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Rethinking the agricultural use of fire and its influence on the occurrence of wildfire in high Andean communities of Cusco, Peru

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ABSTRACT

The use of fire in agriculture has been a fundamental practice since early human societies, playing a key role in land preparation, weed control, and soil fertility management. In the Peruvian Andes, fire remains widely employed by rural communities, despite strict legal prohibitions aimed at reducing wildfire occurrence. However, statistical evidence demonstrates that these punitive policies have failed to curb wildfires, which have instead increased in frequency. This study critically examines the agricultural use of fire in high Andean communities of Cusco, Peru, exploring its socio-cultural, economic, and environmental dimensions.

Through ethnographic research and qualitative methodologies, the study identifies the motivations behind fire use, traditional fire-management practices, local and institutional perceptions, and community responses to wildfires. Findings reveal that fire is an indispensable agricultural tool, deeply embedded in rural livelihoods. The study also highlights the inadequacy of current fire management policies, which rely primarily on prohibition and emergency response without offering viable alternatives for smallholder farmers.

To address this gap, the study proposes a paradigm shift in fire governance, advocating for a more inclusive and sustainable approach. Key recommendations include integrating prescribed burning, implementing incentive-based compensation schemes, and strengthening local governance structures. Additionally, the study underscores the necessity of qualitative research in informing quantitative analyses of wildfire occurrence, ensuring that policy interventions are grounded in local realities. Ultimately, rethinking the agricultural use of fire is not only an environmental concern but also a social and economic imperative for high Andean communities.

1. Introduction

The presence of wildfire on our planet predates the emergence of the first humans [1]. During the Holocene—more than 10,000 years ago—the natural wildfire regime was affected by anthropic intervention [2], as fire and slash-and-burn practices came to be used to convert cropland in the transition process from hunter-gatherer to agricultural societies [3]. Today, fire remains part of the agricultural practices of many communities around the world [4,5], and, when managed and controlled effectively, is even considered a good environmental and territorial management tool [6,7].

Indeed, it should be considered that the knowledge and practices around the use of fire ought to be based on the specific characteristics of the site and relevant to a fire regime in a specific ecological context [8,9], and numerous studies demonstrate the importance of access to information, based on evaluation of social, economic, and environmental factors, in order to identify new approaches that can help prevent wildfires [7,10–12].

In an agricultural context, burning is still regarded in numerous regions as a tool that allows populations to manage unwanted vegetation cover on land intended for crops, and it is also perceived as necessary amid cropland shortages and the desire for greater

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agricultural production [9,13]. However, prescribed burns are prohibited by law or administrative policies in many countries, even in fire-dependent ecosystems; these restrictions often stem from philosophical perspectives, with policies and regulations frequently mandating fire suppression regardless of the actual threat level or the potential ecological benefits [14,15].

In the Peruvian Andes, the burning of fallow land to increase agricultural production, transform the landscape, and control pests intensified during the colonial period [16]. However, it is still a challenge for agroforestry management. Today, in various Andean communities, most of which are located in areas at high risk of wildfire [17], the use of fire continues to represent a cultural practice deeply linked to the agricultural and livestock cycle. This practice combines local knowledge and collective techniques aimed at fertilizing the soil, clearing fields, and controlling pests [18–20]. Although fire continues to play an important role in agricultural activities, its use is not without risks. There is broad consensus that most wildfires in the country are of anthropogenic origin, and that agricultural practices, particularly uncontrolled burning, are often cited as one of the main causes of wildfires [13,21,22]. This situation is further exacerbated during periods of drought, when environmental conditions favor the spread of fire and contribute to the gradual increase in wildfire frequency in Andean areas, as recorded in 2005, 2010, 2016, and 2020 [23–25].

For more than a decade, the practice of burning agricultural stubble has been explicitly prohibited (Decreto Supremo No. 016-2012-AG), while regulations for the prevention of wildfires are aimed at preventing the use of fire in rural environments [22]. The widespread appeal from authorities and various media outlets echoes the call for the eradication of the "custom" of burning agricultural residues [26–28]. However, the introduction of these regulations has not had the desired effect [20,29]. On the contrary, reports of wildfire emergencies in Peru have increased steadily and significantly in recent years (MINAM, 2024; [25]), including the loss of human lives [30–32]. Indeed, nationwide, the number of recorded cases increased from 2936 in 2019 to 7922 in 2020, 3673 in 2021, 11,742 in 2022; 6963 in 2023 and 11,374 in 2024 [33].

This study seeks to critically analyze the agricultural use of fire in high-Andean communities of Cusco, Peru, in order to understand its social, cultural, economic, and environmental foundations, and to challenge the widespread perception that this practice lacks practical purpose. Cusco is one of the regions with the highest frequency of recorded wildfires during the period 2003–2024 [34–36]. The population and ecosystems—mainly dominated by Andean shrublands and grasslands—are considered highly vulnerable to wildfires [37,38], and these ecosystems are among the most affected [23–25].

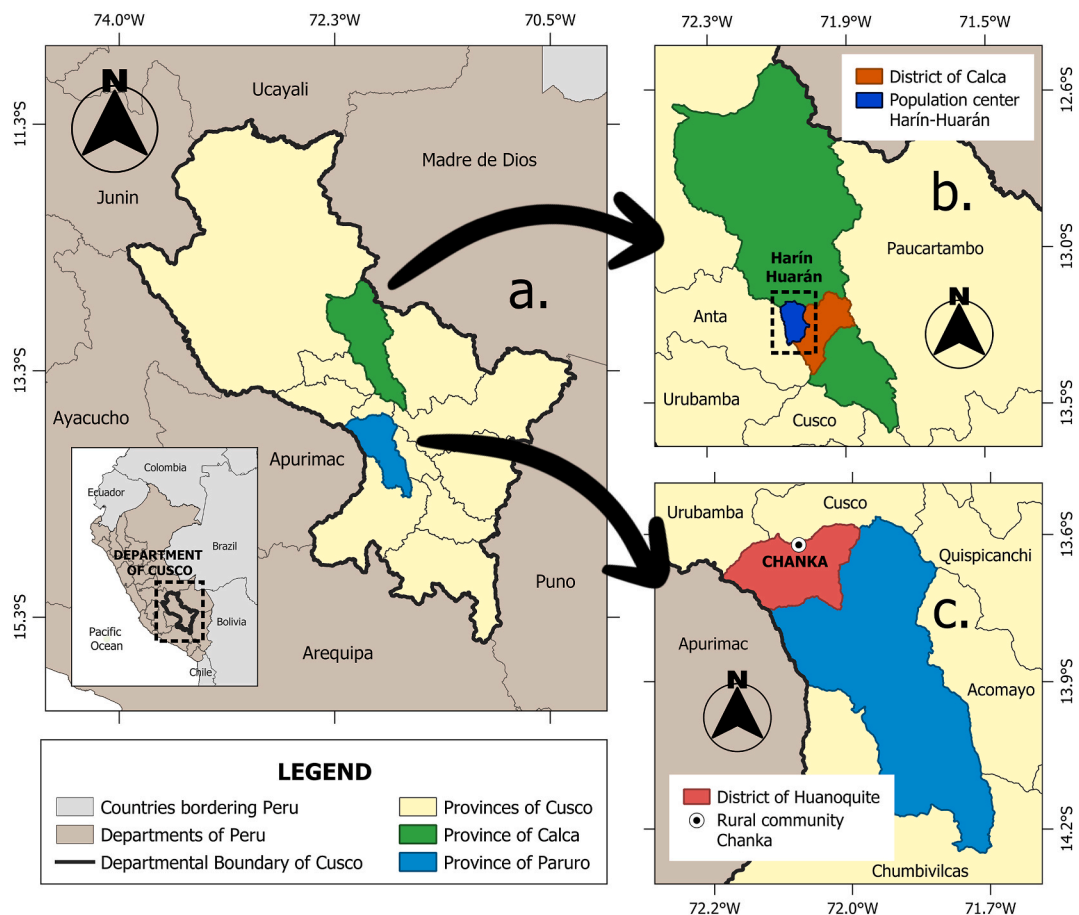


Fig. 1. a. Selected provinces of Calca and Paruro in the Cusco region. b. Geographical location of the Harín-Huarán population center. c. Geographical location of the Chanka rural community.

To achieve this objective, the study will focus on four specific aims or key areas of (1) Identify the reasons for the use of fire in agriculture (social, cultural, and economic motivations), (2) Examine traditional fire-use practices, detailing the methods employed and the factors that influence their application, (3) Analyze local and institutional perceptions of fire use from the perspective of fire users, and (4) Analyze social organization in the control response to wildfires.

2. Study area

For the selection of the study areas, the following criteria were taken into account: Andean rural communities (*comunidad campesina*) or population centers (*centro poblado*) in the Cusco region that experienced major wildfires in the last five years, in which agriculture is the main economic activity, with animal husbandry as an important complementary activity, while other economic activities are primarily in the services and retail sectors [39,40], and where it was possible to establish the interpersonal ties necessary for community outreach and fieldwork.

Rural communities are legally recognized organizations with specific territories managed by families connected through ancestral, social, economic, and cultural bonds, which are expressed in communal land ownership, work, and mutual assistance [41]. In contrast, populated centers are any designated rural or urban locations with a permanent population and shared economic, social, cultural, and historical interests, administered by a municipality [42,43]. Study areas were the rural community of Chanka in the district of Huanquite, Paruro province; and the population center of Harín-Huarán in the district and province of Calca (Fig. 1).

There are differences in the social structure of the two settlements. Chanka is a more traditional community, whose inhabitants have territorial, ancestral, social, economic and cultural ties, while Harín-Huarán is more heterogeneous in composition, and is made up of several sectors that are locally considered communities (but are not all officially so). One important consideration is the topographic characteristics of the two locations, which differ markedly despite their shared Andean setting. In Harín-Huarán, altitudes span a wide range, from 2900 to 4600 m above sea level (m.a.s.l.), allowing for two distinct agricultural zones: the valley floor and the valley top. In contrast, Chanka, located between 3500 and 4200 m.a.s.l., is exclusively high-Andean. Both communities are situated in

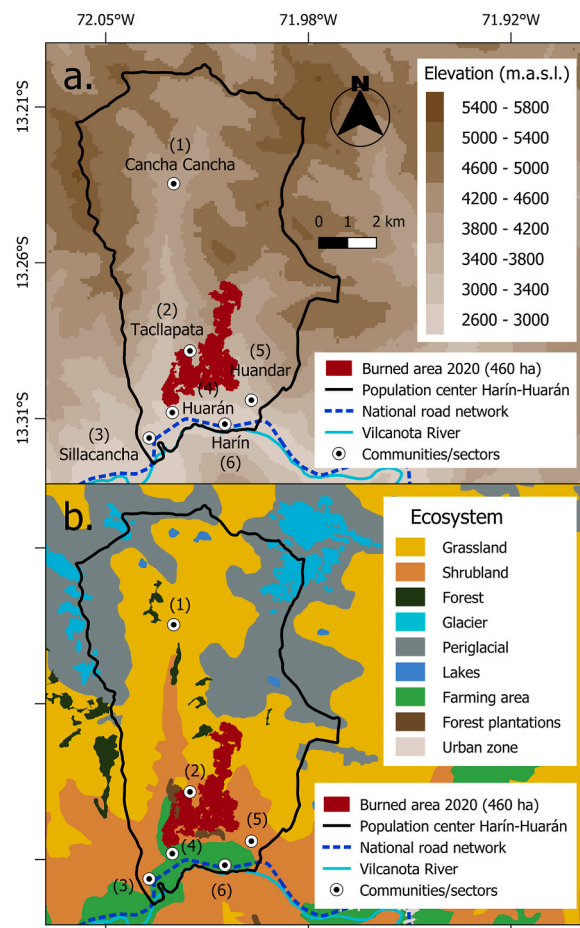


Fig. 2. a. Topographic map of the Harín-Huarán population center. b. Land cover map of the Harín-Huarán population center. Area affected by the 2020 wildfire.

inter-Andean valleys and fall within altitudinal ranges classified as high-risk zones for wildfires in southern Peru [21,25]. Their landscapes reflect this altitudinal diversity, with grasslands in the higher areas (above 3200 m), and at lower elevations, scattered Andean shrublands, agricultural lands—both cultivated and fallow—and small forest plantations, mainly consisting of eucalyptus. These ecosystems are not considered fire-dependent as another's ecosystems located in Brazil [44]; on the contrary, Andean ecosystems are highly vulnerable to the impacts of uncontrolled fire.

However, recent studies in the high Andean region of Peru suggest that some native ecosystems—particularly puna grasslands—exhibit moderate resilience to low-intensity fire events. Native herbaceous species such as *Festuca dolichophylla* have shown the capacity to regenerate through resprouting mechanisms (De La Cruz-Arango & C ndor, 2023). Fire can temporarily alter soil properties by increasing levels of organic matter, phosphorus, and potassium due to ash deposition, which may facilitate early vegetation regrowth [45]. Nevertheless, these positive effects are typically short-lived, and the tolerance threshold of these ecosystems can be quickly surpassed under intense or frequent burning conditions. Therefore, while not fire-dependent, these landscapes may tolerate occasional, controlled fire, but remain ecologically fragile in the face of recurrent or unmanaged burning.

However, even traditional burning is not static. In recent years, socio-economic and cultural shifts have begun to alter how—and why—fire is used in Andean agriculture. For example, intensification and commercialization of farming (with mechanization, irrigation and fencing) as well as changes in land tenure (towards private plots) are reshaping age-old fire practices.

An analysis of rainfall over the past 50 years in the Peruvian Andes indicates a shortening of the wet season and a tendency for the dry period to lengthen [46], which is consistent with the delayed onset of the rainy season [47]. Projected changes in the intensity, duration, and frequency of droughts in the coming decades, under climate change scenarios [48], are likely to alter the fire regime. Notably, the observed drought conditions align with a significant increase in the number of fires reported in Peru [25]. On this context, Luna-Celino et al. (2025) report that while fire remains “an essential tool” for subsistence farming, climatic and ecological shifts are increasing wildfire risk and forcing communities to reconsider what constitutes adequate fire management. Taboada-Hermoza & Mart nez [18] likewise emphasize that although intentional burning remains culturally ingrained, one must now account for “changes in agricultural activity, mutual aid systems, and communal institutions” to understand wildfire dynamics. Taken together, these socio-economic, cultural and environmental transformations suggest that fire use in Andean highlands is in transition, adapting in

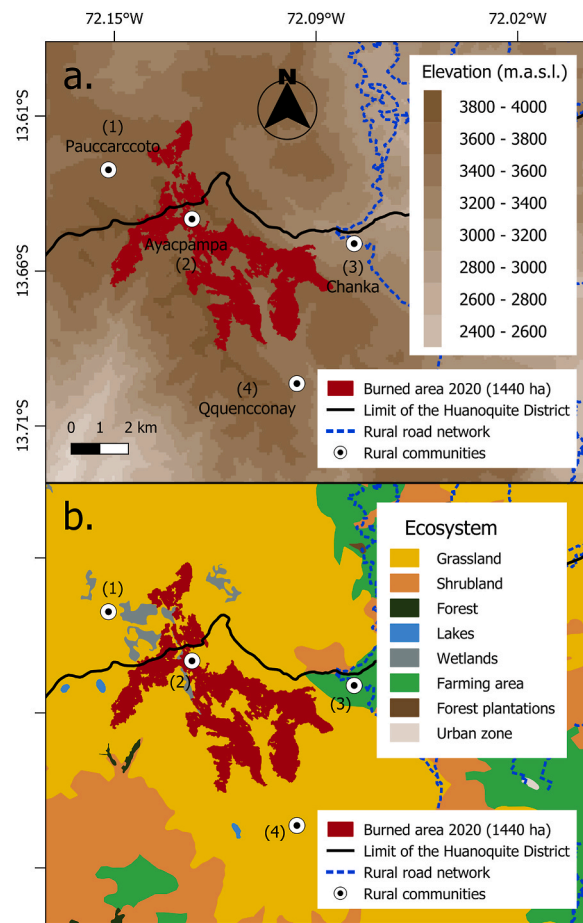


Fig. 3. a. Topographic map of the Chanka rural community. b. Plant cover map of the Chanka rural community. Area affected by the 2020 wildfire.

response to the very changes—market pressures, policy shifts and climate impacts—occurring around it.

2.1. Harín-Huarán population center

Harín-Huarán is located in the central part of the area known as the Sacred Valley of the Incas, in the district and province of Calca. At the last estimate, it had 1755 inhabitants [49]. Classified as a *centro poblado* in 2009, is composed of different communities/sectors: Cancha Cancha, Tacllapata, Sillacancha, Huarán, Harín, and Huandar. On the one hand, Tacllapata (3686 m a.s.l) and Canchacancha (3975 m.a.s.l) are officially classified as rural communities [41], while Huarán, Harín, Sillacancha, Huandar, which are valley communities situated at 2930 m.a.s.l (Fig. 2a), are characterized far more by local market activity. The economy of the population center is founded on two main economic activities: production of potatoes in the higher areas and corn in the valley, and the rearing of small animals. Secondary activities include the likes of manufacturing, transport, education, and commerce [50].

On October 28, 2020, a major wildfire developed in Harín-Huarán, which affected approximately 200 ha of vegetation cover, including eucalyptus plantations [51,52] that were of great importance for the local economy. Thus, the communities/sectors most affected by this event were selected: Huarán, Sillacancha, and Harín in the valley area, and Tacllapata in the high area. Fig. 2b shows the extent of the burnt area.

2.2. Chanka rural community

The Chanka rural community is located in the district of Huanquite, Paruro province. Chanka is located at 3807 m.a.s.l. (Fig. 3a) and at the last estimate had a population of 340 people (INEI, 2017). It was legally registered as a *comunidad campesina* in 1985, when the geographical demarcation was carried out. Agriculture is the main economic activity in the community, and the predominant crops are barley, wheat, and potatoes. Livestock rearing also plays an important role, while complementary activities include retail, transportation, and civil construction.

The community was affected by a wildfire that broke out on September 22, 2020, which was caused by the burning of agricultural stubble prior to planting. The magnitude of this event was so great that it affected the surrounding communities, and it is estimated that the fire consumed between 1500 and 2000 ha of natural pastures, which had been used to feed livestock [52]. The fire was eventually extinguished on September 24 following the efforts of community members from the affected areas, the District Municipality of Huanquite, and the National Police (Fig. 3b).

3. Data and methodology

This research is primarily qualitative, with a strong ethnographic component and significant use of participant observation. For the collection of primary information on the communities, an in situ recognition process was carried out in both localities in order to establish a framework of collaboration [53]. During the initial contact with local leaders, authorization was sought to interact with and interview inhabitants. Collective spaces were sought in the case of the Chanka community, while in the case of Harín-Huarán, extensive conversations were carried out with local authorities. Following this initial approach, participant observation and field visits began in July 2021 and continued through September 2021, allowing for sustained engagement with numerous residents—men and women of different age groups—through direct interaction and observation. In this iterative process, we identified individuals possessing extensive knowledge and experience in fire use or wildfire suppression. As a result, the selected participants naturally spanned a range of ages, since those with significant experience in these activities inherently represented different age groups. It is important to emphasize that this age variation was not an intentional selection criterion but rather emerged from our focus on expertise in fire-related activities. Nevertheless, having participants of various ages enriched the study by incorporating a wide diversity of experiences and perspectives on fire use and wildfire management. We stress that our sampling criteria aimed to capture a broad spectrum of perceptions and experiences—rather than specifically targeting intergenerational knowledge transfer. These preliminary interactions thus laid the groundwork for the research and informed the refinement of our data collection approach.

Building on these insights, structured in-depth guided interviews were conducted in October 2021 with residents selected for their expertise or direct involvement in agricultural burning and wildfire events. This phased methodology ensured that interviews were informed by prior engagement and contextual understanding, enhancing the depth and reliability of the collected data. The in-depth interviews were carried out with a total of 27 participants, including community representatives, farmers, and members of the general population. The resulting in-depth findings were organized according to the four thematic categories stated in the introduction: (1) Identify the reasons for the use of fire in agriculture; (2) Examine traditional fire-use practices, detailing the methods employed and the factors that influence their application; (3) Analyze local and institutional perceptions of fire use from the perspective of fire users; and (4) Analyze social organization in the control response to wildfires. The information collected was qualitatively organized and analyzed using the Atlasti software. Then, a case study approach was employed to analyze differences and similarities with regard to the same phenomenon. To systematize personal information, a code was generated to protect the identity of the participants. Additional details on the types of interviewees, as well as relevant testimonies, have been included in Supplementary Material A and B.

Additionally, a comprehensive literature review was conducted, encompassing laws, regulations, technical reports, and field reports associated with the issue of wildfire, all primarily in Spanish—sources that are typically underutilized in scientific publications despite their relevance for understanding local governance, institutional frameworks, and on-the-ground wildfire management practices. The sources consulted included

the National Forestry and Wildlife Service (*Servicio Nacional Forestal y de Fauna Silvestre*, SERFOR), the National Center for the

Estimation, Prevention, and Reduction of Disaster Risk (*Centro Nacional de Estimación, Prevención y Reducción del Riesgo de Desastres*. CENEPRED), the Ministry of Environment (*Ministerio del Ambiente*, MINAM), local governments of Huanquite and Calca, and the Regional Government of Cusco.

Finally, the information on wildfire occurrences was based on current and historical georeferenced records of fire occurrences (MINAM, 2025a,b), and the wildfire emergency reports provided by the National Institute of Civil Defense (*Instituto Nacional de Defensa Civil*, INDECI) between 2019 and 2024; both has been systematically compiled and can be found in Supplementary Material C.

4. Results

4.1. Reasons behind the use of fire in agriculture

Authors such as Manta [29,54] point out that one of the main reasons for using fire in agriculture in the Peruvian highlands is to prepare and rehabilitate soils for cultivation and to expand the agricultural frontier, and government organizations such as the National Forestry and Wildlife Service [22] and CENEPRED [34], citing a report by USAID [55], point to changes in land use and the burning of pastures for agriculture as causes of wildfires. Furthermore, authorities and various media outlets frequently portray the burning of agricultural residues as a practice driven by “tradition” or considered a “routine activity” by those who use fire [26–28]. However, there are few specific studies that explore the use of fire in agricultural practices and focus on the reasons for its use. Table 1 provides representative excerpts from testimonies in both Spanish and Quechua, highlighting the key motivations for employing fire in agriculture as expressed by participants.

Based on testimonies from the two localities, the primary reason for the use of fire in agriculture is the removal of crop residues, shrubs, and weeds. Participants also reported additional benefits, including the elimination of potential crop diseases, simplification of tasks, reduction of time and costs, and secondarily, the production of fertilizer to enhance soil performance.

In the case of Tacllapata, located in the high part of Harín-Huarán, fire is used to eliminate native vegetation such as pasture and other grasses (known locally as *kikuyo*), which are considered weeds as they inhibit crop growth. Interviewees from this community highlighted the necessity of fire, as they lacked alternative methods for weed control. Additionally, they noted that burning provides nutrients to the soil, benefiting crop growth.

Farmers from the Chanka community stated that agricultural burning is essential for eliminating *q'opa*, a Quechua referring to waste. *Q'opa* consists of agricultural remnants, especially barley, wheat and other crops, which are often piled up in field corners, occupying space and disrupting the agricultural environment. Burning simplifies the removal of these materials, facilitating land clearing, especially when traditional tools are used for plowing or managing fallow land, while also enriching the soil with nutrients through ash for the next crop. Additionally, fire is used to open new agricultural areas. Fig. 4 outlines the reasons given for the necessity of fire in agricultural practices across both locations.

Other external social factors also play a role: the economic crisis caused by the COVID-19 pandemic led to urban-rural migration in Peru [56]. In Harín-Huarán, many returned to rural areas, resuming agricultural work and reusing abandoned land. The need to increase production led to more land clearing, which, combined with a lack of care or experience in burning, may have contributed to the increase in wildfires in 2020. In Cusco, recorded wildfires—which include complementary, journalistic, and police reports in addition to INDECI emergency reports—has consistently ranked among the three Andean departments most affected by fires in recent years

Table 1

Testimonies about the reasons for fire use in agriculture: Land clearing.

Locality	Interview quote (original in Spanish/Quechua) (Code #)	Main ideas about fire use
Harín – Huarán	<p>“Normally it's for clearing. For example, look at this field. Here there were peas. The weeds gather. As there was nowhere to put it, they set fire to it and it that's that.”</p> <p>“There's pasture, grass, that's difficult to kill, so to plant potatoes you have to burn, you need to burn those weeds, they're difficult to kill. [...] They're not affected, and it creates more fertilizer, burning creates more fertilizer.” [Brother intervenes] “Yes, you get more compost.” (CalcaTacllapata_9)</p> <p>“For your field to be clear for growing, for planting [...]. It could be a little to add potassium to the soil, but that's no big thing.” (CalcaHuarán_7)</p>	<ul style="list-style-type: none"> - Clearing necessary for crop rotation: - Removal of residues of prior crops; - Removal of shrubs, weeds or other unwanted plants from the crops. - Removal of previously available pasture for planting - Possible creation of fertilizer - Clearing necessary for crop rotation
Chanka	<p>“For the field to be clear, so that it's not all piled up in a corner, so that, I mean, so that those, those things [the stubble] don't take up the space.” (ParuroChanka_3)</p> <p>“To plant, always when there's q'opa [waste] they have to burn a lot, to plant. It's every year, year after year, we do it like that” (ParuroChanka_4)</p> <p>“Always, every year we always clear. [...] Because it's difficult, the spade doesn't go in with the stubble there, the spade doesn't go into the earth to dig when you're growing broad beans. So, to parahallmear [earth up] you ... siminta lampaqtatapapun, chaymi mana, limpiaykupuni [tie the tip of the spade. That's why we always clear].” (ParuroChanka_5)</p>	<ul style="list-style-type: none"> - Possible creation of fertilizer - Clearing necessary for crop rotation - Weeds as a hindrance to cultivation - Clearing necessary for crop rotation - Clearing necessary for crop rotation - Weeds as a hindrance to cultivation

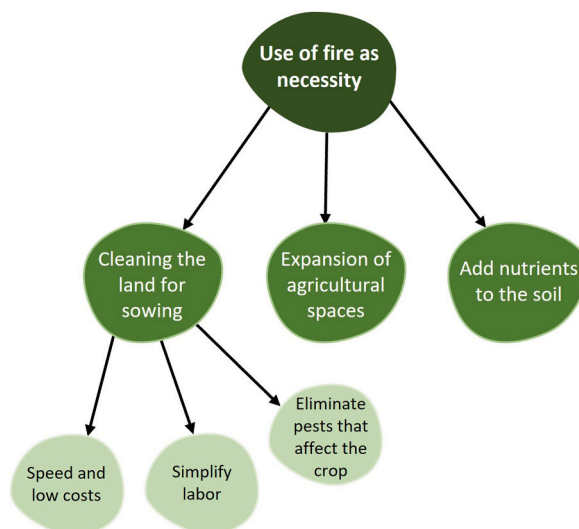


Fig. 4. Reasons for fire use in agricultural work in Harín-Huarán and Chanka, Cusco.

[36].

“Por ejemplo, este año recién hemos empezado a trabajar con la pandemia. Se ha venido la pandemia, han empezado a trabajar este cerro de aquí y todo el mundo está que quema, que quema los arbustos porque como hace años que no trabajaban se ha llenado de arbustos todo, entonces qué han hecho: han cortado lo han amontonado y lo han quemado.” (CalcaHarín_4)

“For example, this year we just started working with the pandemic. The pandemic came, they started working on this hill here, and everyone is burning, burning the shrubs because they haven’t been worked for years, and everything has filled up with shrubs. So, what have they done? They have slashed it, gathered it up, and burned it.”

4.2. Characterization of traditional agricultural fire-use practices

4.2.1. Agricultural calendar and fire use seasonality

Both localities cultivate a variety of altitude-adapted crops, including corn, potatoes, barley, pearl lupin, broad beans, and ullucus; however, potatoes and corn are the primary crops [57,58]. Each primary crop follows a specific production calendar associated with the rainy and dry seasons, determining sowing and harvesting periods [59], and is alternated with minor crops. There are also designated "rest" periods, during which no crops are planted, allowing the land to remain temporarily unused [60–62].

In both communities, sowing and harvesting schedules depend on atmospheric conditions, individual farmers’ arrangements, and land conditions, and the use of fire is directly linked to the agricultural planting and harvesting calendar. Thus, identifying when to prepare the land is crucial, as it is during this period—which can span several months—that fire is used for clearing prior to planting. It should be noted that in Cusco, burning continues until the first rain begins, generally in December, when the practice is no longer possible due to the increase in soil moisture levels. Fig. 5 outlines the seasons in which fire is used for agricultural work in the two

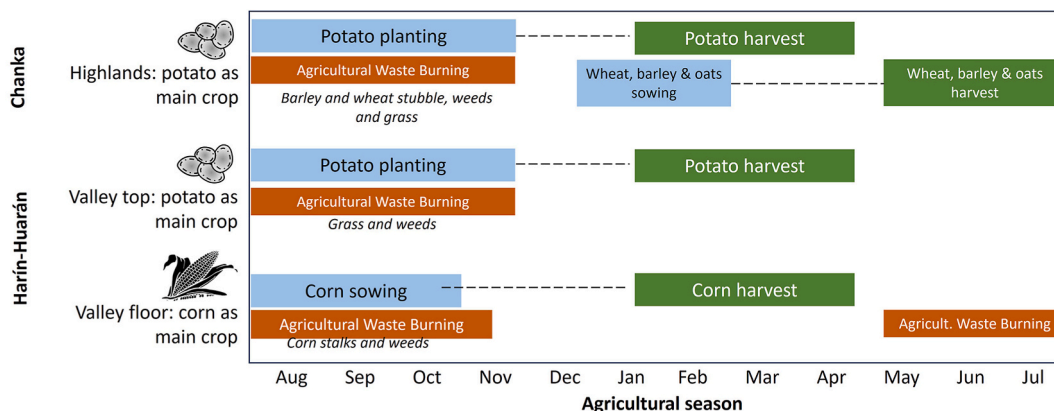


Fig. 5. Systematization of fire-use seasons in agricultural work in Harín-Huarán and Chanka, Cusco. Data compiled in accordance with the MID-AGRI agricultural calendar [59], information from local municipalities, interviews, and participant observation.

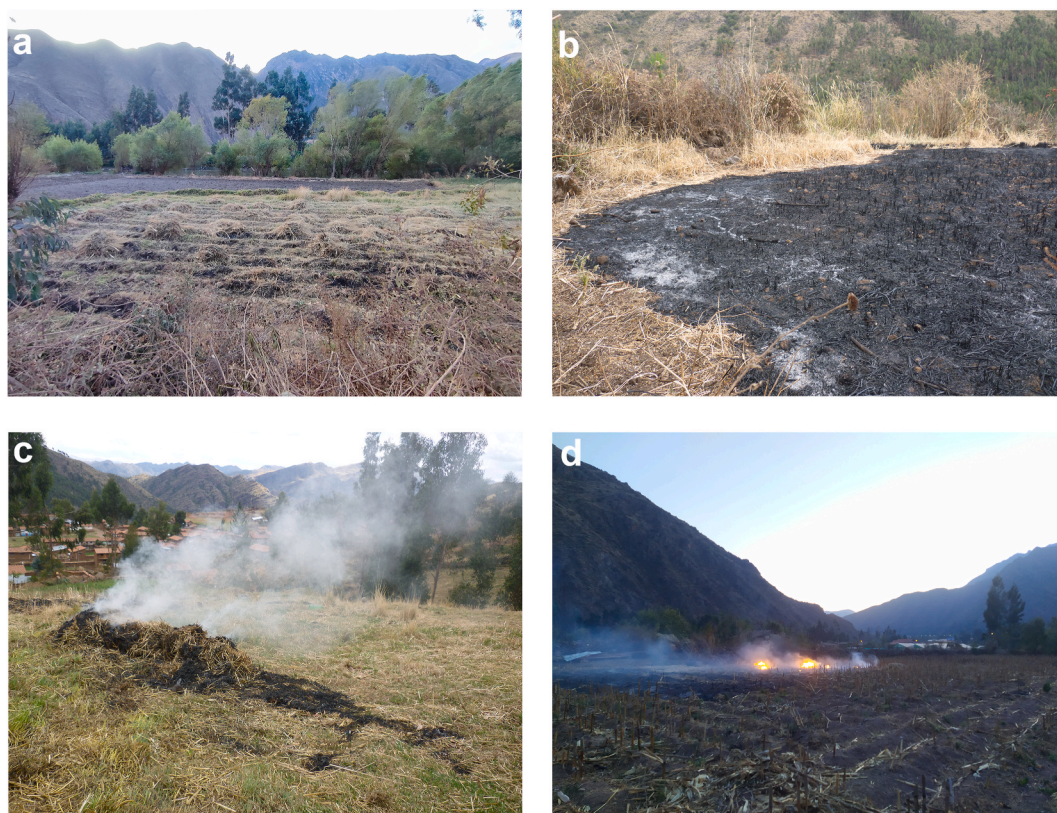


Fig. 6. a. Piles of corn stubble ready for burning in Calca, 2022. b. Dispersed burning in Chanka, 2021. c. Burning barley stubble in a pile in Chanka, 2021. d. Corn stubble burning in piles in Calca, 2021.

locations (see Fig. 6).

Corn is the primary crop in the lower part of Harín-Huarán. After the final harvest in April and May, the *chhalla* (dry corn leaves and stalks) is removed and stored mainly as a reserve of cattle and pig feed. However, the residual corn stalks, known as *toqochos* (a Quechua word meaning “thick and hollow stalks”), are left in the fields. The process of clearing this stubble begins in May and can continue until the end of August, though it may extend beyond this period. Clearing also encompasses the elimination of pests that threaten crops, such as the *waythu* (*Stenoptycha coelodactyla*), a caterpillar of the Lepidoptera order known for its destructive capacity—especially towards corn stalks, in which it can cause withering.

As to potato cultivation in the high-altitude area of Harín-Huarán, early sowing—known as *maway*—begins in August, but in some cases tillage and sowing can continue, into early December (Municipalidad Distrital de Calca, 2018; [60]). Fire management involves land preparation through plowing, a practice known locally as *yapuy*. Depending on the specific needs and tool availability [63], the land is initially plowed using *chaquitaqlla* (foot plows), followed by *kuti* (spades). During this process, weeds, grasses, and stubble are gathered in a pile and burned, typically on the plot intended for cultivation.

“Acá decimos *yapuy* (arado), es *yapuy*, primero en *chaquitaqlla* y después golpeamos [...] *yapuy*, esas gramas tienes que voltear [...] ahí en medio de lo que se ha volteado, hay que quemar.”
(CalcaTacllapata 9)

“Here we call it ‘*yapuy*’ (plowing). It’s *yapuy*, first with the *chaquitaqlla*, and then we hit it [...] *yapuy* is when you have to turn over those weeds [...] in the middle of what has been turned over, you have to burn.”

In the case of Chanka, barley, wheat, and oats are generally planted between December, January, and February, and harvested around six months later in June and July. Site preparation begins in August, when the community occasionally uses the land to grow potatoes. As the same way as in Harín-Huarán the *maway* begins in August [13], and burning to clear and prepare the site for planting starts that same month. The following crops are usually potatoes but can include others. An additional use of burning is *roce* (“sweeping”), a practice used to convert land for cultivation by slashing and burning shrubs, trees, native plants, kikuyu grass, and other obstacles, and this method mainly focuses on clearing trees and bushes from the chosen area.

Finally, two important factors must be considered in both locations: the timing of the burning process and the number of individuals involved in the process. For the first factor, it is well established that various physical elements contribute to the spread of wildfires [64–66], with wind intensity being one of the most critical. In Peru, it is observed that early morning winds in slopeland areas

cause warm air to accumulate in lower-lying regions, which subsequently ascends around midday [29], thereby increasing the likelihood of agricultural fires spreading and escalating into wildfires. Thus, some of the interviewees stressed the importance of burning in the mornings.

*"En las mañanas, porque en la tarde se escapa. Siete, seis a siete se quema eso, eserato no viene viento también pues".
(ParuroChanka_4)*

"[We burn] in the mornings, because in the afternoon the fire escapes. The burning's done from six to seven, at that time there's no wind either."

However, it is up to each individual or family to decide on their preferred time of day to carry out burning—and in practice this is generally the afternoon, after finishing other activities or complementary jobs, when fire users have more time available to clear land. Furthermore, despite this latent danger, several of those interviewed pointed out that the wind helps accelerate the burning process by providing oxygen to the fire, which makes it spread more easily.

For the second one, it is important to highlight that the number of individuals involved in the burning process for both Chanka and Harín Huarán, typically ranges from one to three, usually consisting of family members, neighbors, or acquaintances who can be relied upon.

4.2.2. Burning patterns

In the valley area of Harín-Huarán, the *toqochos* can be arranged for burning using three distinct patterns, all of which involve a gradual burning process until the fire in each pile naturally extinguishes: a) sorted with rakes or by hand into piles 80–100 cm wide, spaced 1–3 m apart in furrows throughout the field; b) in smaller plots, one or more piles are gathered at the center of the field; this pattern is also used when the aim is to expand the farmland; and c) collected and burned at the edge of the field -regardless the plot size-, as some farmers believe this prevents damage to the soil. On the other hand, in the high-altitude area of Harín Huarán, residues are typically burned in a single pile located at the center, along the edges, or in a corner of the field.

Meanwhile, in Chanka, two methods of fire use were identified: a) accumulating residues from barley or wheat crops after threshing, which is done either with a machine (to separate the grain from straw or stubble) or with a horse (trampling the crop to extract the grain), and then the stubble is raked into piles 50–100 cm in diameter, ready for burning; and b) using a single large fire without extensive prior land preparation, except for edging, that consists of using rakes, brooms, or *charamoscas* (fresh branches of native trees) to gather agricultural residues, native vegetation, grasses, and other waste from the plot's edges into the center. The latter method resembles creating firebreak ditches, cleared areas that prevent wildfires by removing potential fuel [29], since the perimeter of the plot is cleared to a width of about 2 m, with residues transferred to the burning area to control fire spread.

*"Como estaba montón, entonces uno solo quemamos, entonces el montón ya se quema, el solo [...], por ejemplo, cuando crece el trigo para sacar sus granitos lo cortan, entonces en un lado lo juntan y eso lo que está juntado a veces pisamos con caballo, a veces hay una máquina para ese trigo y como está amontonado, en ese montón se queda entonces tenemos que prender ahí porque es difícil de llevar allá, acá o a otro lado ..."
(ParuroChanka_2)*

"As it was all piled up, we only have to burn one, so the pile burns by itself [...]. For example, when the wheat grows for its grains to be harvested, they cut it, then they gather it on one side, and what's gathered there is sometimes trampled by horses. Sometimes there's a machine for the wheat, and since it's piled up, it stays in that pile, so we have to ignite it there because it's difficult to take it over there, here or somewhere else ..."

In Chanka, the burning process typically begins at the center of the plot and expands outward, ensuring the systematic removal of crop residues such as barley, wheat, oats, and various grasses and weeds. *Charamoscas* play a vital role in controlling the fire's spread and facilitating its extinguishment. This method not only enhances land clearance but also enriches soil quality, optimizing conditions for future cultivation. Moreover, confining the fire within a defined perimeter mitigates the risk of unintended spread, safeguarding adjacent crops and neighboring plots. Additionally, in Chanka, burning on slopes is done downhill, controlling the fire from the top to prevent it from spreading upward. This is consistent with various studies that have shown that a high gradient increases the risk of fire propagation (Rodríguez-Trejo, 2001; [34,66]).

4.3. Perceptions about fire use from the perspective of fire users

Current Peruvian legislation expressly forbids wildfire, but is somewhat ambiguous regarding the burning of stubble [67–69], with the exception of the Regulation for the Management of Solid Waste from the Agricultural Sector [70], which is explicit on the matter: *The burning of said plant residues is prohibited* (MINAGRI, 2012). Penalties for damaging forest cover involve imprisonment [68]. The Peruvian Penal Code establishes prison sentences of four to six years and eighty days of community service for those who do not have permission, authorization, or a license from a competent authority to burn forestland or forest formations ([71], Art. 310). Meanwhile, the fine for causing wildfires ranges between 10 and 5000 tax units [72,73], which is the equivalent of between 48 and 24,146 national minimum living salaries as at 2023 or between 13,228 USD and 6'533,939 USD. Although the ultimate objective of these punitive measures is to limit the use of fire and prevent wildfires in the country [74], in practice they are not enforced, as identifying those responsible is extremely difficult.

Fire users, both from Harín-Huarán and Chanka, have general awareness of the penalties, which generates ambivalent attitudes towards the use of fire. On the one hand, they recognize burning as a quick, practical, convenient and economical way to dispose of agricultural waste; but on the other hand, they recognize its dangers and many stress the need for technical training to improve the

management of residues in agricultural work. Likewise, some suggest alternatives to eliminate weeds and stubble, technical support in soil nutrition, proper fire management, and so on.

The interviewees argue that preventing and reducing the impacts of wildfire requires a) training in fire mitigation, b) more tools to extinguish fires, c) better organization, and d) practical workshops and awareness raising among the population.

Perceptions about the use of fire focus on two dimensions: its use as a tool for agricultural practices, and the danger of it “escaping” and developing into a wildfire. On the one hand, in and line with the stated reasons for using fire, there is a highly positive assessment of its use to eliminate stubble and clear fields before the next crops are planted, since it simplifies agricultural work due to its speed and ease—natural waste decomposition can take a long time.

However, in both localities, fire users agree that negligence exists when burning, and that this is a major cause of wildfires. This view is shared by local authorities and district representatives, who also point out the need for an improvement in the quantity and quality of training on wildfires—in addition to other actions—in order to help prevent and/or combat them (Table 2). Other situations cited as a potential cause of wildfires include the use of *huatias* earthen ovens, which require the use of fire (by adults and sometimes by children) and feature in tourist and recreational activities in the communities.

As regards the potential damage that a wildfire can cause, in both locations fire users state that they are fully aware of the damage that burning can cause to the environment and their lives, and there is special concern about the loss of wild flora and fauna (Table 3).

In general, the inhabitants recognize that burning stubble poses a risk of the fire spreading and causing a wildfire, and although some testimonies stress the potential biological benefits for the soil, several others felt that such benefits were limited and even that the practice could be detrimental to the soil.

<p>“... de que ahora supuestamente dicen que abona esa tierra negra o la ceniza que queda de los rastrojos, pero no, sino que más bien está esterilizando los suelos.” (CalcaSillacancha_12)</p>	<p>"[...] now they supposedly say that it fertilizes the black soil or the ash left from the crop residues, but no, rather, it's sterilizing the soils."</p>
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4.4. Social organization in the control response to wildfires

In Peru, planning for disasters and emergencies, including wildfires, is carried out through the National Disaster Risk Management System (*Sistema Nacional de Gestión del Riesgo de Desastres*, SINAGERD), while the National Institute of Civil Defense (INDECI) is the agency tasked with discharging the response [75–77]. Following the INDECI protocols, Peru’s volunteer fire brigade is the body with immediate responsibility for responding to wildfires, and depending on the needs arising from the emergency, regional or local emergency operations centers, under the charge of regional and local governments, may be activated. However, the level of development of these operations centers is highly variable [55]. In practice, the most immediate response to wildfires in Andean or high Andean areas is often very local and suppressing them depends—at least initially—on the existing local organization, nevertheless, only 4 % of the total burns or fires (located near roads or rivers) are documented as wildfires emergencies by INDECI in Cusco [78].

In Peruvian Andean communities like Chanka, labor is often gathered for agricultural work and other collective tasks that require the support of many community members. Chanka maintains traditional social organization, where members collaborate on activities such as planting, harvesting, and maintaining local infrastructure. Those who fail to participate in these communal tasks face fines equivalent to one day’s pay. Similarly, during a fire, community members are required to respond if called by the local authorities, with fines imposed for non-participation. The call is made through the loudspeaker located on the community premises in the center of the community, and also by way of cellphones.

<p>“Si produce en cualquier lugar ya nos comunicamos, entre todos, la junta directiva comunica a la población para que vaya a ayudar mediante parlantes. Entonces ya tenemos que ir ya al lugar, si se produce el fuego de repente por ahí hay cabañas, entonces puede ser que los queme así, tenemos que apoyarnos, por la comunicación se hace entender mediante parlantes, celulares, diciendo ¡el fuego está acá ya!, vengan queremos más apoyo de la población, tienes que ir, todos corremos.” (ParuroChanka_1)</p>	<p>"If it happens anywhere, we already spread the word, all of us. The board communicates with the population through speakers so they can go and help. Then we have to get to the site. If the fire suddenly appears there are cabins around, so it might burn them like that. We have to support each other, through communication. The alarm is raised through loudspeakers, cell phones, saying 'the fire is here now!' Come, we want more support from the population, you have to go. We all go running."</p>
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Table 2
Local authorities interview quotes about wildfires.

Interview quote (original in Spanish)	Main ideas about fire use
<p>Last year [2020] we had a lot [of wildfires] and to be honest here civil defense has not worked as it should because they were not trained.</p>	<ul style="list-style-type: none"> - Greater number of wildfires - Lack of training on the part of civil defense
<p>There's still a need to do a lot of work, to keep raising awareness, to keep training brigades, training fire fighters. People still need to be made aware. Because they are burning all of our hills. We need to keep on working and it's a long-term job.</p>	<ul style="list-style-type: none"> - Need for more training and awareness raising.
<p>We do some training, we have forest users' boards so that wildfires do not happen here in the district, but the beliefs of the community members, despite the training we provide, they can be a bit stubborn. They always place emphasis on the ancestral customs.</p>	<ul style="list-style-type: none"> - Cause of wildfires: Ancestral customs - The provision of training alone is insufficient.

Table 3
Interview quotes about motivation of fire use in agricultural practices.

Locality	Interview quote (original in Spanish/Quechua)	Main ideas about consequences of fire use
Harín-Huarán	<i>It's harmful, we're all making things worse.</i>	- Event harmful to everyone
	<i>It's an attack, it's harm done to our nature, to our environment.</i>	- Event harmful to the environment
	<i>I don't agree with these fires, because first of all they ruin the environment</i>	- Event harmful to the environment
Chanka	<i>When they burn it causes harm, it burns and kills some animals</i>	- Event harmful to native flora and fauna
	<i>It's bad for the environment, native plants, as well as the wildlife, it kills them</i>	- Event harmful to native flora and fauna
	<i>They shouldn't exist these fires, they shouldn't exist. It's the environmental pollution more than anything. It's, it's killing all the animals, nature, the trees, the plants. I mean, it practically causes serious harm.</i>	- Causes pollution

The response to wildfire emergencies in Chanka is handled expeditiously and along similar lines of any other community task; the support of the community is required to stop the fire from spreading, and young people and adults attend the scene by horse, motorcycle, or car, while older women provide the necessary resources, such as food, water, and tools, while also helping to fight the fire. During the 2020 wildfire, the community was the first response measure in controlling the flames. The community does not possess the most modern or suitable fire suppression equipment, so the likes of earth, *chamoscas*, and wet clothing or rags were used. In Chanka no water is immediately available in large quantities, so residents must attempt to fight fire by throwing wet clothing or dirt.

Unlike Chanka, each sector of Harín-Huarán is territorial independent in its territory and manages its own organization. Therefore, in general, the locality does not function as a single collective since social organization depends on people registered to each community or sector, in addition to local residents and outsiders. When a wildfire occurs, participation takes the form of voluntary cooperation, and the population as a whole does not participate as it does smaller communities where there is greater coordination.

"Es voluntario, si el que le llame la conciencia, pero organización, organización no hay, no hay, a no ser que se promueva desde otras entidades. Van los voluntarios." (CalcaSillacancha,12)

"It is voluntary, down to whether one's conscience calls them, but organization, organization doesn't exist, unless it's promoted by other bodies. The volunteers go along."

During the event, volunteers organize into brigades or under the command of a single person. Generally, these volunteers include local authorities, young people, and adults, though participation is restricted by fear of involvement in an accident; indeed, inhabitants state that they are aware of the risks of suffocation and injury in the fire. The tools used include fresh *chamisa* branches, *chamoscas*, picks, and shovels to remove earth and put out the fire. Moreover, the settlement has access to water through its irrigation channels, from which water is drawn in drums and buckets to fight the fire.

In this organizational context, between 2018 and 2022 the Regional Government of Cusco rolled out a fire prevention project called "Implementation of Prevention and Control Services for Forest and Grassland Fire in the Cusco Region" throughout the region, the main objective of which was to improve wildfire response capabilities [79,80]. The project beneficiaries were mainly local authorities, disaster risk management offices, and forestry and environmental committees, and the activities included awareness-raising tasks, training talks, and provision of instructional and practical training materials on good agricultural practices aimed at raising awareness to avoid the use of fire. The project also sought to strengthen the wildfires first response brigades.

The Harín community was one of those selected to participate in this project, and so a team made up of trained residents was formed with the purpose of preparing the community to respond to wildfires. However, to date this team has not operated at full capacity due to the absence of some members when fires occur. Therefore, it is common to request that volunteers (local residents), led by individuals with greater knowledge or experience of fire control, join in. In Harín-Huarán, the Regional Government of Cusco displays posters calling for the use of fire on plant cover to be avoided in the most visited areas as a form of wildfire prevention.

In general, the local authorities request that the population do not get involved in fighting fires since they lack the necessary training, tools, and clothing.

"Si una comunidad no está capacitada se le pide que no acuda al incendio forestal. Se le pide que simplemente haga la evacuación de todo lo que tenga cerca de cobertura vegetal y pueda ser afectado, pero se le pide que no entre a hacer el control de la mitigación del incendio. Esto debido a los antecedentes donde muchas veces ha habido comuneros que han actuado y ha habido fallecimiento." (Calca_4)

"If a community is not trained, they are asked not to respond to the wildfire. They are asked to simply evacuate everything near vegetation cover that could be affected, but they are asked not to engage in firefighting mitigation. This is due to past incidents where community members have often taken action, resulting in fatalities."

Indeed, provincial authorities in Calca have pointed out that the burning practiced by farmers is not grounded in technical assistance; that is, no knowledge is imparted on how to foresee and control the spread of fire before and during burning. This is because the regulations in force (MINAGRI, 2012) do not permit the provision of training on the safe burning of agricultural stubble.

"La ley no permite dar solicitud para quema. No hay ninguna parte de la ley que diga tú tienes que autorizar, como no existe eso nadie puede dar autorización y para evitarse problemas nadie entra al tema de manejo de residuos con quemas. Nadie puede autorizar. Si tu das una charla de manejo de residuos orgánicos para quemas o para tratamientos de espacios agrícolas estarías incurriendo en delito porque estarías cometiendo algo que está prohibido." (Calca,2)

"The law does not allow for burn requests. There is no part of the law that says you have to authorize it. As it does not exist, no one can grant authorization, and to avoid problems, no one gets involved in the matter of waste management through burning. No one can authorize it. If you give a talk on organic waste management for burning or for dealing with agricultural areas, you would be committing a crime because you would be doing something that is prohibited."

5. Discussion and recommendations

Peru does not have a comprehensive national fire management policy, and wildfires are understood and managed as an emergency in accordance with SINAGERD protocols [55]. In fact, there is an insistence on strengthening the government's management of forest fires instead of the management of the use of fire [81]. Thus, current legislation—both national and regional—focuses mainly on the

direct or indirect prohibition of the use of fire in agricultural activities as a fundamental measure to prevent the occurrence of forest wildfires ([67,68,70,72,75]; MINAGRI, 2012; [69]). Thus, preventive policy mainly takes a punitive legal approach influenced by the negative view of fire as a cause of considerable damage [82], and the strong pecuniary and imprisonment sanctions in place are expected to reduce or limit the use of fire [83–85], furthermore, without considering that fire in a rural setting serves as both a tool and a necessity for agricultural land clearing activities.

The use of fire in agriculture in the Peruvian highlands is not merely a traditional or routine practice; it is an essential and pragmatic tool for land management. Testimonies from Tacllapata and Chanka underscore its critical role in clearing agricultural residues, controlling invasive weeds, and enhancing soil fertility. In resource-limited rural communities, where viable alternatives for weed management are scarce, fire remains the most accessible and efficient means of preparing land for cultivation. Moreover, economic pressures—such as the urban-to-rural migration triggered by the COVID-19 pandemic—have further reinforced reliance on fire as an agricultural strategy, particularly for land rehabilitation and expansion. While concerns regarding wildfires persist, the widespread dependence on fire for agricultural productivity highlights the need for a more nuanced approach to fire management. Instead of outright prohibition, policies should integrate local knowledge and promoting comprehensive fire management through, for example, controlled burning practices that balances agricultural demands with environmental conservation.

Statistical evidence shows that the punitive approach has not been successful in reducing the number and extent of wildfires in the country ([74]; MINAM, 2025a,b; [25]), and, on the contrary, more than a decade since the enactment of the law that seeks to prevent wildfires through the prohibition of burning in rural environments (MINAGRI, 2012; [22]), reports of emergencies due to wildfires have increased at the national level (USAID, 2020; [25,35]). In contrast, when the fire is adequately controlled, a prescription fire could improve vegetal regeneration by increasing diversity of herb species [45,86].

The use of fire in traditional agricultural practices in the Peruvian highlands is complex and composed by a range of interrelated factors, including individual decision-making, geographical constraints, climatic variations, labor availability and social organization. Evidence from Harín-Huarán and Chanka highlights that fire is employed through distinct and context-specific methods, reflecting the diverse agricultural needs of each locality. The decisions regarding the use of fire, are primarily personal but are also shaped by environmental factors such as wind dynamics, topographical gradients, and seasonal constraints. The diverse approaches to fire use in these regions underscore the necessity of incorporating local knowledge into fire management policies. Rather than enforcing rigid prohibitions, policies should be designed to balance agricultural needs with environmental protection, ensuring that fire remains a viable and controlled tool within traditional Andean farming systems.

For the particular case of the Andean and high Andean communities of Peru, a comprehensive fire management policy will necessarily involve identifying, characterizing, and integrating the daily practices and knowledge of fire users based on their unique perspectives and experiences [18,87]. Wildfire management in Peru's Andean regions is largely contingent on the organizational structures and response capacities of individual communities or settlements. Although an institutional framework for disaster risk management is in place, immediate wildfire response remains highly localized and varies significantly depending on the organizational and social structures of each locality. While communities such as Chanka uphold a traditional system of collective labor that enables the swift mobilization of their members, others, such as Harín-Huarán, display a more fragmented organizational structure, complicating coordinated response efforts. The absence of adequate firefighting equipment and technical training further exacerbates the situation, forcing communities to rely on rudimentary methods to suppress wildfires. Although governmental initiatives have sought to strengthen response capacities, their effectiveness is often hindered by the inconsistent participation of local actors and the insufficient integration of technical knowledge into traditional fire-use practices. In contrast, this suggests the high importance of improving levels of organization and establishing roles within communities.

Rather than imposing outright prohibitions on fire use, Andean communities require viable, context-specific alternatives that align with their organizational structures and local capacities. Fire management plans developed under this policy must extend beyond merely accounting for the physical and climatic conditions of each locality; they must also incorporate the social, economic, and cultural dimensions that shape fire use in these communities. Therefore, we propose the need to deepen the development of at least four alternative strategies tailored to rural communities that rely on fire, ensuring that solutions are both practical and contextually appropriate.

The first strategy must include the identification, training and implementation of alternatives to the use of fire in clearing agricultural waste, which are being promoted in other countries [88]. Although initiatives are being developed to implement alternatives in Cusco, such as the use of agricultural waste to produce compost [89,90], there is still a need to carry out a cost-benefit analysis and to monitor the results achieved by these initiatives. Such an approach will strengthen the successes and avoid errors in the implementation of each of these alternatives, assuring their viability in the medium and long term. It will also prevent needless resource wastage and weariness on the part of training recipients due to involvement in initiatives that may be theoretically and communally attractive but not necessarily effective.

A second strategy, already adopted by other South American countries such as Chile [91] and Argentina [92], is regulate fire use by the adoption of prescribed and controlled burning [93], considering local seasonal climatic factors [94,95]. Various studies suggest that prescribed and controlled burning is a forest management tool and alternative that yields greater benefits by reducing potential losses compared to fire suppression activities, by mitigating the severe effects of fire on plant roots through controlled burning [7,29,96,97]. The benefits of prescribed and/or controlled burning could change the current paradigm of suppression and sanctions. However, adopting such an approach would require amending current legislation, which implicitly prohibits the use of fire for agricultural purposes, and focusing regulations on the use of agricultural fire by small producers in Andean communities. There are also systemic barriers in the way of its adoption, which, according to Tedim et al. [98], include a lack of incentives and/or institutional and political will, biases on the part of decision makers (and evident in the current legislation), and knowledge gaps around the

behavior of wildfires.

A third strategy is the implementation of an incentive-based payment scheme that compensates farmers for refraining from burning, structured within voluntary contractual agreements, for example, an alternative monetary source could be the mechanism for remuneration of ecosystem services approved by the Peruvian government [99]. This approach would enable farmers to formally commit to reducing fire use in exchange for financial compensation, thereby aligning economic incentives with environmental conservation objectives. Compared to existing punitive policies that impose broad restrictions without accounting for the diversity of farming practices, this model offers a more efficient and equitable alternative, fostering greater compliance while addressing the specific needs of different agricultural contexts [15]. Finally, the last strategy requires the organizational and response capacities strength of local rural communities, to include their consultation and participation in local development plans [100] with an emphasis on fire management plans. In this regard, prevention measures against wildfires should aim to identify and recover local knowledge about the use of fire. Further, the adoption of new approaches related to the utility of fire should be promoted at community level, taking into account the perspectives and perceptions of fire users as well as comprehensive landscape management [9,11,101,102].

These four strategies require the inclusion of rural communities in comprehensive fire management [103,104] and seek to ensure that they can meet their agricultural objectives ([105]; Ramos, 2010; [93]). Undoubtedly, the inclusion in comprehensive fire management of new actors who contribute new knowledge and perceptions will pose challenges from an organizational, institutional, and budgetary point of view, and will ultimately mean a change in the governance of wildfires. However, this risk must be approached from a complex perspective that takes into account the social and ecological diversity of fire-prone areas and integrates different perspectives with technical expertise to promote a more complete understanding of the risk and more effective management strategies [104,106].

The proposal by Devisscher et al. [103], of three deliberation spaces to facilitate dialogue between different perspectives on optimum management of wildfires in Bolivia could also be applicable to the cases studied in the present research. These spaces include a willingness to open up the debate given the inconsistencies between fire management policies and the realities experienced by local communities; a second necessary space or “intradialogue” within a social group, such as indigenous communities, given that the perceptions of its members will not necessarily be homogenous; and, finally, the “interdialogue,” referring to the negotiation between different social groups.

6. Conclusion

This study underscores the shortcomings of Peru’s punitive fire management approach, which fails to account for the socio-environmental complexities of rural fire use. Despite stringent legal prohibitions, statistical evidence reveals that wildfire occurrence has not diminished, demonstrating the ineffectiveness of sanction-based policies. The prevailing strategy—centered on prohibition and emergency response—places farmers in a dilemma: they must either comply with restrictive regulations at the expense of agricultural efficiency or continue using fire despite the associated risks. Given the indispensable role of fire in land preparation and weed control within Andean communities, a comprehensive fire management policy must reflect the realities of smallholder agriculture, acknowledging fire as both a necessity and a tool rather than solely a threat to be eradicated. Rethinking the agricultural use of fire requires recognizing its multifunctionality in high Andean communities and its influence on both agricultural productivity and wildfire occurrence.

To address this challenge, it is imperative to explore and implement alternative strategies that transcend suppression and legal restrictions. The integration of prescribed burning, incentive-based compensation schemes, and the development of viable alternatives for agricultural waste management can provide a more effective and equitable framework. Furthermore, strengthening local governance and enhancing response capacities are critical to ensuring that fire management aligns with the organizational structures and traditional knowledge systems of rural communities. Interviewees emphasized the need for technical support, fire mitigation training, and improved fire control tools; however, these measures alone remain insufficient in replacing fire as a fundamental agricultural practice. Overcoming this challenge necessitates a shift from punitive enforcement to proactive investment in research, training, and the development of context-specific alternatives that acknowledge the interdependencies between ecosystems and rural populations. This requires moving beyond the perception of fire use as an isolated problem and recognizing it as an integral component of a broader socio-ecological system that must be effectively managed rather than eliminated.

In this context, qualitative studies such as this one are crucial for establishing a robust empirical foundation for quantitative research on wildfire occurrence. Statistical analyses of fire patterns must be informed by a deep understanding of the cultural, economic, and social dimensions of fire use in rural Andean settings to ensure that policies prioritize practical, community-driven solutions. Without this qualitative foundation, policy recommendations risk being disconnected from local realities and ineffective in implementation. Furthermore, Andean smallholders—who are both the primary users of fire and the most vulnerable to wildfires—must be at the forefront of policy discussions to ensure that fire management solutions address their needs rather than imposing external, impractical restrictions. The objective is not merely to suppress fire but to establish a governance model that ensures its responsible use while mitigating the risks of uncontrolled wildfires.

Ultimately, a paradigm shift in fire governance is essential—one that fosters deliberative spaces where local perspectives are integrated and negotiated within policy frameworks. Although more progressive fire management and wildfire prevention policies are emerging internationally [96,97], restrictive and reactionary approaches still prevail, focusing disproportionately on ignition sources while neglecting factors that influence fire spread [106,107]. Moreover, current strategies often emphasize fire suppression rather than sustainable fire management, overlooking the necessity of coexistence with fire rather than solely attempting to extinguish it once ignited [4,87,101,108]. Future research should focus on assessing the long-term effectiveness of alternative fire management

strategies, evaluating their cost-efficiency, and identifying institutional barriers to their successful implementation. A more holistic, sustainable, and inclusive approach to fire management in Andean agricultural systems is required. Rethinking agricultural fire use is not merely a matter of environmental policy—it is an economic and social imperative for high Andean communities that rely on it for their survival and agricultural sustainability.

CRedit authorship contribution statement

Sigrid Alvarez: Writing – original draft, Methodology, Investigation, Conceptualization. **Alejandra G. Martínez:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Investigation, Conceptualization. **Ricardo Zubieta:** Writing – review & editing, Supervision, Resources, Conceptualization. **Yerson Ccanchi:** Writing – review & editing, Visualization, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijdr.2025.105702>.

Data availability

Data will be made available on request.

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