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Mountain agropastoralism: traditional practices, institutions and pressures in the Indian Trans-Himalaya of Ladakh

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Abstract

Animal husbandry of agropastoral communities in the mountainous region of Leh, Ladakh, has been transformed in response to socio-economic and geo-political changes. This study investigates the current state of agropastoralism in the Trans-Himalaya of Leh, Ladakh, focusing on two objectives: understanding grazing management practices and examining socio-environmental factors affecting traditional pastoral livelihoods. Through a mixed-methods approach, including interviews and focus group discussions, this study explores resource utilisation patterns and decision-making processes within local communities and institutions based on a comparative approach in three pastoral areas of Ladakh. The resource utilisation pattern differs from village to village as a response to meet seasonal fodder demands; accordingly, high-altitude pastures are assessed in winter and/or summer seasons. Key stresses to the perpetuation of traditional pastoral knowledge include livelihood diversification, increasing dependence upon exogenous food production system and diminishing significance of traditional livelihood practices with improved connectivity, higher education aspirations and development of tourism and military services. Broadly, changes could be perceived from the abandonment of regular seasonal migration to pasturelands, in livestock composition and size and the decreasing number of households practising animal herding. Apart from socio-economic and developmental pressures, pastoral practices are simultaneously threatened by wild predators as well as by global warming-induced occurrence of extreme climatic events and pest attacks. While pastoral practices are carried on by a limited number of households in the three detailed study sites, knowledge pertaining to resource management, pastureland system and grazing pattern is still intact considering the resource seasonality and range of social and environmental pressures the region experiences. Ladakh's agropastoral practices, rooted in local ecological knowledge, face challenges from socio-economic changes, risking climate resilience, ecosystem degradation, cultural loss and food security for agropastoral communities and broader societal contexts. Thus, it becomes vital to safeguard these indigenous livelihood practices and to promote a participatory approach to enhance capacity building for the continuation of the practice, which could contribute to local economies in areas with similar socio-environmental settings.

Keywords Combined mountain farming, High-altitude pastures, Trans-Himalaya, Socio-economic changes

Introduction

For centuries, mountain communities have depended upon high-altitude pastures (HAPs) in various systems of transhumant pastoralism and agropastoralism to secure their livelihoods. Altitudinal movements according to the seasonal availability of grazing resources and efficient utilisation of pastures reflect the adaptive strategies developed by communities to safeguard fodder security under

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specific ecological, socio-economic and political conditions (Rhoades and Thompson 1975; Kreutzmann 1993, 2012; Uhlig 1995; Nüsser et al. 2012a, b; Aryal et al. 2018). Agropastoralism has benefitted the integrated mountain agricultural system in many ways by providing diversified grazing resources, reducing pressure from over-grazing-led degradation and alleviating fodder shortages during lean winter months, maintaining pasture productivity and diversity and thereby aiding in lowering the vulnerability of the otherwise fragile ecosystem while contributing to the local economy (IFAD 2010; Wright et al. 2012; Sharma et al. 2014; Aryal et al. 2018; Ingty 2021; Singh and Kerven 2023). In the last few decades, a downtrend in the practice of agropastoralism is seen throughout the Himalayan region as a consequence of rapid socio-economic, developmental and environmental pressures, compromising the unique agrobiodiversity and adaptive capacity of the community (Ehlers and Kreutzmann 2000; Clemens and Nüsser 2000; Wu et al. 2014; Adler et al. 2022; Singh and Kerven 2023).

In the Trans-Himalayan region of Leh, Ladakh (India), a cold-dry region with many remote parts, agropastoralism has been the mainstay since time immemorial ensuring a sustainable food production system relying on limited local resources (Gazetteer 1890, 1901; Crook and Osmaston 1994; Rizvi 1999; Koshal 2001). Cultivation of staple crops (barley and wheat), heirloom vegetables (mustard, radish, turnip), fodder alfalfa, fruit trees of apples and apricots and timber trees of poplars and willows along with the rearing of livestock including cows, yaks, sheep and goats, horses and donkeys features the basic agropastoral practice of the region. The significance of this practice becomes especially pronounced during the lean winter months, when survival hinges on stored resources for food, fodder and fuelwood. The region's cold-arid climate offers a brief growing period from March to August, prompting seasonal migrations to high-altitude pastures (HAPs), known as *doksa/phu* locally, an adaptational strategy contributing to food and fodder security (Koshal 2001; FAO 2008; Raj et al. 2020). As integral parts of traditional land-use systems, agropastoral practices are strongly based on ecological knowledge of pastures and spatio-temporal allocation of grazing resources. The judicious utilisation of resources is guided by social norms and overseen by local institutions, underscoring the importance of community-driven management in sustaining the essence of the traditional agropastoral system. In Ladakh, institutions of *goba* (village head), *chhudpon/chhurez* (responsible persons for irrigation water management) and *lorapa* (livestock monitoring) are common across most villages (Koshal 2001; Angchok and Singh 2006). In the spectrum of village-level decision-making processes, *goba* holds responsibilities that include overseeing the seasonal migration of livestock to HAPs, imposing penalties for non-compliance, monitoring both village-kept livestock and those descending from HAPs through *lorapas* and facilitating conflict resolution. In this way, agropastoralism not only mitigates crop damage by free-grazing livestock but also yields diverse animal products (meat, dairy, wool, leather), enriching agricultural subsistence. Beyond grazing, *doksa/phu* serve as hubs for the processing and preservation of animal products (Raj et al. 2020). Since the herders also have the knowledge of many medicinal and wild edible plants, they occasionally collect them to be used by *amchis* or local healers under the traditional medicine system (Haq et al. 2021).

Similar to other mountain areas, agropastoralism-based food production system and livelihood practices in Ladakh are influenced by ongoing rapid socio-economic and developmental changes, coupled with population growth (Goodall 2004; Bhasin 2011; Dame and Nüsser 2011; Pelliciardi 2013; Takeda and Yamaguchi 2015; Yamaguchi et al. 2016; Dame et al. 2019). Rapid changes in agropastoral practices can result in reduced resilience to climate change, degradation of ecosystems, loss of cultural heritage and impacts on food security for both agropastoral communities and larger societies (Singh and Kerven 2023). Various studies have identified factors such as acculturation, rural-to-urban migration for livelihood and higher education, and increasing reliance on external markets and institutions like public distribution system (PDS) as the key driving factors contributing to rapid urbanisation and livelihood diversification (Fox et al. 1994; Dame and Nüsser 2011; Pelliciardi 2013; Dame 2018; Dame et al. 2019; Müller et al. 2020). Furthermore, the region faces the imminent threat of frequent extreme climatic events, which could exacerbate the risks to agropastoral activities and, subsequently, the resilience of the traditional agricultural system (Thayyen et al. 2013; Ziegler et al. 2016; Schmidt and Nüsser 2017; Chevuturi et al. 2018; Sharma et al. 2023). While a majority of the work related to pastoralism is focused on wildlife predation and, to some extent, land-use patterns and livelihood (Angchok et al. 2016; Takeda and Yamaguchi 2015; Raj et al. 2020), little information is available on the significance of HAPs, its role in traditional farming system to maintain food and livelihood security, local nuances in maintaining pastoral practices and people's perception on its status in the wake of socio-economic and developmental stresses. In light of these research gaps, our study seeks to comprehend the present rangeland management practices of these communities based on a comparative study, documenting changes in livestock composition and numbers grazed at HAPs. Furthermore, we aim to analyse the intricate web of social, political and ecological

pressures influencing the continuity of traditional pastoral livelihoods.

Materials and methods

Study area and profile

The Trans-Himalayan region of Leh, Ladakh, situated in northern India, predominantly lies at altitudes exceeding 3000 m above sea level, characterised by a cold-arid climate. This sparsely populated high mountain area is defined by challenging weather conditions and limited natural resources. Despite its harsh environment, the delicate socio-ecological equilibrium in this region has endured for centuries. In its historical context, the Ladakhi society comprised affluent agropastoralists and aristocrats forming the upper caste, while subsequent settlement led to the emergence of lower castes such as *Beda* (musicians/beggars), *Mon* (musicians/carpenters) and *Gara* (smiths) (Koshal 2001; Garkoti et al. 2018). In the present day, due to urbanisation, even households from the *Beda*, *Mon* and *Gara* communities are engaged in agropastoralism and non-farm livelihoods. Traditional practices like primogeniture, polyandry and monastic celibacy rooted in Buddhism have played a pivotal role in population regulation and safeguarding resources from fragmentation, especially arable land (Wiley 1997; Koshal 2001). At the village level, households function as the smallest socio-economic units, while local institutions of *goba*, *chhudpon/chhurez* and *lorapa* oversee the management of community-owned resources, including the pastoral system. Although, so far, only male representatives of main households or *khangbas* contested for *goba's* position in the study area, these institutions are open to all community households, and decisions are collectively made during community gatherings under *goba's* guidance (Koshal 2001; Bajpai et al. 2022). Due to its strategic geopolitical importance and unique landscape, military presence and tourism, along with ongoing economic, political and developmental advancements, play an influential role in the otherwise secluded community of Leh, Ladakh (Geneletti and Dawa 2009; Pelliciardi 2013; Dame et al. 2019).

The primary objective was to select villages situated within a proximity of 50–100 km from Leh town, exhibiting diverse pastoral practices, for the purpose of feasibility and comparative analysis. Hence, three study sites were chosen, namely, Igoo-Langkor, Shang and Gya-Sasoma-Rumste from Kharu block of Leh, Ladakh, India (Fig. 1 and Table 1). Igoo-Langkor (Lat. 33° 54′, Long. 77° 55′) represents a linear settlement along the stream with an altitudinal range of 3400–4100 m a.s.l. on the right bank of the Indus River. The village of Shang (Lat. 33° 53′, Long.77° 43′; Elev. 4000 m a.s.l.) represents a V-shaped valley with two hamlets Chokdo and Shang, located on the left bank of river Indus in the core zone of Hemis National Park. Gya-Sasoma-Rumste villages (Lat. 33° 40′, Long. 77° 45′; Elev. 4100 m a.s.l.) represent clustered settlements, situated on an alluvial fan. Gya is one of the earliest settlements documented for Leh, Ladakh (Kaul and Kaul 1992), and the neighbouring hamlets Sasoma and Rumtse share the same grazing resources as well as participate in joint management practices with Gya; thereupon, the study area Gya-Sasoma-Rumste would be represented by Gya village. Igoo and Gya are conveniently positioned along the Leh Manali Highway. While Shang and Igoo offer tourism-related activities, treks and homestays, Igoo engages locals in pilgrimage-related activities. Consequently, all three villages are subjected to diverse socio-economic and developmental influences. The study area is a largely homogenous community, belonging to the *Bot* ethnic group, with the majority practising Buddhism and few households following Islam. They practise single cropping and animal husbandry as part of subsistence agropastoralism (Census 2011).

The selection of pastures was mainly based on the reconnaissance survey focused on temporary settlement status of the local herders in the HAPs, followed by vegetation types and pastoral patterns and practices. To explore the spatio-temporal pattern of utilising pasturelands, in Igoo-Langkor, two pasturelands were chosen Pabaling and Tsolung and one grazing area, Khaspang; in Shang, three pastures were chosen, namely Shangphu, Gyumchu and Tanda; and in Gya, there exists the practice of exploiting both summer and winter pastures; therefore, summer pasture of Targyug and winter pasture of Kyamar were selected. All the studied HAPs were located above the elevations of 4300 m a.s.l., and temporary settlements called *pulu* as well as animal resting places were found between approximately 4300–5000 m a.s.l.

Research methodology

A reconnaissance survey was done before field studies in the three villages, and secondary information relevant to the study was gathered from various sources. The preliminary survey identified sites representing different stages of agropastoralism management: intact, dwindling and abandoned practices. The term "intact" referred to villages where traditional agropastoralism was still practised, characterised by seasonal migration to HAPs, diverse livestock composition and the presence of herders and temporary settlements. On the other hand, "dwindling" indicated changes in management, while "abandoned" denoted the absence of seasonal migration and herders and a significant decrease or absence of livestock suitable for practice. Based on the information gathered, two HAPs in Igoo-Langkor, three in Shang and

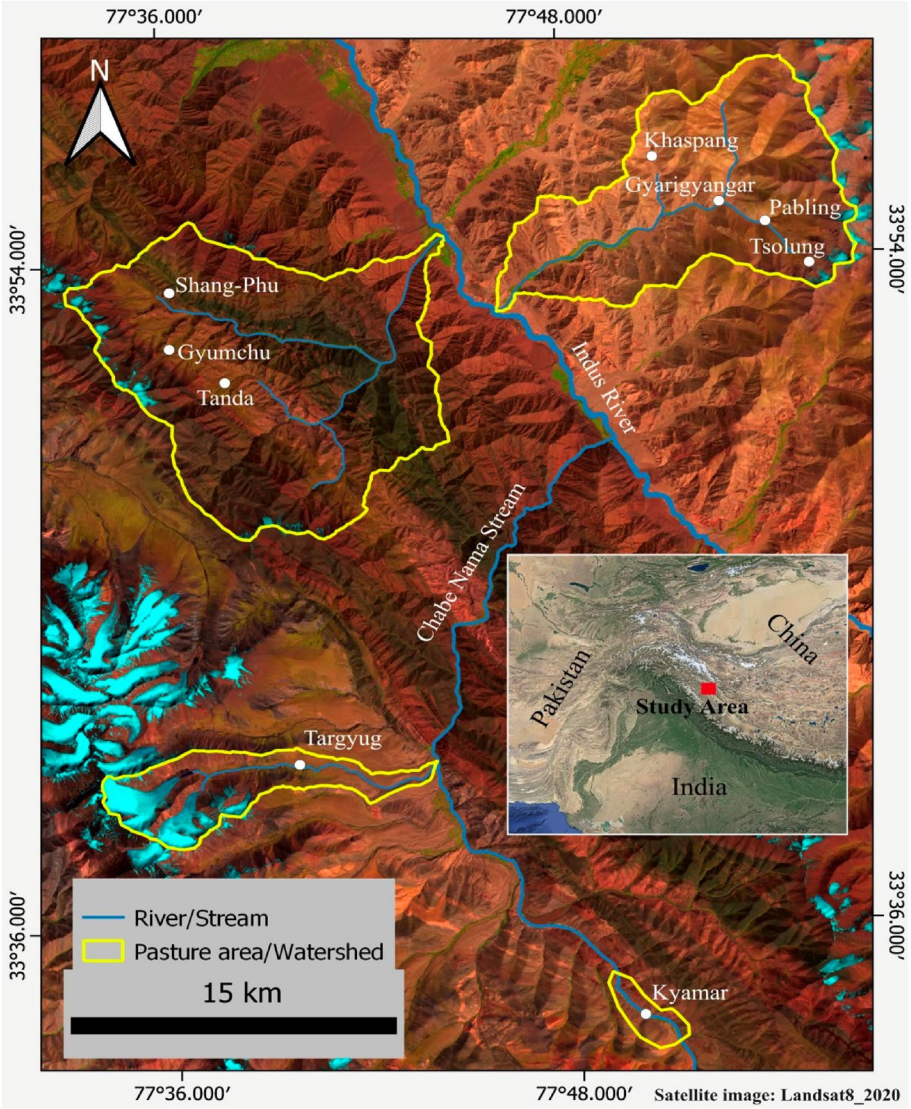

Fig. 1 Map showing the location of the study area

two in Gya were selected for the study. Secondary information was collected from line agencies and personal communications. Data collection took place from July to September 2019 and 2020, employing a semi-structured household questionnaire (Additional file 1). All household members were considered as one household for the interview, for they add up to the same information. Thus, a total of 84 household interviews were conducted for this study, covering 20% of households in each village. Secondly, following the chain referral method, 33 key knowledge holders (KKHs) were identified comprising 14 shepherds, 12 yak herders, two *amchi*, three *lorapa* and two *goba*, while the remaining respondents included farmers, line agency personnel and individuals employed in public and private sectors (Huntington 2000). The participants were encouraged to share their knowledge about the existing agropastoral system and focused on the information on the seasonal migration and challenges and risks they face, their perception and possible solutions. In addition, two focus group discussions (FGDs) with herders were conducted, one in the village and one at their temporary settlement. The FGDs were carried out with three to eight participants. Interviews generally lasted for 60 to 80 min and were conducted in the locally spoken language *Ladakhi*. Personal interviews with key knowledge holders and focus group discussions were used to investigate and validate the information to understand the specific factors of socio-economic

Table 1 Study area profile and descriptive statistics for socio-demographic characteristics of the 84 respondents

Variables	Altitudinal range (m a.s.l.)	Total population (no. of households)
Study area		
Igoo	3400–4100	1190 (325)
Shang	3600–4000	238 (51)
Gya	3900–4100	658 (140)
Age	Age of the participant	Mean = 59 (min. = 25, max. = 88)
	Share of age (%)	
	Age < 25–40 = 7.14	
	Age < 40–65 = 76.19	
	Age < 66–88 = 16.66	
		Percentage (%)
Agriculture	Participants involved in agriculture practices	98
Pastoralism	Participants involved in sheep/goat/yak rearing	51
Tourism	Participants involved in tourism	19
Significance of HAP	Participants with experience in HAP as herder, farmer, local healer, etc	51
Has any idea about HAP	Information on HAP	100

changes, local perceptions of these changes and associated impacts on pastoral practices and pasture resources. Wherever feasible, the data was noted down; otherwise, the narratives were recorded with their consent.

Results

In all studied villages, households including communities from lower castes followed agropastoralism as the main livelihood practice. While the position of *goba* continued to be held by main households only, the institution of *lorapa* included participation from all communities as observed in Igoo village. However, resources like irrigation water and grazing lands are not open to all agropastoralist households, irrespective of caste. With the onset of the agricultural season in April to May, the villagers are engaged with three main tasks: (1) preparing the water channels and fields for farming, (2) sending of animals (cows, yaks, dzos, sheep and goats) to HAPs for daily and seasonal grazing sessions and (3) constituting the institution of *lorapa* in the presence of village community on the rotational basis under the supervision of *Goba*, where few households are assigned to check the free grazing livestock in open cropped areas within the limit of the village to avoid crop loss and impose a penalty on the defaulters. Seasonal migration to these HAPs helps the households (1) in meeting food and fodder requirements and, thus, lowering the risks incurred with the subsistence agriculture; (2) in promoting growth and development of their livestock, as HAPs provide a range of nutritional forage species to graze; (3) in spatio-temporal respite to carry out agricultural activities without the risk of free-grazing animals and lastly; and (4) in generation of additional income from trade items (wool, hair, skin, etc.). The temporary settlement could be understood as a small cottage industry where herders collect and process milk products and stock wild edibles and fuelwood (species of *Caragana versicolor* and *Acantholimon lycopodiodes*) for the household. Mostly, all the pasturelands studied are common property resources and are accessible to all the households of that village, except for a few which are accessed by monasteries only. This could be understood from the socio-religio-political status the monasteries played in earlier times when monasteries too reared livestock for various purposes (Mann 1985; Koshal 2001). The grazing resource usage pattern varied according to the prevalent bio-physical and socio-economic pressures which impact the adaptive capacity of the community.

Apart from their role in livestock rearing, herders possess essential knowledge about pasture vegetation, phenology, habitat and use, which includes insights into rare and key indicator species. Therefore, some herders routinely collect medicinal plants for the local healers, *amchi*, to provide traditional healthcare services. Furthermore, they exhibit an understanding of the biophysical and climatic conditions at the local level. These fundamental observations hold the capacity to identify potential threats and risks, thus aiding in the mitigation of extreme climatic events. Consequently, this knowledge plays a crucial role in the development of effective climate change adaptation strategies. However, it is observed that changing socio-economic dynamics had varying levels of influence on the local pastoral practices, and as such, there is a transition in the traditional

livelihood aspirations, herd composition and locals' perception of the pastoral system. The traditional grazing patterns and various factors affecting the practice in the study area are discussed below.

Grazing practices in Igoo-Langkor

Traditionally, with the beginning of the spring season, the herders with their livestock arrange for vertical migration to summer HAPs of Pabaling, Tsolung and Zinggug and stay until the harvest period arrives. Except for the lactating cows, young and sick animals, which are stall-fed, all livestock is sent for grazing (Fig. 2). The two studied HAPs namely Pabaling and Tsolung are approximately 3–4 walking hours away from the nearest settlement or the pasture's valley floor named Gyarigyangar. As per the routine, the herders settle at *pulu* sites (Pabaling and Zinggug) and take their livestock mainly sheep and goats for daily grazing to and from nearby pastures, while yaks and dzos graze in herds and look after themselves. The animal resting places are located at an elevational range between 4500 and 5000 m a.s.l. (Fig. 3).

Currently, the practice of seasonal migration and, particularly, rearing of sheep and goats are entirely abandoned in the village. As a result, the *pulu* at the HAP sites are in ruins and, therefore, no longer used by shepherds or yak herders (Fig. 3; Table 2). There is also observed a decrease in the composition and size of livestock reared by the households; where earlier households reared cows, yaks and hybrids, sheep and goats, horses and donkeys (Supplement 2), presently, it has been reduced to cows and its hybrids for procurement of milk products only and few yaks for traction. Consequently, a preference for high-breed cows over local was realised with the sole purpose of surplus milk production for trade in the nearby markets of Kharu and Leh. These exotic breeds are usually stall-fed and sent to nearby grazing lands like Khaspang and Gyarigyangar (elevational range up to 4200 m a.s.l.), and during winters, they graze on hay, field stubbles and other supplementary fodder during the day.

Occasionally, the HAPs of Igoo and its neighbouring villages (Nang, Sakti, Stakmo and Arzoo) are visited by herders of Tibetan refugee (TR) nomads with their flocks

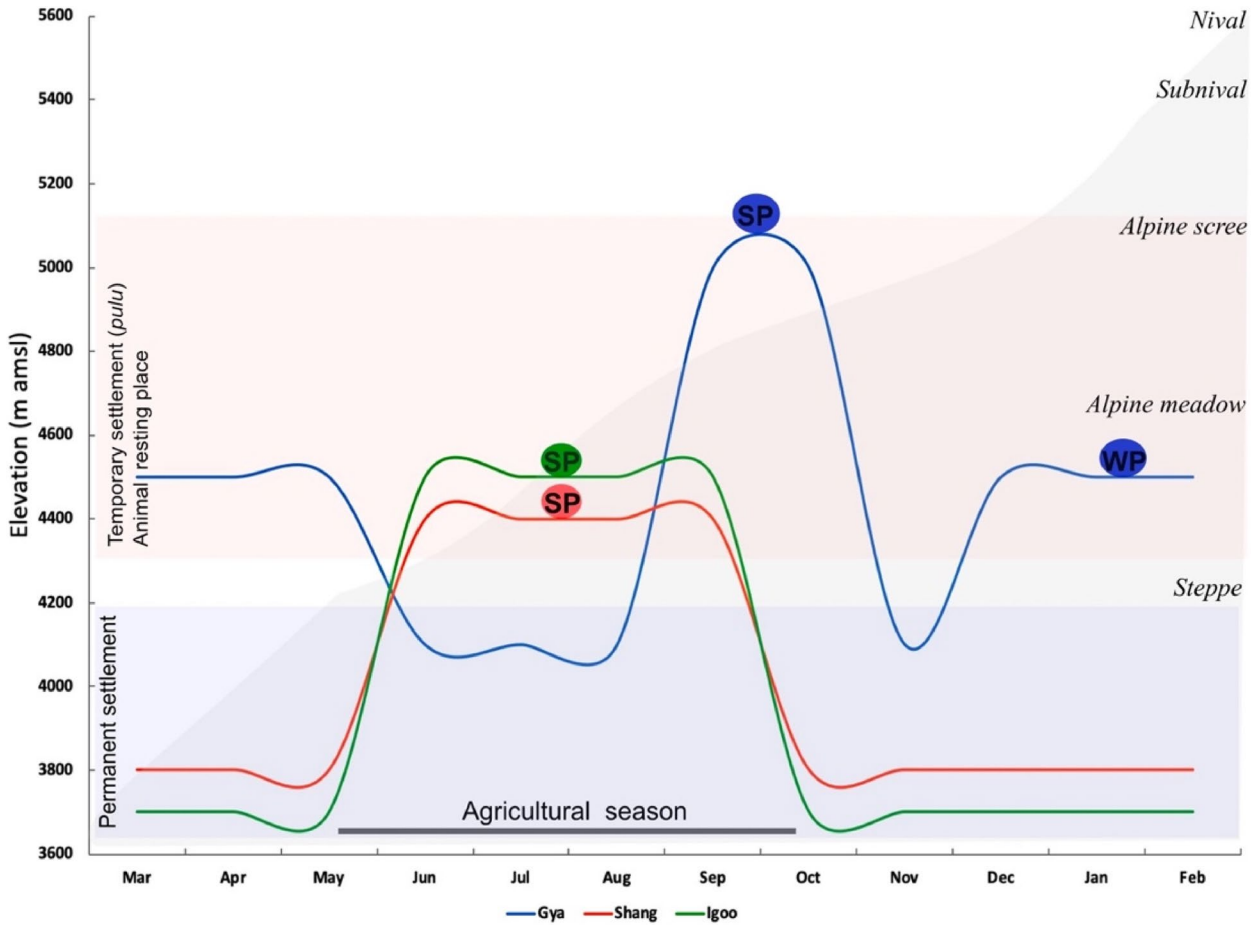

Fig. 2 Elevational distribution of pastureland and grazing patterns in Igoo, Shang and Gya villages. SP, summer pastures; WP, winter pastures

Fig. 3 The status of livestock migration to HAPs in the study villages of Igoo, Shang and Gya

Table 2 Status of utilisation of HAPs in the study area (studied HAPs are shown in bold)

Village (households: with goats and sheep)	Pasturelands	Temporary settlement	Herders	Livestock	Status
Igoo (238:0)	Zinggug, **Pabaling**, **Tsolung**, **Gyarigyangar**	Abandoned	Absent	No sheep and goats; yaks/dzos present	Abandoned
Shang (51:5)	**Shang-phu**, **Gyumchu**, **Tanda**, Keechan	Partly intact	Present	Present	Dwindling
Gya (140:66)	Summer pastures: Tari, Yabad, Kyambu, Chubab, **Targyug**, Amda, Shigul, Chultichan, Puzey, Chaktsang, Pungdurma Winter pastures: Mingfa-kyangbu or Jungmat, Kotsa phu, Kotsa mat, Ngayul, Paktse, Nilung, Kyam, **Kyamar**	Intact	Present	Present	Intact

of sheep and goats during the winter months (Additional file 2). Hence, the HAPs are currently grazed by the remaining individuals of yaks and dzos and sometimes by livestock from neighbouring villages (Chemday and Serthi) and TR herders.

Grazing practices in Shang

The management of HAPs in Shang could be understood in two ways: firstly, the three pasture valleys (Shang, Gyumchu and Tanda) are distributed among three villages (Shang, Changa and Martselang, respectively) for settling their *pulu*, and secondly, in terms of grazing resource, it is shared among the herders and/or villages, there is no demarcation of the valleys per se (Table 2). In a personal interview with a senior key respondent, it was revealed that an institution known as *Dewa* existed until the 1970s; *Dewa* was an elected monk affiliated with Shang Monastery. Its role included overseeing the agropastoral practices and pastures for the monastery as well as resolving conflicts with the assistance of the *Goba* system. The institution had neither been replaced nor handed over to existing institutions; therefore, the utilisation of these pastures is based on mutual understanding among the villages, which have worked successfully to date as there are no reports of disputes so far.

The grazing practices in Shang village differ between its two hamlets Chokdo and Shang due to their distance from the nearest HAPs, which is approximately

3 km and 7 km, respectively. The grazing pattern and practices of Shang hamlet are similar to that of Igoo-Langkor where herders undertake vertical migration to HAPs during summer and stay in temporary settlements rearing livestock until the agricultural season is over. Whereas, in Chokdo hamlet, since it is located at the base of pasture Tanda, herders perform daily grazing of the livestock to these HAPs throughout the year instead of seasonal migration and as such, there is no need to maintain temporary settlements in the pastureland. The *pulu* and animal resting place of Shang, Gyumchu and Tanda were located at an elevational range of 4300–4500 m a.s.l. During winters, livestock are taken for daily grazing to nearby pastures, and occasionally, when there is a scarcity of fodder or daily grazing is hindered because of bad weather conditions like heavy snowfall, the livestock are stall-fed (Fig. 2).

The pastoral practice is at a dwindling stage, with only five (four from Chokdo and one from Shang hamlet) out of 51 households involved in sheep and goat rearing; the temporary settlements in Shang-phu are still in use and intact (Fig. 3). Some 20–25 years ago, in addition to pastoralism, herders in Shang-phu also practised cultivation of barley near the settlement, which was currently left fallow. The *lorapa* system, which involved monitoring of free-grazing livestock, was previously practised in Shang hamlet about 15–20 years ago. However, in the present times, individual households have taken up the responsibility of managing their own livestock. During the field visit, *pulu* was resided by two herders, of which one is engaged in rearing sheep and goats and visits HAP every year, while the other visits occasionally and looks after lactating cows only and focuses primarily on milk products. Since the villages of Changa and Martselang have abandoned rearing of sheep and goats entirely, *pulu* in Gyumchu and Tanda pastures were abandoned and damaged, but the custom of sending livestock for grazing (yaks, dzos and non-lactating cows) during the agricultural season is still in practice. Aspiration for higher education and off-farm employment options is one of the primary factors putting a risk on the preference for this livelihood practice. Tourism is further influencing the local livelihood practices, with households involved in homestays, camps and as porters and guides since Chokdo hamlet is en route from the Markha trek, one of the prominent trekking routes in the region. Nevertheless, the pastoral practices of the village could be still represented by few households and that too managed by household members. Till then, the households engaged in grazing practices had not hired any paid labour for herding.

Grazing practices in Gya

Due to the challenging biophysical and socio-economic impacts, locals utilise around 19 summer and winter pastures as an adaptive approach; therefore, apart from the elevational distribution of the grazing resource use, temporal management of the grazing area is also significant for this study village. Out of a total of 140, 66 households still practice rearing sheep and goats along with cows, yaks, dzos and horses. The seasonal migration ranged from the lower grounds of the village at approximately 4000 m a.s.l. to temporary settlements in HAPs at 4500–5000 m a.s.l. (Fig. 2 and Table 2).

With the beginning of the agricultural season, after ploughing of fields, horses and dzos are sent to summer pastures like Targyug, where they graze by themselves for the whole agricultural season and are stall-fed during the winter months, while yaks could be either accompanied by herders depending upon the availability of the herder or left by themselves, as in the case of dzos and horses until harvest (Aug-Sep), after which the herders descend down to contribute to the agrarian workforce. On the contrary, sheep and goats are taken for daily grazing to the nearby pastures from the permanent settlement area during the agricultural season. During this stay, they may share the same grazing grounds; collect manure, wool and pashmina hair; and cleanse the livestock. For the next 2–3 months, i.e. September to November, the shepherds and yak herders ascend to high and far-located summer pastures where the pastures are abundant and livestock have the strength to cross high passes with ease. The herders descend down the valley and stay in the village for a period of approximately 20 days until the 15th of the tenth month of the lunar calendar or till Ladakh's New Year *Losar*, which falls around December. For this short period, the livestock is either taken for daily grazing or stall-fed, depending on weather conditions (Figs. 2 and 3). In addition, the practice of *Choldak* system exists where one herder manages the sheep and goats of 3–4 households. In return, these households assist with the transfer and transportation of goods and livestock between different grazing sites. This arrangement also extends to occasions when the herder is occupied or unwell, thereby easing the herder's responsibility as well as avoiding the need of hiring herders from outside or non-locals.

Although there are no regulations for choosing a particular summer pasture and is, therefore, random, there is a custom for the distribution of winter pastures which hints on a sense of territoriality needed due to the scarcity of grazing resources during the cold seasons. In this sense, winter pastures are not accessible as common pool resources for these pastures are distributed via *Cholo* system, a traditional dice game, to each herders or group

of two herders based on herd and pastureland size and herder's mutual relationship. Therefore, after the *Losar* break, all the yak herders and shepherds move to the common winter pasture of Kyamar and depending upon the pasture availability and their preparedness to move to winter pastures, they can stay for a month (December to January) or more. They stay in their allotted winter pastures until the 15th of the fourth month of the lunar calendar, corresponding to the months of April to May (Fig. 2). If one continues to stay beyond the mentioned date, a penalty of losing one sheep or goat to the village community is imposed, a practice called *gyalug*. There is also a prohibition on the collection of dung or pellets. If during the stay, the livestock breaches into another's winter pasture boundary designated by streams, the defaulter has to pay a fine of a total of Rs. 1000 or Rs. 10 INR per animal and the money goes to the village community. Additionally, in Gya, four pasture valleys were accessed by livestock of the Hemis Monastery. Two valleys are allocated for yak grazing and the other two for rearing sheep and goats. While the traditional practice of raising large sheep and goat herds has diminished, some rescued individuals are still raised on a rotational basis by households. In return for this arrangement, these households are granted access to graze their own sheep and goats in the designated areas. Even though the pastoral practices of the village are still intact, soon it could face a shortage of herders as the younger generations aspiring for higher education and influenced by tourism and military sectors may opt for off-farm livelihood sources.

Factors contributing to the decline in pastoralism

The different grazing pattern reflects the varying dependence of the village communities on the traditional livelihood in response to limited resource availability and extreme climatic conditions to maintain food and fodder security. Interviewees narrated the ongoing changes in socio-economic and developmental dynamics in their villages and region in general mainly with the shift from subsistence farming to market-dependent communities. Changes in social systems, including the practice of polyandry, along with the diminishing efficacy of local institutions over time, could significantly affect sustainable resource management. They emphasised factors such as higher education, diversified livelihood options, tourism, land-use change and adoption of hybrid livestock and mechanised farming as fundamental aspects for the abandonment of traditional livelihood practices and lifestyle in general. Preference for higher education, off-farm livelihood options and smaller families were ranked as the prime factors by most of the respondents (26%). This is because the absence of younger members leads to a shortage of assistants to the herders in managing the livestock which also creates a gap in the transfer of knowledge and experience on grazing pattern, pastoral system and pasture vegetation as well as overall knowledge on the bio-physical condition setting of the HAPs. Around 22% of respondents claimed diversification of livelihood as the second driving factor impacting traditional practices. With the introduction of tourism, military and sectoral jobs and private business, there is observed an out-migration for off-farm employment leading to the abandonment of the local livelihood practices. About 21% of the respondents believed choosing nuclear families was the third major factor causing fragmentation of the farmlands and shift to off-farm income. In addition, decreasing household size for the sake of providing better health and education facilities is contributing less to the agrarian workforce. For the villagers of Shang and Gya, tourism has offered employment as homestays, porters and guides, as the villages are part of the famous treks (Genelleti and Dawa 2009). Of the total 84, 19% of the respondents were engaged in tourism offered services throughout the agricultural season (Table 1). Land-use change and adoption of hybrid livestock were the least concerned factors, as they are still practising farming either by arranging the presence of all family members or through paid labour, and since villages of Shang and Gya are situated at high altitudes, exotic breeds like jersey cows could not adapt to be reared and, therefore, limited to local stock. A similar concern was also acknowledged by the participants in the conducted FGDs (Fig. 4). In recent times, environmental pressures with increased frequency of extreme weather events (such as GLOF event in Gya (2014) and Cloud bursts in Leh Valley (2010, 2015 and 2023)) may also pose a potential threat to the pastureland and to the practice (Schmidt et al. 2020; Luxom et al. 2022; Anonymous 2023; Sharma et al. 2023). Therefore, a comprehensive strategy offering an upgradation of this livelihood with due recognition and support may assist in safeguarding the unique livelihoods and be explored by mountain communities facing similar challenges.

Discussion

The role of HAPs in mountain agriculture, especially in the cold and arid region of Leh, Ladakh, is a crucial adaptive strategy which includes vertical exploitation of this resource. In order to identify and differentiate site-specific differences in pastoral practices, our study is based on a comparative approach. For that matter, in case of Igoo-Langkor and Shang, seasonal migration to HAPs during summers satisfied the pressures of resource seasonality thereby maintaining food and livelihood security, while in Gya, the adaptational system required vertical migration to HAPs during both summer and winter

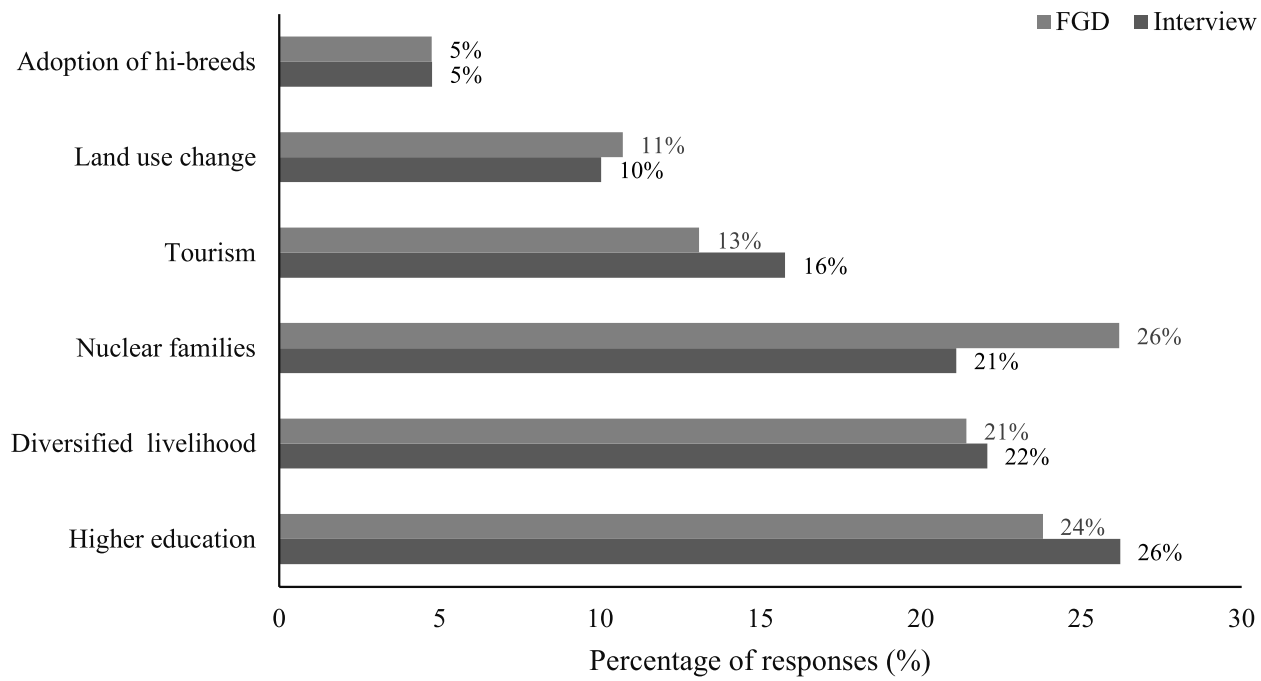

Fig. 4 Household interviews and focus group discussion responses to factors impacting pastoralism

seasons to facilitate the deficits of the agriculture. The presence of diverse livelihood avenues, including tourism, military and governmental employment, has resulted in scarcities of agricultural labour, especially during the crucial summer growing season. This phenomenon has notably impacted both agricultural and pastoral practices within Shang and Gya villages. Simultaneously, the emergence of alternative livelihood prospects and heightened aspirations for higher education among the youths has steered their focus towards non-farming income-generating activities, thereby diminishing the reverence for traditional livelihoods. This transformation has consequently led to a discernible gap in the transmission of knowledge, posing a substantial risk to the continuity of pastoral practices. A specific incident in Gya village in 2019 exemplifies this challenge, where an injured shepherd's absence resulted in the sale of sheep and goats due to the lack of capable herders. This scenario underscores herders' concerns about the transfer of pivotal insights into pasture ecology, patterns and systems, accentuated by the younger generation's pursuit of novel livelihood avenues. Hence, the absence of herders remains a pivotal driver of escalating abandonment rates in the studied villages, particularly in the context of sheep and goat rearing. Similarly, in Shang village, of the five households engaged in sheep and goat rearing, four belong to Chokdo hamlet, eliminating the necessity for temporary settlement stays. Consequently, a single herder from Shang hamlet manages the practice for the entire village. This pattern might expand to other practising households in the future, as observed from the representation of herders across multiple households in both Shang and Gya. Herders have, therefore, voiced concerns about the waning reverence for traditional livelihoods and the diminishing opportunities due to rapid urbanisation, further exacerbating the challenges to the continuity of the herding occupation. While government initiatives have focused on supporting pashmina production and existing herders in the region, there is still a lack of encouragement and security for the younger generation to pursue herding as a viable livelihood (Anonymous 2019). Comparable findings have emerged from studies on other pastoral communities (Namgail et al. 2006; Shaoliang et al. 2007; Namgay et al. 2014; Aryal et al. 2014; Gentle and Thwaites 2016; Tiwari et al. 2020; Hameed et al. 2022; Luxom et al. 2022).

Changes in herd size and composition are yet another challenge faced in the study area. Livestock composition has been reduced to rearing only lactating cows for milk production in case of most of the villages near Leh town in general and Igoo village of the study area. In Gya village, due to the declining size of sheep and goats, one winter pasture has been excluded from distribution and designated as a community pasture. As such, herders interested in grazing their livestock in that particular winter pasture are required to pay a grazing fee of approximately 13,000 INR, thus limiting the already scarce resource and, furthermore, challenging the livelihood of the households who are still practising.

Consequently, few of the respondents have also noticed an increase in plant height of species *trama* (*Caragana versicolor*) and *tsepad* (*Ephedra* sp.) in the absence of sheep and goats; similar observations have been reported in Nepal (Sharma et al. 2014) and in Sikkim, India (Singh et al. 2021). Besides the know-how on pastoral practices, herders also have ethnobotanical expertise on pasturage species and often collect medicinal herbs for local healers, *amchi*, to be used in the traditional healthcare system. They also possess an understanding of the physical, climatic and phenological attributes of the pastureland as well as of key indicator species and, therefore, may contribute to climate change adaptation strategies (Ingty 2017). The agropastoral practices are also facing challenges due to the declining effectiveness of local governance in resource management. The institution of *Goba* and *lorapa* (and *dewa* in Shang), responsible for making decisions at the village level, has experienced changes in its structure and functions, leading to difficulties in effectively managing the resources in the study area as well as the region in general (Bajpai et al. 2022).

Although a decline in traditional pastoral practices is evident, it is also realised that knowledge and the resources managed are still intact. The grazing pattern in the studied villages has remained unaltered. There have been no modifications such as the hiring of non-local herders or changes in grazing routes. The provision of consolidation of livestock (under *Choldak* system in case of Gya), lack of local knowledge on the socio-ecological system and economic infeasibility have led to the absence of hiring of non-locals in the study area. As such, the pastoral knowledge retains the ability to continue the practice with the presence of key knowledge holders to share and conserve this knowledge. As a result, the status of the grazing pattern is characterised by either being intact or completely abandoned. In case of Shang village, a notable illustration emerges wherein a herder who had previously pursued an alternative livelihood has redirected his activities towards sheep and goat rearing for an 8-year duration. This transition was made feasible through the implementation of a programme initiated by the Sheep Husbandry Department, Leh. This resurgence underscores the resilience of traditional livelihood practices, affirming the retention of local knowledge regarding pastoral activities. Incorporating input from various stakeholders like Ladakh Pashmina (Anonymous 2019), integrating technological advancements and garnering government support could significantly enhance the resilience and sustainability of traditional pastoral practices.

For centuries, pastoralism has functioned in tandem with subsistence agriculture, addressing the survival needs of local populations (Goldstein and Messerschmidt 1980; Nüsser and Clemens 1996; Aryal et al. 2018; Singh et al. 2021; Luxom et al. 2022). The utilisation of HAPs reflects the intricate variations in pastoral practices based on socio-economic and environmental contexts within mountain communities (Aryal et al. 2018). The process of globalisation, marked by economic expansion and enhanced connectivity, has reached even remote Himalayan regions, precipitating shifts in pastoral and lifestyle practices. This shift has disrupted the delicate socio-ecological equilibrium between agropastoralism and the environment (Aryal et al. 2018). This transformation endangers the resilience of this intricate system. The evolution of traditional knowledge systems is linked to the changing ambitions of the younger generation, the emergence of alternative livelihoods and the gradual decline of traditional pastoralism (Wu et al. 2014; Singh et al. 2015; Luxom et al. 2022). The shift from local subsistence-based food production to reliance on external markets and mechanised agriculture has contributed to a decline in traditional livelihood practices. Therefore, ensuring financial stability for herders, leveraging scientific advancements in pashmina production and implementing strategies to mitigate predation risks and address adverse climatic conditions are crucial for reinforcing the practice and effective resource management. Vital to this approach is fostering a sense of pride and security in pursuing traditional livelihoods, thereby promoting herding and traditional agropastoralism as viable options. Recognition of local institutions by the formal system in the management of community resources may also contribute to the conservation and continuity of this traditional practice in a sustainable manner. This comprehensive strategy not only safeguards traditional knowledge but also bolsters the adaptability of these practices in the face of evolving circumstances, ensuring their continued vitality.

Conclusion

Pastoralism in Leh, Ladakh's, agropastoral communities complements subsistence agriculture through the strategic utilisation of HAPs. However, socio-economic and geopolitical shifts, including urbanisation, and changing livelihood opportunities, challenge traditional pastoral practices HAPs play a pivotal role in adapting to the region's cold and arid conditions. Yet, globalisation's impact and changing aspirations of the younger generation contribute to the decline of traditional practices. The erosion of traditional pastoralism affects not only livelihoods but also cultural and environmental aspects. The study underscores the need for a holistic approach that merges traditional knowledge with scientific intervention to enhance the sustainability of traditional livelihoods and address emerging challenges. Environmental pressures such as extreme

weather events also pose threats. In conclusion, the intricate interplay between agropastoralism and the environment is at risk due to changing socio-economic dynamics. Safeguarding traditional knowledge, supporting herders and integrating scientific insights are crucial to ensure the continuity of these unique livelihoods in the face of evolving circumstances.

Supplementary Information

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Additional file 1. Semi-structured household questionnaire.

Additional file 2. Sheep Husbandry Census Record Data (Centre: Meeru and Sakti) 2020-21. Livestock population as per 20th Livestock Census 2019 (Kharu Block).

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Authors' contributions
PL and SCG conceptualised the study and analyses required and led the preparation of the manuscript. PL followed up on the field data capture and contributed to the data analyses. MN provided critical input in the analyses of data and contributed to the study design and revision and editing of the manuscript. PL reviewed the analysis and revised and edited the manuscript. The authors read and approved the final manuscript.

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Availability of data and materials
The Census 2011 dataset used and/or analysed during the current study is available in the [Census Leh District 2011] repository [https://censusindia.gov.in/nada/index.php/catalog/499]. The dataset generated during the field study is available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Prior informed consent in the local language was approved by all the participants for the survey as well as for the sharing of the information.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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