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Authors: Pandit, Arif, Mir, Masood, Mir, Mohsin, Wani, Yaqoob, Bisati, Irfan, et al.

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Pastoralism in Changthang, Ladakh: Adaptations, Challenges, and Pathways for Sustainability

Arif Pandit^{1*}, Masood Mir², Mohsin Mir³, Yaqoob Wani⁴, Irfan Bisati⁴, Saif Un Nisa⁵, Hilal M. Khan³, and Riaz A. Shah¹

* Corresponding author: arif.pandit@skuastkashmir.ac.in

¹ Mountain Livestock Research Institute, Sher E Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

² Directorate of Research, Sher E Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

³ Faculty of Veterinary Sciences and Animal Husbandry, Sher E Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

⁴ Directorate of Extension, Sher E Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, Jammu and Kashmir, India

⁵ Government Degree College Baramulla (Boys), Jammu and Kashmir, India

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In the Changthang region of Ladakh, India, pastoralism serves as the cornerstone of both the local economy and the local way of life. However, recent socioeconomic shifts and environmental constraints put this economic structure, which has been expertly adapted to the difficult trans-Himalayan geography, in danger of becoming unsustainable. To explore methods for balancing development, ecology, and Indigenous culture, this review analyzes pastoralism in Changthang. The sole dependable method of food production for generations has been mobile pastoralism, supported by high-elevation rangelands. Breeds of native livestock adapted to scant vegetation and seasonal variation have been selectively bred by generations of pastoralists. Sale of wool and cashmere provides financial stability for pastoralist families, mitigating income vulnerability to climate shocks and market fluctuations that would otherwise disrupt predominantly livestock-rearing livelihoods. However, traditional transhumance cycles and collective resource

management have been hampered by sedentarization, population growth, conservation constraints, and market integration. Climate change and unrestricted grazing contribute to grassland degradation. Promising programs combine conventional methods with innovations like mobile veterinary services and satellite forecasting to preserve breeds and grazing resources while increasing productivity and climate resilience. These initiatives seek to support regulated grazing practices. Comanagement practices that involve communities in conservation planning are essential. This production system and culture can be maintained through integrated strategies respecting pastoralists' stewardship.

Keywords: pastoralism; transhumance; livestock; Changthang; Ladakh.

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Introduction

The Changthang region of Ladakh (~33°N; 77°E) features high-elevation plateaus and valleys at 3950–5800 masl. The extremely harsh and arid conditions—with sparse vegetation, low precipitation, temperature extremes from –40 to 25°C, and a short growing season—make agriculture highly challenging (Tiwari et al 2016). Yet traditionally, animal husbandry has supported the livelihoods of the population. Fewer than 5 people per square kilometer inhabit this remote trans-Himalayan cold desert (Dame and Nüsser 2011).

Similar mountain pastoralist communities, such as Tibetan nomads inhabiting the Tibetan Plateau, Basque shepherds residing in the Pyrenees of Europe, and Quechua llama herders of the Andes of South America (Dong et al 2011; Fernández-Giménez and Fillat Estaque 2012), have faced pressures from climate change, land policies, socioeconomic shifts, and market integration. This has increased settlement and altered seasonal mobility patterns, significantly affecting traditional practices (Foggin 2018). However, some communities are adapting

through cooperative resource management, through ecotourism, and by adding value to wool products (Yeh et al 2014). Similar challenges of balancing traditional practices, conservation, and development are seen in other highland regions, necessitating inclusive governance regimes and innovations tailored to local contexts.

This review examines the ecological setting, evolution of pastoralism, native livestock breeds, recent changes, and sustainability issues for the Changpa nomads of Changthang. It integrates findings across sources to identify resilience tactics and suggests balancing pathways among pastoral livelihoods, conservation aims, and development needs. Safeguarding livestock production is essential for Ladakh's economy, food security, and cultural heritage. Appropriate policies, programs, and technologies tailored to the geoclimatic context are vital.

Theoretical framing

Examining the interconnections across ecological factors, agricultural practices, and sociocultural dynamics helps to provide a biocultural landscape conceptualization

(Smith-Hall et al 2012). This framework seeks balance across environmental integrity, production vitality, and resilience of cultural dimensions. In addition, sustainability encompasses more than solely economic or ecological aspects, including facets such as social cohesion and Indigenous knowledge transmission the underpin adaptation capacity (Alessa et al 2016). Together, these multidimensional lenses facilitate the assessment of risks, responses, and pathways forward, considering ecosystem health alongside the retention of communal governance, linguistic traditions, spiritual practices, and other cultural community strengths through change processes.

Methodology

The literature review and analysis were based on this integrated biocultural landscape framework, examining interlinkages across ecological, agricultural, and sociocultural dynamics that shape pastoral sustainability in Changthang. Systematic literature searches were conducted in Web of Science, Scopus, and Google Scholar for publications over the period 2000–2020 using the following search string: (“Changthang” OR Changtang OR “Chang Tang”) AND (pastoral* OR transhum* OR livestock OR sustainability) AND (Ladakh)). Results from this 20-year period were screened; selection criteria favored documents published within the last decade, where possible, especially peer-reviewed academic literature (Pickering and Byrne 2014). Data on practices, changes, issues, and solutions were synthesized within our conceptual framework to assess environmental sustainability alongside livelihood and cultural viability outcomes. Two authors conducted thematic coding independently to identify key themes, with more than 80% interrater agreement initially refined through discussion (Leach et al 2010). The analysis examined interlinkages across ecological, agricultural, and sociocultural dimensions, embracing an expanded notion of sustainability encompassing ecosystem health, production vitality, and cultural heritage viability (Thomas et al 2020). Findings were integrated to assess pressures, responses, knowledge gaps, and potential integrated pathways forward across research, policy, and development spheres (Curty 2016).

The cold desert ecology of Changthang

Spread across Ladakh, Himachal Pradesh, and Tibet, the Changthang plateau occupies an area of more than 35,000 km² at elevations above 3950 mm (Rawat and Adhikari 2005). The mean annual precipitation is 100–300 mm, mainly in winter snowfall. Summers are short and cool, whereas winters are severely cold, with temperatures dropping below –40°C (Dame and Nüsser 2011). The low oxygen levels, high solar radiation, and frequent intense winds create an extremely harsh climate (Namgail et al 2004).

Sparse vegetation, including alpine grasses, sedges, and shrubs, grows in the short summer, lacking year-round grazing capacity. Although desert conditions occur westward, the east and south have subalpine characteristics (Chundawat and Qureshi 1999). Rivers like the Indus, Shyok, and Changchenmo provide water resources, but water is scarce. Flora that exhibits adaptations to cold, arid

conditions includes *Acantholimon*, *Krascheninnikovia*, and *Artemisia* (Mishra et al 2004). Fauna includes wild herbivores such as Tibetan gazelle, argali, and kiangs; predators such as snow leopards and Tibetan wolves (Bhatnagar et al 2006); and endangered black-necked cranes (Namgail, Van Wieren, Mishra, et al 2010). Despite the extreme climate, unique native species thrive in this high-elevation ecosystem.

Evolution of pastoralism in Changthang

Livestock farming provides the primary means of subsistence in this ecologically fragile cold desert because of the lack of an arable agricultural base. Archaeological evidence indicates pastoral activity in Ladakh as early as 4000 years ago (Aldenderfer 2011). Ethnographic records suggest nomadic yak herding practices were present by AD 1200, as Tibetan tribes migrated into northern India (Rao et al 2003). Pastoralism has evolved as the most rational production system for using the vast rangelands while coping with low and variable biomass production (Goldstein 1981).

Keeping mobile herds of sheep, goats, yak, horses, and crossbred varieties allows the optimal use of scattered pastures across the terrain and through seasonal cycles.

Transhumance practices involve moving livestock between fixed winter and summer habitats. Winter pastures are in low-elevation valleys and areas near villages. In summer, herds are moved to highland pastures or alpine meadows where nutritious cool-season grasses sprout (Chundawat and Qureshi 1999).

Pastoralist Changpa tribes and communities have intimate ethnobotanical knowledge of the landscape’s biodiversity and ecology. Their production practices and migration patterns have developed in synchrony with seasonal variability and the spatial heterogeneity of resources (Tiwari et al 2016). Kinship ties between tribes enable regulated access and collective management of the sparse grazing and water resources (Bhasin 2011). However, in recent decades, the transition toward intensified livestock production has led to year-round grazing pressure (Bhatnagar et al 2006). This has degraded the fragile high-elevation grasslands, scrublands, and wetlands that demand more sustainable pastoral practices, and rangeland management policies are now needed (Bhasin 2012).

Importance of livestock in local livelihoods

Livestock production is central to the economy and livelihoods in Changthang, providing the main income source for 90–95% of households (Chundawat and Qureshi 1999; Dame and Nüsser 2011; Akand et al 2019). With 7–15 animals, on average, including goats, sheep, yaks, horses, donkeys, and dzomos (crossbreeds), households depend significantly on pastoralism compared with national figures (2–3 animals per household), reflecting the remote geography where animal husbandry focused on vast rangelands is the sole reliable production system (Ahmad et al 2016).

Livestock constitutes a resilient buffer asset against agriculture risks and climate shocks. The region only allows marginal crop cultivation of barley and pulses, so pastoralism is the production foundation. Families

TABLE 1 Livestock population figures for Ladakh from 1997–2019.

Livestock	1997	2012	2019	% of change (1997–2019)
Cattle	0.21	0.18	0.17	–19.05
Buffalo	0.01	0.01	0.01	0.00
Sheep	1.67	1.36	1.23	–26.35
Goat	0.88	1.06	1.28	45.45
Yak	0.03	0.02	0.02	–33.33

Sources: Directorate of Economics and Statistics 2009; Ministry of Fisheries, Animal Husbandry and Dairying 2003, 2014, 2019.

accumulate livestock holdings to sustain themselves through harsh winters and droughts when crops fail (Bhasin 2011).

The total livestock population is more than 2.6 million, outnumbering the human population per the 2011 census of India (Hamadani et al 2022). Recent census data show a decreasing trend of 8.9% in the share of pastoralist communities (Directorate of Census Operations in Jammu and Kashmir n.d.), which can be attributed to urban migration influenced by factors like loss of grazing lands, market integration, and livelihood transitions. However, in recent decades, the transition toward sedentary livestock production concentrated within Changthang districts has led to year-round grazing pressure on the limited rangelands of Korzok, Nyoma, and Durbuk areas. Satellite analyses indicate clustered patterns of concentrated and likely excessive energy extraction (Namgail et al 2012). Expansion of sedentary villages and goat herds owned in Changthang has contributed to year-round grazing that is no longer aligned with historic transhumant cycles. In particular, the *20th Livestock Census 2019: All India Report* (Ministry of Fisheries, Animal Husbandry and Dairying 2019) indicates an increase in goat and a decline in sheep populations (Table 1). Dolker (2022) highlights the implications of these changing livestock compositions for environmental pressures.

The sale of wool products, such as pashmina, accounts for most household income in Changthang tehsil in the district of Leh, Ladakh (Bhattacharya et al 2004). According to a study by (Bahuguna and Ramaswamy 2022), the household income composition of Changthang pastoralists has changed significantly over the last 2 decades, reflecting reduced dependence on livestock and increased reliance on off-farm sources. A recent study (Dolker 2022) found pastoral families derive 30–40% of income from nonlivestock activities, up from 10–15% historically, indicating increasing livelihood diversity. Major government welfare programs, including the Mahatma Gandhi National Rural Employment Guarantee Act and Pashmina Development Scheme account, for more than half of these supplemental earnings. Additional off-farm sources comprise tourism receipts, remittances, pensions, trade activities, and local handicrafts.

On average, livestock rearing generates 300–550 days of employment per household annually across Changthang (Akand et al 2017, 2019). The semiarid and cold climate only allows animal husbandry as the main food production system with livestock; its dairy output also supplies one third of nutritional fat and 22–25% of protein intake for families. Cultivation of barely and pulses is limited and only

for subsistence (Akand et al 2017). Moreover, livestock produces manure, wool, transportation, and draft power. Ladakh exports fine pashmina and cashmere wool, with earnings exceeding US\$0.5 million to US\$1.0 million annually (Bhasin 2011).

Indigenous livestock breeds of Changthang

The rangeland-based pastoral economy of Changthang relies on native livestock breeds that are uniquely adapted to survive and thrive in the high-elevation trans-Himalayan ecosystem. Generations of selective breeding have resulted in traits tailored to local conditions.

The Changthangi goat breed, also known as Changra, is globally renowned for producing pashmina fiber and is considered a Changthang specialty (Misra et al 1998; Ganai et al 2011). It is a medium-sized breed with a white coat and an average weight of 30 kg (males) and 29 kg (females). The fine undercoat has a fiber diameter of 12–16 microns, yielding up to 227 g of the finest pashmina wool. The Changthangi sheep, also known as Changluk, is another native breed valued for meat and wool (Ganai et al 2011). These seasonal breeders have adapted to the extremes of the Ladakhi winters and sparse vegetation. The coat is predominantly white, with some black or brown. Males are larger than females, with an average annual wool yield of 1.42 kg.

Yaks, dzomos, and dzos are essential to the Changpa pastoral economy as sources of milk, meat, and transportation (Namgail et al 2007). The sure-footed yak provides essential transport along treacherous mountain routes. Wealthier herders also keep the double-humped Bactrian camel. Horses and donkeys are used for riding and as pack animals, which are crucial for the nomadic lifestyle. Crossbreeds, such as dzomo (yak and cow), combine the hardy traits of yaks with greater milk production.

These Indigenous breeds have adapted through natural and artificial selection to thrive on sparse vegetation dominated by sedges, forbs, and scrub (Mukesh et al 2022). They exhibit unique physiological adaptations, such as high hemoglobin to use oxygen efficiently in hypoxic conditions. The body structure, feeding behavior, reproduction, and migratory capabilities are finely tuned to the ecology. Hence, the native livestock biodiversity underpins sustainability in a challenging environment. Their conservation must be a priority alongside breed improvement programs.

In summary, Changthang's Indigenous livestock assets provide the basis for pastoral sustenance and must be valued alongside modernization efforts. Protecting these animals' genetic diversity will be key to building resilience against environmental and economic disturbances.

Adaptations to socioeconomic and environmental changes

The nomadic Changpa tribes of the Changthang plateau have endured for centuries by pastoralism, moving livestock between seasonal grazing lands. However, recent decades have brought immense socioeconomic changes, disrupting their traditional transhumance practices. Changthang's integration with the cash economy and geopolitical factors

have affected Changpa (Bhasin 2011). Many now earn income from trade in pashmina wool, tourism, and government subsidies (Bhasin 2012). Pashmina production provides new economic opportunities, but increasing goat herds have deleterious environmental impacts (Namgail, Van Wieren, and Prins 2010). Increasing goat populations degrade fragile arid rangelands through overgrazing, trampling, and soil erosion. This leads to the loss of native vegetation cover and affects wild herbivores. For instance, the habitat of the endangered Tibetan gazelle has deteriorated in parts of Ladakh because of such pressures (Mishra et al 2002). Growth in goat herds also raises demand for camping sites, leading to land use and resource conflicts with other groups.

The spread of veterinary medicine and transportation has reduced seasonal mobility. Government development programs, such as health clinics, schools, and subsidized food, have brought amenities but weakened traditional social systems and practices (Bhasin 2012). Settlement in permanent villages has reduced pastoral mobility. With these changes, fewer Changpa youths carry forward pastoralism, migrating for urban jobs instead (Dame and Nüsser 2011).

Climate change poses another threat as pastureland degrades and weather patterns shift with rising temperatures, changes in precipitation patterns, and more intense storms, thereby disrupting transhumance cycles tuned to seasonal variability (Bhattacharya et al 2004; Herrero et al 2016; Dimri et al 2021). Limited pasture access because of geopolitical disputes also threatens their production system. However, cross-border kinship ties maintain regulated resource access between communities (Ahmad et al 2016).

The Changpa have developed diverse strategies to adapt their production systems, mobility patterns, and herd composition in response to climatic, socioeconomic, and policy shocks and changes (Bhasin 2012). These include the following:

- Adjusting herd structure by reducing more drought- and temperature-sensitive sheep numbers while increasing proportions of the heartier native Changthangi goat breed (Changra), which provides valuable pashmina down wool, during periods of high rainfall variability. This buffers economic and nutritional vulnerability from anticipated climate shifts.
- Splitting herds by subdividing valuable livestock assets across family members heading separate grazing groups bound for different summer mountain pastures. This distribution minimizes concentrated foraging pressures across any grassland area during higher climatic stress seasons.
- Sharing information on localized knowledge regarding precipitation patterns, snowfall, glacial melt, and associated pastureland conditions. Such collaborative tracking and communication allow more predictive and adaptive scheduling of seasonal herd movements to optimal grassland areas (Bhasin 2012).

However, top-down policies and forced settlement reduce the Changpa's resilience, flexibility, and self-sufficiency (Kassam et al 2016). More participatory programs could support them in sustaining their culture

and livelihoods amid modernization. Although the Changpa have diverse strategies to adapt to their harsh, unpredictable environment, pasture degradation now threatens their livelihoods. The Changpa pastoral system is tailored to the local ecology, so one-size-fits-all government policies are poorly suited to it. Top-down governance and forced settlement have reduced the Changpa's adaptability and self-sufficiency (Kassam et al 2016; Yu and Farrell 2016).

The integration with mainstream society and the cash economy has profoundly affected the nomadic pastoralist communities of Changthang. It has brought opportunities but also rendered their specialized production system more vulnerable. Policies and interventions must balance development with protecting Changpa's locally adapted pastoral knowledge and resource stewardship practices.

Threats and challenges to pastoralism

Major threats stem from recent wildlife conservation initiatives that restrict grazing and access to rangelands, as well as shifts in pashmina production that have increased goat herding unsustainably. In addition, climate change impacts on grasslands have disrupted traditional transhumance cycles, whereas geopolitics limit access to certain pastures (Bagchi et al 2004). Sabharwal (2016) argues that conservationists wrongly blame the Changpa's pashmina goat herding for environmental degradation and wildlife loss in Changthang. However, establishing protected areas has restricted the Changpa's access to grazing lands and limited their traditional subsistence hunting. Fox et al (2004) note that conserving species such as the chiru antelope and wild yak led China to establish the Chang Tang Nature Preserve, restricting the Changpa's grazing. Though nomads have hunted for subsistence, conservation now limits this.

Changes in the pashmina industry also threaten the Changpa. Namgail, Van Wieren, and Prins (2010) explain that pashmina production is crucial to the Changpa economy, but increasing goat populations to boost pashmina output has resulted in rangeland degradation and negative impacts on wildlife habitats and populations. However, Wani et al (2008) argue that the Changpa follow traditional migratory routes to prevent overgrazing and that identifying and protecting key pastures could support sustainability.

Studies show that Changthang pastoralism faces interlinked political, economic, and environmental threats. Conservation limits grazing and hunting, whereas socioeconomic changes disrupt nomadic life. However, valuing traditional knowledge and cooperating with nomads on sustainable resource management may help to support this ancient way of life in the modern world.

Government schemes to provide veterinary services and settle nomadic herders have had limited success in effectively serving pastoral communities across the vast rugged rangelands of Ladakh (Bhasin 2011; Table 2).

These multiple pressures necessitate integrated policies and programs to address issues of resource access, grazing rights, livestock healthcare, breed conservation, and valorization of pastoral products. Bottom-up participatory approaches involving pastoralist communities and civil society groups are vital for devising solutions attuned to

TABLE 2 Summary of major government policies affecting pastoralism in Ladakh's Changthang region.

Policy	Year	Key objectives	Outcomes	Reference
National Rangeland Policy	2010	Improve rangeland quality through grazing controls and scientific management. Promote community institutions for rangeland stewardship.	Unclear community rights over resources. Top-down approaches to rangeland conservation.	Singh et al (2022)
National Livestock Policy	2013	Enhance livestock productivity and commercialization. Promote breed improvement and fodder development.	Inadequate focus on Indigenous breeds' conservation.	Gowane et al (2019)
Wildlife Protection Act	1972, amended 2002	Conserve threatened species, such as snow leopard, through protected areas. Limit livestock grazing and human access in reserves.	Restricted mobility and grazing access for pastoralists. Human-wildlife conflicts.	Mishra et al (2017)
Integrated Watershed Development Program	2009	Manage natural resources and promote sustainable livelihoods through watershed conservation.	Variable project performance. Need for better inclusion of mobile pastoralists.	Rasul (2016)
Payment for Ecosystem Services	2011	Provide incentives for communities to maintain ecosystem services like carbon sequestration.	Limited adoption for pastoral systems. Need for local institutional frameworks.	Badola et al (2013)

local ecological and geographical realities. Multilevel collaborations of communities, government agencies, and researchers can help gather data for informed decision-making.

Recent initiatives and sustainability practices

Several promising initiatives have emerged in recent years to promote sustainable pastoralism in Changthang, including interventions through innovative technologies and inclusive policies. However, interventions must balance productivity goals with risks to the surrounding social-ecological system. For instance, the Changthang Pashmina Improvement Project (Misra 2019) increased cashmere output through imported Changra bucks. But biodiversity conservation aims warrant caution about potential dilution of native genetic diversity critical for environmental resilience. Telemedicine centers and mobile animal clinics are expanding access to livestock healthcare in distant areas (Ahmad et al 2016). Early warning systems using satellite data help pastoralists adapt to climate risks by planning mobility schedules (Sabu and Kumar 2019). Co-management policies facilitate participatory pasture and wildlife conservation decision-making by empowering pastoralist groups (Bhatnagar et al 2006). The application of geographic information system tools and Indigenous knowledge helps map key pastures and resources for protection (Wani et al 2008). Payment for ecosystem service programs and biocultural protocols valorize pastoralists' stewardship roles (Misra 2019). Overall, although appropriate technologies can enhance production, accompanying policies and participatory monitoring

mechanisms must be strengthened to safeguard Indigenous stocks and knowledge forms tied to this landscape. The introduction of practices or external inputs should be gradual and contained, based on evidence from impact analyses, and should balance all outcome dimensions.

Conclusion

Although pressures threaten the sustainability of Changthang's pastoral system, integrated strategies embracing participation, innovation, and incentives, alongside impact monitoring, can sustain sensitive livelihood landscapes. Suggested priorities include the following:

- Development programs: Invest in breeding initiatives jointly elevating yield potential and retaining adaptation to avoid risks of exotic introductions undermining Indigenous integrity. Support added-value enterprises incentivizing sustainability only along dimensions of productivity, ecology, community, and culture.
- Research agendas: Quantify intervention outcomes across environmental stability, production gains, and cultural knowledge conservation factors. Monitor programs with indicators tied to comprehensive sustainability metrics encompassing broader vitality notions.
- Policy and governance agendas: Secure formal communal grazing rights through tenure policies and negotiated agreements balancing uses. Incorporate traditional institutions into collaborative stewardship models, empowering community regulations and duties over resources.

With proactive steps respecting pastoral stewards' intergenerational insights on nourishing productivity within ecological limits and cultural traditions, this ancient way of life and the biodiverse rangelands interwoven together can persist sustainably despite the forces of modernizing change.

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