulting in the abandonment of natural pastures in more remote areas.

1.1.2. Uses of Fire in Agricultural Activities

Controlled burnings, widely practiced on lands suitable for pasture and agricultural production, involve the intentional use of fire to manage livestock, agricultural, and forestry resources [7]. Performed under low-risk conditions by trained and knowledgeable individuals [38], these burnings fulfill multiple purposes: removing dry, unpalatable grasses to encourage regrowth [39]; controlling woody vegetation; replenishing soil nutrients through post-burning rainfall; reducing fuel loads from agricultural residues; and managing fauna by enhancing or conserving habitats [38,40–42]. Additionally, controlled burnings are used to expand grazing areas [43] and create firebreaks to mitigate the spread of wildfires [5,44].

Agricultural burning, historically rooted in orally transmitted knowledge [39], has been altered or abandoned in certain communities. In Colombia's Sáliva indigenous community, Huertas Herrera et al. [6] found that younger generations lack ancestral fire knowledge, shifting from native savannas to monocultures. Similarly, in Venezuela's Pemón community, Bilbao et al. [5] observed that population growth and changes in settlement patterns have disrupted traditional burning practices, thereby increasing wildfire risk. In Bale, Ethiopia, Johansson et al. [44] noted that the cessation of controlled burning reduces grazing potential while elevating the likelihood of large-scale wildfire risk. These studies collectively emphasize the profoundness of societal changes on wildfire dynamics, including vegetation accumulation and the erosion of traditional fire-related knowledge.

Anthropogenic wildfires occur when control is lost during burning activities. Their occurrence and intensity are influenced by a combination of physical and social factors, including land-use changes and the implementation of strict fire prohibition policies. These factors have contributed to a diminished understanding of the ecological and social roles of burning, resulting in the loss of traditional fire knowledge [38,39].

Myers [39] notes that numerous countries have adopted policies that uniformly classify all wildfires as detrimental, banning prescribed burns and criminalizing the use of fire in agriculture. Such measures are frequently implemented without considering the needs of subsistence farmers or offering viable alternatives, as exemplified by the case of Peru. These actions underscore a broader failure to recognize and understand traditional agricultural fire practices ([39], p. 15).

1.1.3. Wildfires in Peru

According to the National Forestry and Wildlife Service (SERFOR) [45], although the use of agricultural fire is associated with wildfires, its causes differ significantly across Peru. In the Amazon, fire is employed to clear vegetation in deforested areas for crop cultivation, a practice often intensified by road construction. In the Andes, fire is used primarily to renew pastures, including wetlands, for livestock grazing. In the inter-Andean zone, it serves as a tool for crop management by removing weeds. Meanwhile, in northern Peru, *mieleros* (honey hunters) ignite the bases of trees to facilitate honey collection and fire is also utilized in agriculture land preparation.

Manta Nolasco [7] categorized the causes of wildfires in the Peruvian Andes, highlighting the role of negligence in livestock-related activities. The author observes that the loss of fire control in these areas frequently results in the spread of flames into "natural forests", with pastures being the most adversely affected ecosystem. According to SERFOR wildfire records from 2017 to 2020, wildfire causes are classified into fourteen probable categories. Notably, over 50% of the records are attributed to "unknown causes", while agricultural residue burnings account for 35.8%, pasture burnings intended to attract rain comprise 6.2%, and intentional fires arising from conflicts represent 1.4% [46].

In the Peruvian highlands, the wildfire season, which extends from July to November, aligns with the agricultural calendar and is inversely correlated with the rainy season [7,8].

The majority of wildfires occur during the dry period, when conditions are most conducive to fire spread. In the Puna region, overgrazing and the excessive use of fire contribute to soil degradation, a decline in plant diversity, and the erosion of the economic value of native pastures [16].

Research on fire use and wildfires at the communal level in Peru remains limited but is steadily expanding. Alvarez Rios [8] found in Cusco that fire use, as a cultural practice, is shaped by crop type and geography. This practice persists due to its affordability and multiple benefits, including land expansion, agricultural clearing, and soil fertilization. Furthermore, Alvarez Rios observed that the increase in fires in 2020 was associated with community members returning to rural areas during the COVID-19 pandemic, leading to the reopening or recovery of agricultural lands.

In the wet Puna of Ayacucho, Arones [9] identifies wildfires as primarily anthropogenic, driven by activities such as the opening of new fields, stubble burning, and the burning of *ichu* grass to promote pasture regrowth. Cultural practices, including children playing with fire, also contribute to these occurrences. Additionally, Arones highlights the gradual expansion of cold-resistant oat crops into the Puna zone, where agricultural burning is commonly employed to clear land, occasionally leading to wildfires.

In Peru, the group involved in wildfire risk management remains relatively small. At the national level, regulatory frameworks penalize agricultural burnings and assign liability for wildfires (DS No. 018-2015-MINAGRI, DS No. 016-2012-AG, Article 310° of DL No. 1237). Additionally, SERFOR has developed a Wildfire Prevention and Reduction Plan [45], which was scheduled for an update in 2023. Despite budgetary constraints, regional governments have developed wildfire prevention projects. In particular, the authorities in Cusco have implemented a risk prevention and reduction plan for the 2022-2026 period. NGOs like the Centre for Disaster Studies and Prevention (PREDES) and the Amazonian Conservation (ACCA) in Cusco have reportedly collaborated with peasant communities on wildfire prevention efforts. These initiatives have included the integration of norms and sanctions into communal statutes, although detailed documentation of these activities remains lacking.

In Peru, although research on fire use and wildfires is still developing, evidence indicates that wildfires, particularly those impacting pastures, are closely associated with agricultural burning practices employed for land clearing, fertilization, and pest control. Politically, responses have predominantly emphasized punitive measures aimed at suppressing or reducing wildfires and been implemented by both governmental and non-governmental actors. This narrow approach hampers the development of a comprehensive fire management policy. Achieving such a policy requires a deeper understanding of the cultural, environmental, and economic dimensions of fire use, alongside the active participation of rural communities [40].

1.1.4. Wildfire Risk Perception

Risk perception encompasses how individuals assess the probability and severity of wildfires impacting their surroundings, including people, livelihoods, and landscapes [47,48]. Schneiderbauer et al. [49] reviewed studies on risk perception and adaptive behavior, finding no definitive link between awareness and adaptive actions. Their review further identifies a significant research gap regarding how mountain-specific factors—such as biophysical, economic, social, or cultural elements—influence risk perception.

Gordon et al. [50] found that wildfire risk perception in the Eastern United States is shaped by a combination of social, cultural, and biophysical factors, with direct experience and ecological conditions serving as key drivers of concern. In Colorado, Champ and Brenkert-Smith [51] observed that while perceptions of wildfire probability remained

unchanged after a fire event, concerns about its severity intensified. Similarly, Champ et al. [47] also noted no consistent relationship between perceived risk and mitigation behavior, a complexity also corroborated by Larsen et al. [52]. Their study revealed that even in Colorado's Animas Valley, where residents exhibited low perceived vulnerability, mitigation actions were still undertaken.

McCaffrey [53], in a comprehensive review of wildfire response research from 2000 to 2010, concluded that perception alone is insufficient to motivate protective actions. Christianson [38] highlighted that in indigenous communities across Australia, Canada, and the United States, other pressing social issues often take precedence over wildfire risk, despite their vulnerability due to remoteness and limited connectivity. Moreover, Christianson [38] identified negative perceptions of prescribed burns, citing health and disaster risks as significant concerns. This perspective is echoed by the Sáliva in Colombia, who associate fire use with property damage and ecosystem degradation [6].

Despite heightened awareness of wildfire risk, societies frequently fail to adopt preventive measures, such as abandoning the use of agricultural fires. Multiple studies [47–53] suggest that risk perception alone does not consistently translate into mitigation actions. Christianson [38] argues that persistent social challenges may perpetuate risky practices, while the absence of affordable alternatives further impedes the adoption of safer measures [4,40].

1.2. Conceptual Framework

Bollig and Göbel [25] highlight that pastoral communities have traditionally managed risk through livestock mobility, often maintaining dual residences in both urban and rural areas. However, recent studies on Andean livestock systems reveal a shift toward reduced mobility in semi-intensive systems involving "improved" cattle that are more reliant on cultivated pastures.

Primary data from this study indicate that cultivated pastures and improved livestock are typically maintained near irrigation systems and primary residences, often located in or near populated areas with greater accessibility. Improved cattle are predominantly raised in lower-altitude areas and confined to enclosed pastures [17], resulting in the abandonment of higher-altitude areas and the subsequent accumulation of vegetation. In contrast, *criollo* cattle continue to graze in higher regions, where grasses no longer grow tall enough to support traditional uses, such as house roofing. Due to the proximity of cultivated crops and pastures, uncontrolled fires from agricultural burns can spread more easily, particularly during the dry season or when vegetation moisture is low and when winds are stronger [7–9,19].

Research conducted by Gordon et al. [50] and Champ and Brenkert-Smith [51] identifies a direct relationship between wildfire occurrence and risk perception that is influenced by ecological, socioeconomic, and political factors. However, a heightened perception of risk does not necessarily result in the adoption of mitigation measures, such as halting agricultural burning practices. Thus, understanding the use of agricultural fires and wildfire risk in pastures requires an in-depth examination of the ecological, socioeconomic, and cultural contexts of the study area, alongside broader processes affecting peasant families and organizations in the Andes.

The conceptual model of agricultural fire use and wildfire risk perception (Figure 1) illustrates the interconnectedness of its key components. Socioeconomic, cultural, and ecological factors, combined with agricultural practices, are critical for comprehending fire use and assessing wildfire risk through the lenses of hazard, vulnerability, and perception within the study areas.

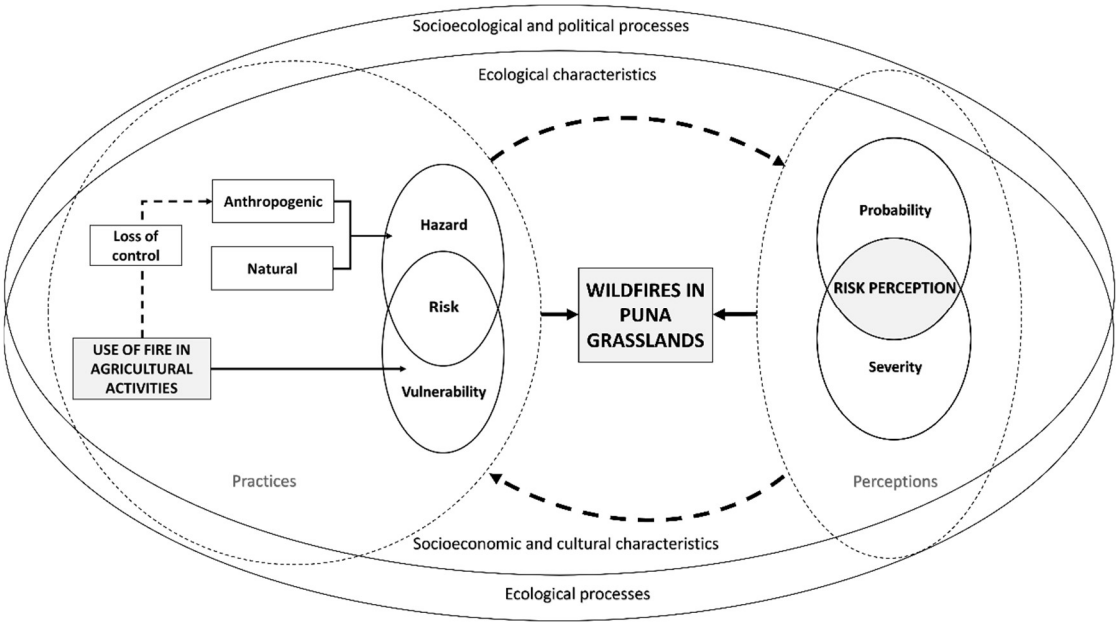


Figure 1. Conceptual model of fire use in agricultural activities and perception of wildfire risk in pastures. Based on Wisner B. et al. [54], Paton D. et al. [55], Oliveira S. et al. [56], and Taboada Hermoza [19].

2. Research Methods

2.1. Research Methods

This study utilized a mixed-methods approach, incorporating qualitative techniques such as participant observation and interviews, alongside quantitative methods, including surveys and the review of monitoring records. Originally conceptualized in 2023 as a thesis focusing on a case study in the dry Puna (Apachaco) [19], the research was later expanded to include the wet Puna zone (Vilcabamba) to examine both differences and commonalities. The research was conducted in three main stages: the selection of study areas and cases, the execution of ethnographic fieldwork, and the administration of the Fire Use and Wildfire Risk Perception Questionnaire (CUFPER).

2.1.1. Selection of Area and Cases

Historical records from 2003, compiled by the Ministry of the Environment (MINAM) [14] and the National Institute of Civil Defense (INDECI), show that Cusco consistently reports the highest number of wildfires. Between 2003 and 2023, MINAM reported 4877 fires (13.2% of national cases), while INDECI recorded 1472 wildfire-related emergencies. The discrepancy likely reflects INDECI's practice of only logging emergencies that received a formal response, whereas MINAM includes both attended and unattended fires.

The Apachaco and Vilcabamba communities were selected for ethnographic research based on three key criteria: their location within the Puna grassland ecosystem, the scale of their social organization, and the prominence of agriculture in their livelihoods. To identify fire-affected grasslands used for livestock, MINAM's wildfire records were cross-referenced with the National Ecosystems Map [57] and data from the National Agricultural and Livestock Census (CENAGRO) [58]. The peasant community was specifically chosen as the unit of social and spatial organization to examine its potential influence on fire use.

Between 2003 and 2023, MINAM recorded 251 wildfires in dry Puna grasslands and 2113 in wet Puna grasslands within Cusco (Figure 2). At the peasant community level, Apachaco (Coporaque district) experienced 17 wildfire incidents in dry Puna (DP), whereas Vilcabamba recorded 42 incidents in wet Puna (WP). Both districts play a vital role in

livestock production, with Cusco ranking third nationally in the number of agricultural units, where natural pastures dominate the landscape covering 1,647,508.70 ha [58].

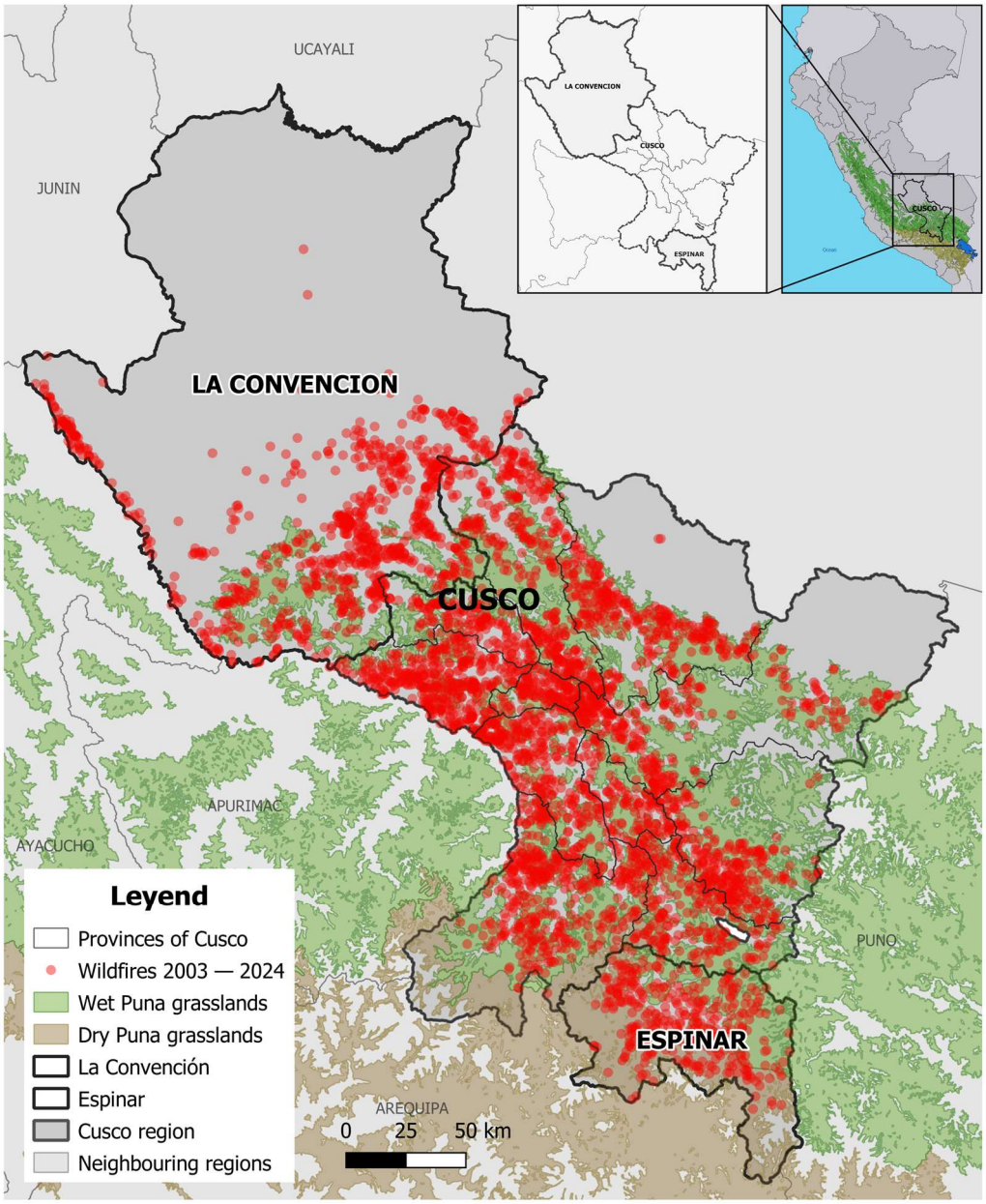


Figure 2. Distribution of wildfires in dry and wet Puna grasslands in Cusco.

2.1.2. Development of Ethnographic Work

Ethnographic fieldwork for this study was conducted from July 2023 to June 2024. Initial visits in July served to confirm the selection of communities, while fieldwork officially commenced in August, coinciding with the land preparation period when fire is commonly used. Regular visits and active participation in communal and family activities helped overcome initial hesitancy to discuss fire use, with the support of local leaders proving crucial to building trust.

A semi-structured interview guide (Supplementary Material) was utilized, comprising four main sections: interviewee and family demographics, agricultural practices, fire use, and perceptions of wildfire risk. A total of 35 interviews were conducted with household heads (both men and women), communal leaders, and civil defense personnel from district municipalities tasked with local risk management (Table 1).

Table 1. Characteristics of CUFPER interviewees [1].

Community	Apachaco	Vilcabamba
Interviews	22	13
Sex	F (5)–M (17)	F (6)–M (7)
Age range	28–73	32–70
Average age	56.8	49.4
CUFPER	84	88
Sex	F (55%)–M (45%)	F (45%)–M (55%)
Age range	23–75	22–78
Average age	47.6	47.8
Distribution per sector	Chiralana (30%), Machu Puente (21%), Machaccoyo (18%), Pucará (15%), Apachaco (13%), Pisccatuyo (2%)	Vilcabamba (27%), Pampaconas (15%), Salinas (11%), Minasmayo (8%), Collpa (8%), Atoqsaico (7%), Vista Alegre (7%), Valle Chancavine (6%), Valle Concevidayoc (5%), Challcha (5%), Coylluychu (2%)

[1] At the start of each interview, informed consent was explained and approval for recording was requested (see Supplementary Material). All interviews were transcribed, organized using Atlas.ti 8 (free trial version) software applying 16 codes, and analyzed.

2.1.3. Fire Use and Fire Risk Perception Questionnaire (CUFPER)

The CUFPER questionnaire was designed using KoboToolbox to gather data on fire use and wildfire risk perception through closed-ended questions (Supplementary Material).

The final questionnaire, comprising 36 questions, was administered in Apachaco between September and November 2023 and in Vilcabamba in June 2024. The surveys were conducted during communal assemblies, with translation assistance provided by community members (two in Apachaco and three in Vilcabamba) for Quechua-speaking participants. Data from 172 household heads were collected through completed CUFPER questionnaires (see Table 1), and the information was processed using basic tools in Microsoft Excel.

2.2. Study Cases

2.2.1. The Peasant Community of Apachaco

Apachaco, located at an elevation of 3900 to 4100 m.a.s.l., is predominantly characterized by extensive natural grasslands, although significant cultivation occurs on flatlands and slopes (Figure 3). The community comprises six sectors—Pisccatuyo, Machaccoyo, Pucará, Chilarana, Apachaco, and Machupuente—situated within the dry Puna grassland ecosystem.

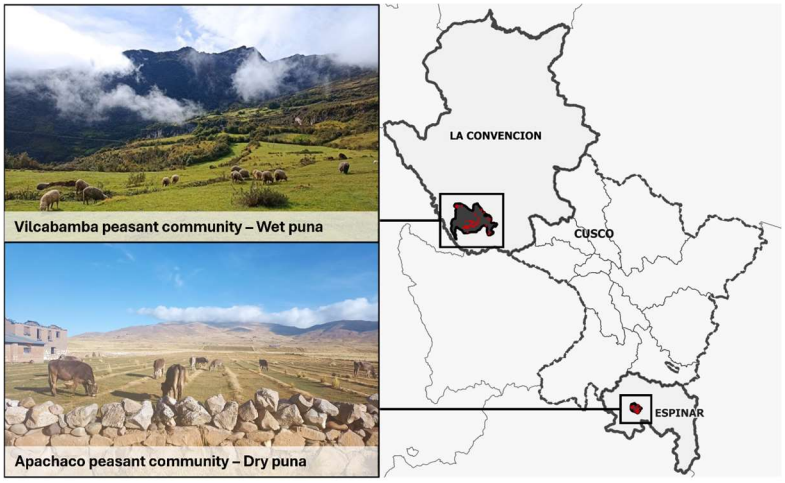


Figure 3. Map of the location of Vilcabamba and Apachaco communities in Cusco.

Two major events have shaped Apachaco's recent history. The first was the separation of its annexes, Tarucuyo and Checcane, into newly established communities, which substantially reduced Apachaco's territory. The second, and arguably more impactful, was the land parceling process initiated in 2000 and spanning approximately six years. This process sought to rectify severe inequities in the allocation of cultivated and grazing lands, fostering a sense of "equality" among community members.

> "Others had larger plots, while some of us had none; there was inequality. Therefore, as approved in the meeting, we divided the land into parcels. I had nothing [. . .]. So, we had to borrow to farm, paying a small rent. [. . .] Only a minority had land, and it produced good potatoes. That's why it was decided to parcel the land for equality". (M.C.C.—female, 49 years old, member of the Apachaco Communal Board).

Ultimately, the allocation of land during the parceling process was determined by the type of property (cultivation or grazing) and the length of a family's residence in the community. Consequently, many community members who had migrated to Cusco, Lima, or Arequipa returned to Apachaco during the 2000s. Currently, the community consists of 228 registered families and approximately 1000 inhabitants, including non-members (those who do not hold the status of *comunero*). Parceling limited land to 10 hectares per family; however, it resulted in the treatment of collective land as private or family-owned, as evidenced by the construction of fences and the weakening of communal land management decisions. Livestock practices also evolved, with a decline in camelids and sheep and an increasing preference for cattle, with herds reaching up to 30 animals. Furthermore, the traditional *criollo* breed was replaced by Brown Swiss cattle, a shift driven by public and private investment projects. Since 2013, no fewer than 24 public investment projects related to cattle management and genetic improvement have been implemented in Espinar province [59]. Privately, the mining company Antapaccay—formerly Tintaya— has significantly invested in agriculture under a framework agreement with Espinar since 2003. These investments include the provision of Brown Swiss cattle, livestock fencing, reservoirs, irrigation channels, and tractors for community use [60]. In Apachaco, many community members have transitioned to semi-intensive farming to increase their income, resulting in cattle being kept in middle- and lower-altitude areas closer to the residential dwellings.

Although *ayni*, the traditional mutual aid system, continues to be practiced, most interviewees noted its decline, as families increasingly choose to cultivate smaller plots or hire labor instead. This decline is likely attributable to the introduction of the communal tractor service in 2006, which offers a more cost-effective alternative (PEN 40 or USD 10.5)

compared to manual labor (PEN 50 or USD 13.2 per day) or the provision of food and beverages required for *ayni*.

In Apachaco, all families engage in agriculture to some extent, often supplementing their income through temporary employment. The majority (82%) of families primarily produce crops for self-consumption, while milk and other dairy products derived from livestock are notably predominantly intended for sale. Agricultural production in the community includes potatoes, quinoa, cañihua, fava beans, oca, oats, barley, and an expanding area of cultivated pastures (38% have both natural and cultivated pastures), with rest periods ranging from 2 to 10 years. Although most agricultural activity relies on rainfall, 37% of families have access to irrigation systems, which are regarded as highly valuable assets. Additionally, 75% of surveyed families own livestock, including cattle, sheep, and camelids.

2.2.2. The Peasant Community of Vilcabamba

The community is divided into nine sectors: Vilcabamba, Salinas, Collpa, Challcha, Pampaconas, Minasmayo, Vista Alegre, Coylluychu, and Atoqsaico. It additionally includes the Concevidayoc and Chancavine valleys, which are accessible through the dense jungle of the Ayacucho region. Portions of the Vilcabamba, Challcha, Collpa, Salinas, and Pampaconas sectors fall within the wet Puna grassland ecosystem (Figure 3).

Over the past four decades, three pivotal events have significantly influenced the community. The first was the internal armed conflict during the 1980s and 1990s, characterized by clashes among the Armed Forces, the Shining Path, and the Tupac Amaru Revolutionary Movement (MRTA), which forced many families to flee. The second was the construction of a road to the Pampaconas sector, which prompted a shift in settlement patterns, with most residents relocating closer to the road. This development led to the decline of the *laymi* cultivation system, a collective farming method that operates under the still practiced *ayni* mutual aid system. The most recent event was the COVID-19 pandemic, which prompted the return of many individuals who had migrated since the 1980s. In 2020 alone, the population increased from 650 to 800 families residing in the community.

Some families frequently travel to or have established residence in Pucyura, a part of the Lucma Peasant Community, which provides access to a wider range of services. Despite the arrival of a road nearly 20 years ago, not all sectors are connected. While Pucyura is accessible within 30 min by road, other sectors can only be reached on foot, requiring journeys of up to three days. The community also lacks reliable cellular coverage, with connectivity available only to families who have installed satellite internet antennas.

Vilcabamba has not undergone a parceling process, resulting in substantial variation in landholdings, which range from small housing plots of 150 m² to over 80 hectares per family. Despite some community complaints, the communal authority stated that implementing parceling would be challenging. The community retains "free" communal land, primarily utilized for grazing approximately 60 head of *criollo* cattle, with land rentals for grazing or cultivation remaining uncommon.

In Vilcabamba, where 95% of the population participates in agriculture, 67% of surveyed families own cattle or sheep and 68% primarily use their agricultural output for self-consumption. Unlike Apachaco, Vilcabamba has forested areas planted with *Pinus radiata* and *Pinus patula* as part of public investment projects. Temporary employment in construction, cleaning, and other services provides a highly valued income due to increasing risks from climate-related hazards and livestock diseases.

Agriculture in the region predominantly relies on rainfall, with only 3% of families having access to irrigation systems. In the wet Puna, the main crops include potatoes, oca, lisas, tarwi, and fava beans. Meanwhile, in the valley—characterized by slash-and-burn

practices and shrub-dominated landscapes—coffee and maize are cultivated. In the higher wet Puna zones, land rests for 2 to 6 years between crop cycles, with natural pastures typically regenerating within a year. The practice of planting pastures following potato harvests has become increasingly common. Agricultural practices remain largely manual, with the traditional *chaquitaclla* plough still in use.

Livestock management is extensive and focused on *criollo* cattle that primarily graze on natural pastures in communal or family-owned open fields, where they are often left unattended for weeks. Families typically own between 4 and 30 head of cattle. Among respondents, 72% manage natural pastures, while 24% utilize a combination of natural and cultivated pastures. Regardless of pasture type, some families have expanded grazing areas and constructed fences in formerly shrubby or grassland areas.

3. Results

3.1. Uses of Fire in the Wet and Dry Puna

Although this article primarily examines the use of fire in agriculture, it is important to acknowledge its broader significance in daily life, particularly for cooking. Fire is used for household cooking and becomes particularly important during intensive agricultural periods, such as sowing and harvesting, when *huatias* (small earth ovens) are used to cook tubers in the fields. In Apachaco, as in other dry Puna communities, the fuel sources are primarily dry grass and cow dung, whereas in Vilcabamba, located in the wet Puna, wood serves as the main fuel source.

In the dry Puna (Apachaco), 52% of families reported using fire for agricultural purposes, compared to 42% in the wet Puna region (Vilcabamba). The subsequent sections will provide a detailed examination of fire use within these agricultural activities.

3.2. The Use of Fire in the Agricultural Cycle

3.2.1. Purposes

Fire fulfills multiple functions, with soil fertilization being its primary purpose. In the dry Puna, it is a common practice to burn wild grasses, shrubs that grow during fallow periods, or crop residues from the previous season; this practice also serves a secondary purpose: clearing fields. A third purpose is to clear new areas for cultivation or grazing when "free" land is available. In such cases, vegetation—including grasses and shrubs—is burned. In the wet Puna, a specific practice involves leaving taller shrubs or trees to provide shade for livestock and encourage grass growth.

A fourth use of fire is pest and disease control, particularly against *rancha*, a condition that affects potatoes in both regions. In the dry Puna, community members reported addressing an animal pest, the *poroncoe* (*Cavia tschudii*), a rodent whose urine damages cultivated grasses and harms cattle. The fifth purpose is to mitigate the effects of frost and hail, particularly in the dry Puna, during critical periods of crop growth. This practice is more controlled and involves the "smoking" of residues and debris in small mounds. A sixth, nearly obsolete purpose, is pasture rejuvenation or "re-sprouting". In the dry Puna, interviewees noted that this practice was once widespread when *criollo* cattle relied exclusively on natural grass for grazing. In the wet Puna, where extensive livestock farming persists, interviewees emphasized that re-sprouting burns should occur before the rainy season.

3.2.2. Locations for Burning

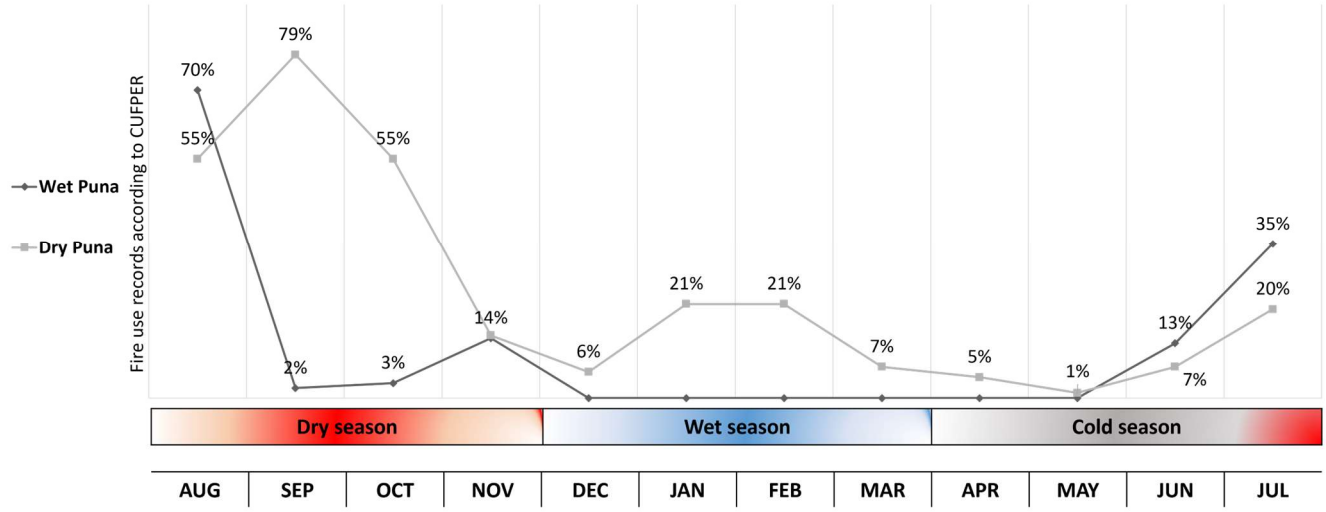
In the dry Puna of Apachaco, burning is conducted in cultivation plots designated for tubers, grains, or pastures. With the transition to semi-intensive livestock farming, fire is no longer used in the high grasslands of the community. Instead, burning is now limited

to plots near homes or pathways, where improved livestock has also been relocated. In the wet Puna region of Vilcabamba, although *criollo* cattle graze freely in higher areas with natural pastures, fire is primarily employed in cultivation plots. In both cases, plots are located near grasslands, posing a risk of wildfires from uncontrolled burns. To mitigate this risk, community members implement techniques based on location, timing, and prevention techniques.

Location-based techniques involve ensuring that burning takes place away from the edges or boundaries of plots. Community members report creating piles of residues or vegetation in specific areas of cultivation o grazing plots—either lateral, central, or dispersed—while maintaining a safe distance from plot edges. Timing-based techniques involve assessing the time of day with favorable conditions for burning while minimizing risk. The preferred timing varies between the two regions: in the dry Puna, burning is avoided in the afternoons due to higher wind speeds, whereas in the wet Puna, afternoons are preferred as the wind facilitates the burning process. Prevention techniques focus on minimizing fire risk through edge cleaning, preparing tools such as buckets of water and cloths to extinguish uncontrolled burns, and closely monitoring the burn until it is fully extinguished.

3.2.3. Timing of Burns

Burning periods are linked to the agricultural cycle and its various purposes (Figure 4). In both the dry and wet Puna regions, the dry season, spanning from July to September, witnesses the highest frequency of burns. These burns are primarily conducted to fertilize the soil with ash from burned residues, clear plots, and control pests, particularly *rancha*. A secondary burning period, specific to the dry Puna, as indicated by CUFPER data, takes place between January and March during the cold and rainy season. These burns are intended to mitigate the effects of hail and frost.



Land use	DP	*Sowing*	*Cultivated land*	*Harvest*	*Preparation*
	WP	*Cultivated land*	*Harvest*	*Preparation*	*Sowing*
Purpose		*Fertilizer / Cleaning / Plague control*	*Alleviate climate hazards (DP), Huatia (WP)*	*Huatia (cooking) (DP)*	*Cleaning / Fertilizer*
Time		*Dawn, Morning (DP) / Afternoon (WP)*	*According to Hazard signal (DP)*	*Afternoon (WP)*	*Dawn, Morning (DP)*
		Dawn (DP 61%) — Afternoon (WP 73%)			
Participants		***DP**: 1=15%, 2=19%, **3—5=35%**, 6—8=11%, 9—11=6%, +11=14%* ***WP**: 1=34%, **2=47%**, 3—5=19%*			

Figure 4. Relationship between agricultural cycle activities and uses of fire in the dry Puna (DP) and wet Puna (WP).

The timing of burns depends on the intended purpose and prevailing environmental conditions. To mitigate the effects of frost and hail, burns are conducted when these hazards are deemed imminent, based on traditional indicators known as *señas* or *lomasas*. For fertilization, cleaning, or opening new areas, burns in the dry Puna are typically carried out in the early morning (61%) before 6 a.m., when low wind speeds and higher humidity levels cause the fire to burn more slowly. In the wet Puna, burning is generally performed in the afternoon (73%) to take advantage of, or be "assisted" by, wind and heat. Notably, in Vilcabamba's valley areas, the timing of burns differs, as conditions such as wind and heat are avoided due to the steep terrain.

3.3. Relationship Between Changes in Agricultural Activity and the Use of Fire

In both cases, interviewees observed changes in seasonal patterns that were characterized by a more intense dry season and the occurrence of frosts and hail throughout the agricultural cycle, extending beyond the cold season. Figure 4 illustrates the increase in fire use in both the dry and wet Puna for soil preparation and sowing, especially towards the end of the cold season and throughout the dry season. The use of fire diminishes during cultivation and harvest, particularly in the wet Puna. CUFPER data records indicate that fire is used to mitigate the effects of frost and hail exclusively in the dry Puna; however, interviews reveal that *huatia* fire practices occur in both the wet and dry Puna.

Despite remaining a prevalent practice, the use of fire in agricultural activities (agricultural burning) has undergone changes driven by evolving socioeconomic and political processes. Among pastoral communities in the Peruvian Puna, the practice of using fire to rejuvenate pastures (promoting re-sprouting) has been discontinued in areas where semi-intensive livestock farming is practiced (e.g., Apachaco in the dry Puna) because community members report that re-sprouted pastures are harmful to "improved" cattle. Conversely, in areas of extensive livestock farming (e.g., Vilcabamba in the wet Puna), community members indicate that the location of natural grasslands on rugged and steep terrain poses a risk of cattle falling and dying. Losing a head of cattle—whether *criollo* or "improved"—is a significant loss for these families, who are now unwilling to take such risks.

Another significant change reported in fire use is its decreasing frequency. In both contexts, community members noted that fire use has declined over time due to the adoption of alternative methods for achieving similar objectives. For example, plot cleaning is increasingly performed using machinery, such as tractors, which facilitates residue accumulation in cultivation or grazing plots, while offering greater control than fire use. This transition is more common in areas with improved connectivity, particularly in regions with paved or upgraded road infrastructure and favorable topographic conditions.

Community members report that penalties, particularly at the communal level (e.g., Vilcabamba), have either reduced fire use or encouraged more cautious practices. As engagement in agricultural activities decreases, fewer individuals are involved in burning practices. In the dry Puna, burning activities commonly involve three to five participants (35%), while in the wet Puna, participation typically involves only two individuals (47%). Furthermore, in both cases, families composed solely of elderly members report avoiding fire use due to concerns about causing wildfires and the lack of physical capacity to control them ("there is no strength", some interviewees mentioned).

Nevertheless, the perception of agricultural burning as beneficial is marginally higher in the dry Puna (49% compared to 48% who deem it not beneficial), whereas in the wet Puna, the majority (59%) consider it not advantageous. Finally, in the past five years, local governments have implemented awareness campaigns to restrict agricultural burning. In Vilcabamba, interviewees reported that these campaigns emphasized "exercising caution"

during burns to prevent wildfires from damaging reforested pine areas, which are highly valued by the community for housing construction.

3.4. Relationship Between the Use of Fire in Agricultural Activities and the Occurrence of Wildfires

3.4.1. Experiences with Wildfires

Out of the 150 wildfires documented in the Coporaque district between 2002 and 2023, 20 were recorded in the community of Apachaco. Similarly, out of the 124 wildfires in the Vilcabamba district, 42 occurred in the district's namesake community (it is worth mentioning that more than half of the fire records (28) in the wet Puna of the Vilcabamba community occurred in what is now the Totora Community (not titled), which was formerly part of Vilcabamba). In both communities, wildfire incidents were primarily recorded between July and December, corresponding to the dry season. The highest number of wildfires occurred in 2020, coinciding with the COVID-19 pandemic, a period when many migrants returned to the community.

All interviewees reported witnessing a wildfire, although not all acknowledged causing or being directly affected by one. In Apachaco, nearly half of the respondents surveyed by CUFPER (48%) identified "Concern" as their initial reaction to the last wildfire they recalled. In Vilcabamba, this sentiment was expressed by at least 70% of surveyed families, with "Fear" being the most common reaction in both cases (19% in Apachaco and 25% in Vilcabamba).

3.4.2. Causes of Wildfires Associated with Agricultural Activities

All interviewees stated that wildfires are unintentional, including those ignited inadvertently by the elderly or children during play. Accounts of wildfires in the grasslands reveal that these events result from poor practices ("carelessness") in agricultural burning, in playing with fire, improper fire management during food preparation (e.g., *huatias*), and natural causes like lightning. Community members emphasized that such incidents could affect anyone involved in agricultural activities and life.

> "I thought I was free from such things, 'it won't burn me', I said, and it happened to me". (D.H.V.—male, 64 years old, Chilarana sector, Apachaco Community, Dry Puna).

> "We must be well-prepared, [...] as you see with this climate change, when we burn our forests, we are contributing to climate change. Also, even when we burn, we do not replace the damaged plants; they re-sprout on their own, but we must be responsible. I also consider future generations, they will pay the consequences. So, that's what I mean. No one is safe, nor is it the case that they won't burn, so at any moment, there could be a fire". (M.D.Q.—male, 54 years old, Challcha sector, Vilcabamba Community, Wet Puna).

The "carelessness" observed in fire management during agricultural burns is attributed to a decline in traditional fire management knowledge, including the ability to identify safe burning conditions, appropriately position individuals, account for wind direction, and ensure proper extinguishment. Such "carelessness" also occurs during the preparation of *huatias* in the fields and in the use of fire to remove *poroncoy* in the dry Puna or to establish new grazing or cultivation areas in the wet Puna.

> "The wildfire occurs because they don't know how to burn. [...], there are people who burn from wherever and it gets out of control". (S.E.—female, community member of Lucma, Pillaupata sector, Wet Puna).

Perceptions of environmental factors contributing to wildfire occurrence were also documented, with particular emphasis on the high temperatures (heat) and hazardous

winds (*totoca* and *soqawayra*) that prevail during the dry season, collectively forming the "fire triangle". However, it should be noted that in the wet Puna, high temperatures, while risky, are considered necessary by farmers for conducting a burn given the area's humidity.

> "Mostly because of the wind, that causes [fires]. [. . .] Sometimes, the wind blows more. There's a wind we call *totoca*, in whirlwinds that blow; those are the dangerous ones. It can come any time, starting around 10 in the morning". (A.C.—male, 56 years old, Chilarana sector, Apachaco Community, Dry Puna).

> "My father said that August and September are 'pregnant', and that's why there's always fire because the wind escapes. [M:] In Quechua, they say '*Chichu*', just as a woman is pregnant, fire behaves the same way, they say. [D:] That's why they say it always gives birth or escapes". (D.H.V.—male, 64 years old; M.C.H.—female, 60 years old, Chilarana sector, Apachaco Community, Dry Puna).

> "Now [the wind] is stronger, and with that heat, the fire spreads more. [. . .] When the wind comes, it's fatal. [. . .] When we burn, the wind always comes from the middle and lifts it up, 'Fiuu!' *Soqawayra*, they say. That evil wind, they say. On the little hills, there are always *qariwas*, yellow ones, from there it lifts up, they say. 'There, in that part, there's *qariwa*, that's why it lifted up'. [. . .] [Qariwa is] a little lizard that raises the wind, you see. [. . .] From here, it can go up to the top, it can burn the whole house". (M.C.H.—female, 60 years old, Chilarana sector, Apachaco Community, Dry Puna).

> "[E:] [Wildfires occurs] Because of carelessness, perhaps. [K:] Sometimes people don't gather the clearings properly. Or they don't gather them to burn in one place. So, they set fire everywhere. [E:] For example, here in July and August, there's quite a bit of wind. Here, they say August is the month of wind. And they always tend to go dig their potatoes or plant their potatoes in August, and they set a small fire to cook something. And maybe due to carelessness, they might leave it, the wind blows, and 'Fua!' it catches fire. Mostly, here there aren't many wildfires because, as they say here, there are neighborhood meetings, and municipal staff come to provide training, and this is avoided". (K.C.—female; E.—male, community members from Pampaconas sector, Vilcabamba Community, Wet Puna).

Regarding environmental conditions, it is noteworthy that wildfires can also be caused by natural factors, particularly lightning. However, there is limited trust in the validity of this explanation, as community members suspect that actual perpetrators may attribute fires to natural causes to evade penalties.

A particularity of Apachaco in the dry Puna is that "envy" has been noted as a cause of wildfires, stemming from the unequal accumulation of resources (such as pastures, cattle and land) by a small number of *comuneros.* This disparity persists despite parceling and is exacerbated by restrictions on movement between parcels due to fencing. As outlined in the classification of wildfire causes developed by SERFOR [46], grassland fires can arise within the context of disputes between families or communities.

3.5. Perception of Wildfire Risk

3.5.1. Probability

In Apachaco, part of the dry Puna, 94% of the surveyed residents reported that a wildfire is likely to occur in their community, whereas in part of the wet Puna, 72% of the surveyed population in Vilcabamba agreed with this probability. The perceived probability may be influenced by the timing of data collection (e.g., during rainy or cold months), as well as by the specific characteristics of the respondents' sectors and plots. For example,

in Vilcabamba, where a lower probability rating was observed, respondents noted that burning conducted on clean plots with minimal vegetation, such as bushes or *pajonal* tussocks, reduces the risk of wildfire, as well as in higher sectors, where they report greater humidity.

3.5.2. Severity

In this study, severity is defined as the assessment of the magnitude, danger, and risk of impact on the assets and livelihoods of the respondents, particularly as heads of households. Consequently, the findings indicate that in both cases, the severity rating exceeds the probability rating. In Apachaco, this rating corresponds to 98% of the surveyed families, while in Vilcabamba it is 93%. That is, in the wet Puna, the perceived likelihood of a wildfire is lower than in the dry Puna; however, in both cases, it is perceived that a wildfire would be severe.

Assets and livelihoods present a differentiated risk rating. In Apachaco, CUFPER data reveal that livestock (92%) is highly likely to be most affected in the event of a wildfire, primarily due to the burning of natural and cultivated pastures. In Vilcabamba, the population considers crops (77%) to be highly vulnerable, as most community- and district-level wildfires tend to occur in lowland areas. Finally, 38% of families surveyed in Apachaco said they would "not recover" from being affected by fire, while 58% would "slowly" recover. In Vilcabamba, 95% said they would recover "slowly".

3.5.3. Perception of Changes in Wildfire Occurrence

Based on the experiences of community members in Apachaco, their perception of wildfire frequency indicates a decline in occurrence, although wildfires are perceived as inevitable during the dry season. In contrast, perceptions of wildfire intensity show considerable variability.

> "In every community, it always happens, but why is that? I wonder. But sometimes also, no. They also say it's because of a good year. How does it escape? It always happens, we are not safe here". (D.H.V.—male, 64 years old, Chilarana sector, Apachaco Community, dry Puna).

Most of the respondents indicated that wildfires are currently less intense. Community members attributed this higher intensity of past wildfires to the fact that burns were more frequent and that land management for cultivation and grazing was communal, resulting in less control by each individual family or producer over burn management.

> "There were always wildfires. They were stronger, bigger. One day, two days they lasted. Now, almost not, people no longer burn as much, before it was more. [And why do you think the wildfires were stronger before?] Before there were no plots, it was the whole community, so now each one has their little plot, we no longer have to extinguish a lot". (T.C.—male, 60 years old, Apachaco sector, Apachaco Community, dry Puna).

Consistent with the perception of greater wildfire intensity in the past (prior to land), it was observed that the division of land has led some families to work their plots more intensively, effectively eliminating dry vegetation and residues that could pose a wildfire hazard or exacerbate its intensity.

Another contributing factor to the reduction in burns and wildfires is the establishment and communication of rules and sanctions, particularly at the community level. For instance, in Vilcabamba (wet Puna), the 2022 communal statue stipulated that "indiscriminate burning of forests or natural pastures" would incur a fine of no less than PEN

1000 (equivalent to USD 263) and, depending on the severity, would be reported to the competent authorities.

> "[H:] It is decreasing. People are reflecting on all this a little more, the fines. Now there are fines, sanctions. I think there's even a prison sentence, with all this, people are reflecting more. Before, the fire would run, in the valley they would light it, even if unintentionally, but now no longer". (J.—female, H.—male, Pampaconas sector, Vilcabamba Community, wet Puna).

Hector Maletta ([28], p. 39) established a clear connection between pasture-use regulations and the conservation behaviors exhibited by community members. While Apachaco and Vilcabamba lack explicit regulatory frameworks for fire use, communal normative mechanisms appear to effectively influence and regulate community members' behavior, consistent with the anticipated outcomes.

4. Discussion

Agricultural burnings remain a common practice, despite a high perception of wildfire risk, with an average probability of 83% and severity of 96%. This persists alongside the perceived decline in fire use and the punitive measures embedded in Peru's institutional framework, both at the national level and, in certain instances, within communal levels of governance. In this context, Pismel et al. [13], in their study on the governance of native wildfires in the Madre de Dios, Acre, and Pando regions, identify the low or negligible cost of agricultural burning as a significant barrier to wildfire reduction. This is particularly evident in subsistence farming areas like the Puna, where burning is employed as a cost-effective land management tool. Regarding the punitive approach to burns, Myers [39] points out the importance of recognizing that even under conditions deemed highly risky by experts, burning is driven by the economic benefits that agricultural producers anticipate in such environments. Consequently, the proposed changes to fire management are unlikely to gain acceptance among producers if they undermine their subsistence or exacerbate the inherent risks of their activities or if the costs of implementation outweigh the anticipated benefits. Carmenta et al. [4], in their investigation of burning practices among smallholders in Brazil, Madagascar, and the Philippines, argue that a prohibitive stance on burning is counterproductive to reducing wildfire risk. At its worst, such an approach can undermine conservation efforts and jeopardize local food security. Thus, the challenge lies in identifying and promoting a viable alternative that fulfils the purposes of agricultural burning, remains under the control of community households, and requires minimal costs and execution time.

Records from specialized entities, including MINAM and INDECI, indicate a rising incidence of wildfires during the drier months. However, firsthand information reveals differing perceptions regarding the frequency and intensity of wildfires. The observed perception of a decline in wildfire incidents, corroborated by personal recollections, raises concerns that official statistics may underreport actual occurrences. This issue has been previously identified, particularly for incidents affecting areas smaller than 100 hectares [1, 20]; even during fieldwork, two wildfires were documented that were absent from historical records. Furthermore, community members perceive that wildfires were more intense, a perception linked to the use of fire over larger land areas, which consequently resulted in more extensive impacts.

Although the use of fire in grasslands is decreasing, as noted in both cases, an important question arises: why have official reports shown an increase in wildfire incidents? Specialists from Cusco's risk management office initially attributed this rise to enhanced monitoring efficiency. However, hotspot data from SERFOR indicates that the increase occurred independently of improvements in data recording processes.

Based on the findings of this article, we can state that shifts in land use and land management systems (from collective to private/family), changes in community composition (increase due to returnees during the pandemic), alterations in the demographic makeup of agricultural participants (predominance of adults and the elderly), and diversification of economic income sources (temporary jobs and progressive abandonment or reduction of agricultural activity) have significant implications for the social conditions influencing wildfire occurrence, specifically by affecting the amount of fuel (grasslands).

In a community practicing semi-intensive livestock farming and with greater private/family management of communal land (e.g., Apachaco), the increase in wildfire incidents can be attributed to changes in agricultural activities. Natural grasslands in high-altitude areas, where livestock presence has diminished, or on plots left fallow or uncultivated serve as fuel for wildfires ignited by lightning or carelessness during the burning of cultivation or grazing plots. In such settings, livestock no longer performs its traditional role as a "pasture collector, an aid in valuing natural vegetation, harvest residues, and weeds" ([27], p. 275), as is still observed in extensive livestock farming systems. Conversely, in a community practicing extensive livestock farming with a focus on communal land management, such as Vilcabamba, carelessness may occur during land recovery periods or the opening of cultivation or grazing areas. This risk is heightened in families that have lost traditional knowledge of controlled burning and face a declining number of participants in agricultural activities.

This study finds that Puna community families perceive a significant risk of wildfire occurrence, with the expectation that any such incident would be severe. As expressed by the phrase *nadie está libre* ("no one is safe"), wildfires pose a universal threat, regardless of the preventive techniques and measures implemented before or during burning. These measures, while often known, are inconsistently applied in practice [61].

5. Conclusions

Agricultural burning remains a prevalent sociocultural practice in the agropastoral communities of the Puna, communities that encompass both extensive farming systems and those transitioning to semi-intensive livestock farming. Meanwhile, community members report its gradual abandonment and diminishing recognition of it as a beneficial practice. Fire serves multiple purposes, including fertilizing soil, clearing crop residues, opening new areas for cultivation or grazing, controlling pests and crop diseases, and mitigating the impacts of climatic hazards such as frosts and hailstorms. Although the existing literature highlights the use of fire to rejuvenate or promote grass regrowth, this study finds that, in both the wet and dry Puna regions, this practice has been abandoned due to the potential risks it poses to crops (including cultivated grasses) and livestock.

The anthropogenic causes of wildfires are primarily non-intentional. Wildfires may result from "carelessness" during activities such as burning, preparing *huatias*, or smoking to alleviate frost, reinforcing the notion that "no one is safe". The perception of wildfire risk remains high, with respondents estimating an 83% likelihood of occurrence, although respondents state a decline in the frequency and severity of wildfires, as well as a reduction in fire usage.

Beyond environmental factors, socioeconomic and cultural changes within peasant communities also contribute to wildfire occurrences. These include land parceling, the dismantling of the *laymi* cultivation system, the weakening of the *ayni* system, erosion of communal institutions, the loss of ancestral knowledge, technological advancements in agriculture, decreased mobility and land use in livestock activities, and the introduction of sanctions. As human–nature interactive systems [15], transformations in agropastoral systems, such as those examined in this article, inevitably impact the socioecosystem,

thereby influencing the conditions for wildfire occurrence. Therefore, it is essential to conduct comprehensive research on the technological, cultural, economic, and social changes affecting agricultural societies. Such research should integrate local-scale dynamics and their unique characteristics with broader processes to elucidate the factors driving wildfire occurrences. Furthermore, risk reduction strategies, including access to early warning systems and technical assistance for controlled burning [62], must be addressed within the framework of an integrated fire management approach [61].

The risk perception of wildfire is widespread among community members, who would be the primary victims in the event of an emergency and are also the first responders. However, this does not suggest the abandonment of agricultural burning, as it remains integral to the agricultural and livestock production cycle. To mitigate wildfire risks, the community—both collective and individually—can implement various techniques for fire use, prevention, and, in some instances, enforcement through sanctions. Thus, agricultural burning is generally characterized by careful control; apathy is an exception rather than the norm. However, when apathy occurs alongside favorable environmental conditions, it can lead to wildfires in the Puna grasslands. This underscores the pressing need for interdisciplinary and transdisciplinary research to better understand current fire-use practices and how they can be optimized to reduce wildfire risk.

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