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PERCEPTION ON LIVESTOCK CHANGES AND ITS SOCIO-ECONOMIC IMPLICATIONS AMONG AGRO-PASTORALISTS: A CASE STUDY OF JOSHIMATH BLOCK IN CHAMOLI DISTRICT, UTTARAKHAND, INDIA

PERCEPCIÓN SOBRE LOS CAMBIOS EN LA GANADERÍA Y SUS IMPLICACIONES SOCIOECONÓMICAS ENTRE LOS AGROPASTORILES: UN ESTUDIO DE CASO DEL BLOQUE DE JOSHIMATH EN EL DISTRITO DE CHAMOLI, UTTARAKHAND, INDIA

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ABSTRACT

This study examines evolving livestock ownership and management patterns among agro-pastoralist communities in Joshimath block of Chamoli district, Uttarakhand (India), from 1990 to 2024 and analyses their socio-economic implications. Using stratified random sampling, primary data were collected from 50 households across three elevation zones through structured questionnaires, in-depth interviews with key informants, and focus group discussions. The research reveals significant transformations over three decades (1990-2024), with a 32.5% decline in overall livestock numbers. Sheep numbers dropped by 48.6% and goats by 27.9%, while cattle ownership increased by 22.6%, buffalo ownership by 75%, and pack animals by 88.9%. Management practices shifted from long-distance transhumance (declining from 68% to 36% of households) toward settled livestock keeping and stall feeding systems. Key drivers include climate change impacts on highland pastures, labour constraints due to outmigration, emerging tourism opportunities, and land use restrictions. Livestock's contribution to household income declined, while tourism income increased. Gender roles transformed as well, with women now performing more hours of daily livestock management tasks compared to the past. Cultural implications include erosion of traditional ecological knowledge. The agro-pastoralist communities are blending traditional elements with new opportunities. Policy interventions should support sustainable adaptations while preserving traditional knowledge through integrated approaches.

Keywords: Agriculture, Fodder, Livestock, Socio-Economic, Himalayas, Pastoralis

RESUMEN

Este estudio examina la evolución en la tenencia y manejo del ganado entre las comunidades agro-pastoriles del bloque de Joshimath, en el distrito de Chamoli, Uttarakhand (India), desde 1990 hasta 2024, y analiza sus implicancias socioeconómicas. A través de un muestreo aleatorio estratificado, se recolectaron datos primarios de 50 hogares distribuidos en tres zonas altitudinales mediante cuestionarios estructurados, entrevistas en profundidad a informantes clave y discusiones en grupos focales. Los resultados revelan transformaciones significativas en tres décadas, con una disminución del 32.5 % en el número total de animales. Las ovejas disminuyeron en un 48.6 % y las cabras en un 27.9 %, mientras que la tenencia de ganado vacuno aumentó un 22.6 %, los búfalos un 75 % y los animales de carga un 88.9 %. Las prácticas de manejo cambiaron de la trashumancia de larga distancia (del 68 % al 36 % de los hogares) hacia un sistema más estable y con alimentación en establos. Los principales factores incluyen el cambio climático en los pastizales, la migración laboral, el auge del turismo y las restricciones de uso del suelo. Disminuyó el ingreso por ganado y aumentó el proveniente del turismo. Las mujeres asumen más tareas diarias. Se pierde conocimiento ecológico tradicional. Las comunidades muestran una fuerte capacidad de adaptación.

Palabras clave: Agricultura, Forraje, Ganado, Socio-económico, Himalayas, Pastoralismo

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1. INTRODUCTION

Pastoral communities of the Himalaya have sustained a very unique socio-ecological system for centuries. Their seasonal migratory encampments on a rugged, marginal mountain environment and consultation of religious specialists indicate how they have adjusted to the difficulties of the mountain environment but yet maintain a special, distinct form of livestock management. Of these, agro-pastoralists of Chamoli district of Uttarakhand are one of the most widespread single communities, whose livelihood practices have evolved around agriculture, livestock rearing, seasonal migration, and the like economic activities (Negi 2007; Rawat, 2017). But these old age pastoral systems have undergone substantial changes.

This has resulted in significant changes in livestock composition, herd size, and management practices (Nautiyal et al., 2003; Maikhuri et al., 2020). The Bhotia community residing in the high-altitude valleys of Chamoli district has historically practised transhumance. They move between winter settlements in lower valleys and summer settlements in higher alpine pastures (Hoon, 1996). This mobility pattern has allowed them to optimise resource utilisation across diverse ecological zones while maintaining substantial herds of sheep, goats, yaks, and cattle that formed the cornerstone of their economic and cultural identity (Bhasin, 2011). Traditional Bhotia livelihoods were characterised by a complementary balance between agriculture, animal husbandry, and trade activities. The livestock served multiple functions, including transportation, wool production, dairy products, meat, and manure (Farooquee and Rao, 1999).

The Indo-Tibetan border trade, which was officially closed following the India-China war in 1962, historically represented a critical economic activity for the Bhotias. The livestock played a key role in transportation and as tradable commodities (Bergmann et al., 2008). This closure of the traditional trade route precipitated the first major wave of adjustments in their livelihood strategies and animal husbandry practices (Bhasin, 2011). Subsequent decades witnessed further transformations driven by multiple factors. Key factors include market integration, changing policy landscapes, development interventions, climate change, and shifting socio-cultural aspirations (Negi, 2007; Farooquee, 1998; Bhatt, 2012; Rawat and Sharma, 2019). Many research have documented significant changes in the livestock compositions among Himalayan pastoralist communities. A general trend have been observed, showing a reduction in sheep and goat populations and increased emphasis on cattle and pack animals (Mishra et al., 2003; Sharma et al., 2016). However, the specific nature, extent, and driving forces of these changes remain inadequately understood. An important aspect arises in terms of how these transformations intersect with broader socio-economic changes and what implications they hold for sustainable mountain development (Nautiyal et al., 2019). The dynamics of change in pastoral systems worldwide have attracted considerable scholarly attention. The researchers have highlighted both the resilience and vulnerability of these systems in the face of modernisation pressures (Dong et al., 2011). Within the Indian Himalayan context, studies have examined the complex interplay between environmental policies, market forces, and changing pastoral practices (Saberwal, 1999; Agrawal and Saberwal, 2004; Singh et al., 2015; Sharma et al., 2020). These studies emphasise that transformations in agro-pastoral systems must be viewed and understood within the broader political economy of development and environmental governance. Climate change represents another critical dimension affecting the Himalayan traditional systems. Many research highlights how changing precipitation patterns, rising temperatures, and increased frequency of extreme weather events affect pasture productivity, water availability, and livestock health (Aryal et al., 2017; Pandey et al., 2021; Kumar et. al., 2024; Kumar et. al., 2025). Therefore, these influence agro-pastoral decision-making and adaptive strategies. The Chamoli region, located in the sensitive upper Himalayan zone, is particularly vulnerable to these climatic variations (Singh and Thadani, 2015).

Institutional transformations further complicate the landscape within which agro-pastoral changes unfold. The modification of traditional common property regimes, implementation of conservation policies, and changing governance structures have significantly altered the resource access patterns for pastoral communities (Agrawal, 2014; Shrestha et al., 2019). The creation of protected areas, forest conservation policies, and changing administrative jurisdictions have reconfigured the spatial and temporal dimensions of pastoral mobility (Rautela and Karki, 2015). Demographic and socio-cultural changes constitute another important domain influencing livestock management decisions. Educational expansion, outmigration, changing

cultural values, and aspirations have contributed to labour shortages and shifting preferences regarding livelihood strategies (Chakravarty-Kaul, 1998; Barua et al., 2013). The younger generation's increasing orientation toward non-agro-pastoral livelihoods has implications for the intergenerational transmission of ecological knowledge and pastoral skills (Kreutzmann, 2012; Suryawanshi et al., 2019). Therefore, understanding the specific trajectories of livestock change among the agro-pastoralists of Chamoli assumes critical importance as a prerequisite for informed policy interventions. The changes in livestock compositions and management practices have far-reaching implications for household economies, social organisation, cultural continuity, ecological sustainability, and regional development (Nüsser et al., 2012; Joshi et al., 2020; Maikhuri et al., 2020; Nautiyal et al., 2019). Previous research has documented aspects of agro-pastoral practices. However, a comprehensive analysis of contemporary livestock changes and their multidimensional implications remains limited. More recent studies have highlighted emerging challenges, but lack detailed analysis of the adaptive strategies and differences. This research seeks to address these knowledge gaps by examining the nature, extent, and drivers of livestock changes among agro-pastoralists in Chamoli district. It further analyses the socio-economic implications of these transformations at the household level. By integrating economic, ecological, and sociocultural perspectives, this study aims to provide an understanding of how agro-pastoral communities negotiate complex change processes while maintaining or transforming their relationships with livestock and landscapes. The findings from this research can help create development programs that better suit the real needs of pastoral communities living in mountain areas. These programs can take into account the complex and varied ways in which pastoral communities live and work, leading to fairer and more effective support for them.

2. METHODOLOGY

2.1. . Study Area

The study was conducted in the Joshimath block of Chamoli district, located in the state of Uttarakhand in the central Himalayan region of India. Joshimath (30.55°N, 79.56°E) is situated at an elevation of approximately 1,890 meters above sea level and serves as a gateway to several important religious and tourist destinations, including Badrinath, Valley of Flowers, and Hemkund Sahib. The block comprises 36 villages with a total population of approximately 25,000 people. The region is characterised by a temperate climate with cold, snowy winters and mild summers. Annual precipitation averages around 1,200 mm, with the majority occurring during the monsoon season (June to September). The topography is dominated by steep slopes, deep valleys, and high mountain peaks, with vegetation ranging from subtropical forests at lower elevations to alpine meadows above the treeline. Traditionally, the local economy has been based on subsistence agriculture, horticulture, and livestock rearing, with many communities practising seasonal transhumance. However, in recent decades, tourism, hydropower development, and government employment have emerged as important sources of income, leading to significant socio-economic transformations in the region. Figure 1 below shows the study area.

2.2. . Sampling Technique

A stratified random sampling technique was employed to select 50 agro-pastoralist households across the Joshimath block of Chamoli district. The sampling strata were defined based on three key criteria: elevation zones, village-level distribution and identification of agro-pastoralists. The elevation zones (1800-< 2800 m+) were specifically selected because they represent the complete cycle of agro-pastoralists in the region. The 1800-2300m zone covers winter settlements and base villages where livestock are sheltered and crops cultivated. The 2200-2800m zone represents transitional grazing areas used during spring and autumn migrations and minor agriculture. The above 2800m zone encompasses the high-altitude summer nutrient-rich alpine pastures (Bugyals) and other ecosystem-based resources. This altitudinal gradient ensures the study covers the entire vertical spectrum of seasonal livestock movement and resource utilisation patterns essential to transhumant livelihoods in the Himalayas. This approach ensured adequate representation of the spatial, ecological, and socio-economic diversity present in the study area. Within each stratum, households were randomly selected for participation. The stratified design enhanced the representativeness of the sample and allowed for more in-depth analysis of patterns and variations in livestock ownership, management practices, and livelihood strategies across different ecological and social contexts. Additionally, purposive sampling was used to identify 15 key informants for in-depth interviews and five villages

for conducting focus group discussions, ensuring inclusion of individuals and communities with extensive knowledge and experience related to transhumance and livestock rearing.

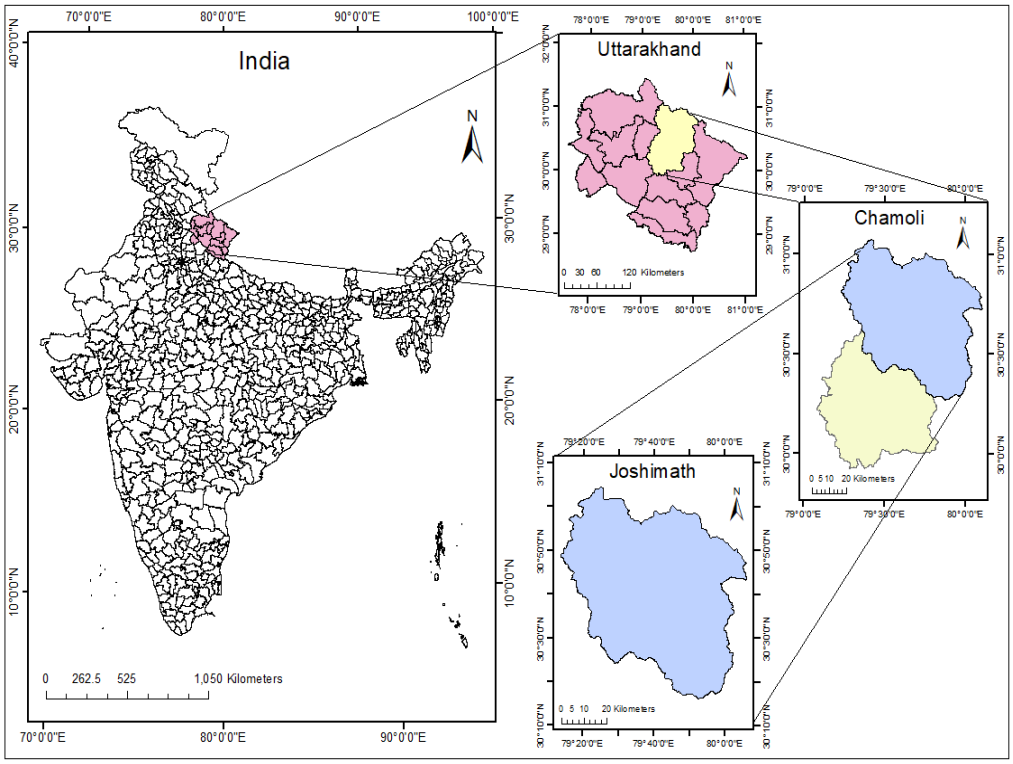

Figure 1: Study area, Joshimath block (Chamoli district).

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Table 1: Sample selection.

Elevation Zone (In meters)	No. of Villages	No. of Households
1800-2300	5	20
2300-2800	5	15
2800 above	5	15
Total		50

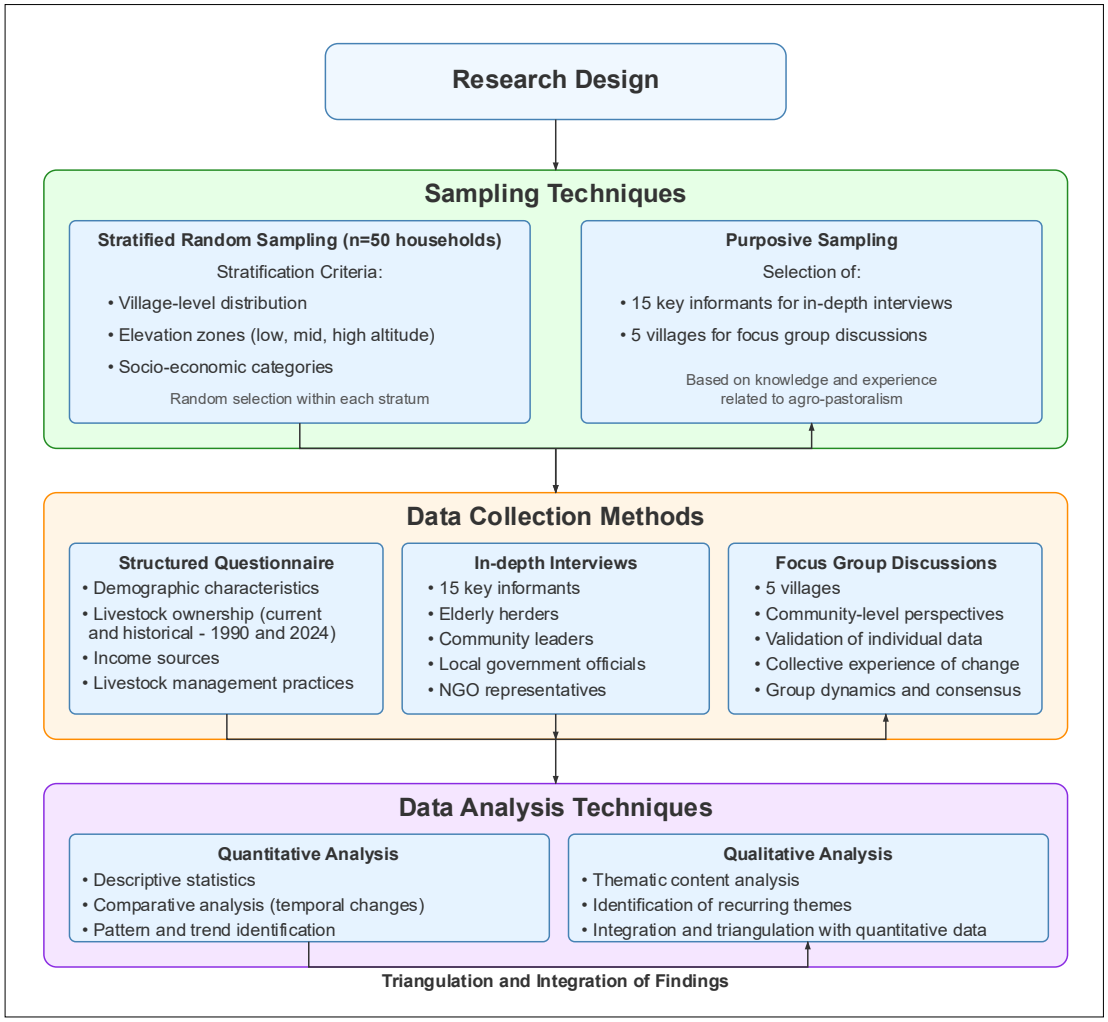

Figure 2: Research design, methodological framework.

2.4. Data Source

Primary data were collected from 50 agro-pastoralist households in the Joshimath block using a mixed-methods approach combining quantitative and qualitative techniques. The sample households were selected using a stratified random sampling method to ensure representation from different villages, elevation zones, and socio-economic categories. A structured questionnaire was administered to gather information on demographic characteristics, livestock ownership (both current and historical), livestock management practices, income sources, livelihood strategies, and perceptions of change. The questionnaire included both closed and open-ended questions to capture quantitative data as well as respondents' perspectives and experiences. In-depth interviews were conducted with 15 key informants, including elderly respondents. These interviews focused on understanding the broader context of change, historical patterns of agro-pastoralism, and institutional factors affecting livestock management. Focus group discussions were organised in five villages to validate and complement the information obtained through individual interviews and to capture community-level perspectives on changes in livestock ownership and management practices.

2.5. Data Analysis

Quantitative data from the household survey were compiled and analysed using descriptive statistics to identify patterns and trends in livestock ownership, herd composition, income sources, and other variables. Comparative analysis was conducted to examine changes over time, with respondents asked to recall livestock ownership and management practices from thirty-five years ago (1990) and compare them with the current

situation (2024). Qualitative data from interviews and focus group discussions were analysed using thematic content analysis to identify recurring themes, explanatory factors, and perceived implications of changes in livestock management systems. The integration of quantitative and qualitative analyses allowed for the triangulation of findings and a more comprehensive understanding of both patterns and processes of change. Figure 2 below shows the methodological framework of the study.

3. RESULTS AND DISCUSSION

3.1. Demographic and Socio-economic Profile of the Household

The demographic and socio-economic characteristics of the sample households provide important context for interpreting patterns of livestock ownership and management. The average household size was 5.3 members, with a range of 2 to 11 members. The majority of households (84%) were headed by males, with an average age of 53.2 years. Educational attainment among household heads was relatively low, with 28% being illiterate and 42% having only primary education. Despite the emergence of alternative livelihood options, agriculture and livestock rearing remained the primary occupation for 64% of households, followed by tourism and hospitality (18%) and government service (12%). Land ownership was generally limited, with an average landholding size of 0.85 hectares, reflecting the constraints imposed by the mountainous terrain. Annual household income varied considerably, ranging from INR 68,000 to INR 420,000, with an average of INR 175,240. More than half (54%) of the households reported having at least one member who had migrated either seasonally or permanently for education or employment. Table 2 presents a summary of key demographic indicators for the surveyed households.

3.2. Changes in Livestock Ownership Patterns

The data indicate a substantial overall decline in livestock numbers, with the average total livestock ownership per household decreasing from 56.3 animals in 1990 to 38.0 animals in 2024, representing a 32.5% reduction. However, this aggregate change masks important variations across different types of livestock. The most pronounced decline occurred in sheep ownership, with a 48.6% reduction in average numbers (from 28.4 to 14.6 per household) and a decrease in the proportion of households owning sheep from 76% to 48%. Similarly, goat ownership declined by 27.9% in terms of average numbers, with the percentage of households keeping goats falling from 84% to 66%. In contrast, there were notable increases in the ownership of cattle, buffaloes, and pack animals (horses and mules).

Table 2: Demographic and socio-economic profile of surveyed households (n=50). Source: Compiled by Authors based on primary survey

Characteristics	Mean	Range	%
Household size	5.3	2-11	
Age of household head	53.2	32-78	
Female-headed households			16
Education of household head - Illiterate			28
Education of household head - Primary education			42
Education of household head - Secondary education			24
Education of household head - Higher education			6
Primary occupation - Agriculture and livestock			64
Primary occupation - Tourism and hospitality			18
Primary occupation - Government service			12
Primary occupation - Other			6
Land ownership (hectares)	0.85	0.2-3.5	
Annual household income (INR)	175,240	68,000-420,000	
Households with migrated members			54

The average number of cattle per household increased by 22.6%, while buffalo ownership rose by 75.0%, albeit from a low base. The most dramatic increase was observed in horses and mules, with a 105% rise in average numbers and an increase in the proportion of households owning these animals from 34% to 56%. These changes indicate a significant shift in livestock composition from small ruminants (sheep and goats) traditionally associated with agro-

pastoralist pastoralism toward cattle, buffaloes, and pack animals that are more compatible with settled or semi-settled lifestyles and emerging economic opportunities in the region. Table 3 and Figure 3 present comparative data on livestock ownership in 1990 and 2024, highlighting changes in both total numbers and composition of livestock.

Table 3: Change in livestock ownership patterns. Source: Compiled by Authors.

Lives-tock Type	1990	2024	% Change	House-holds Owning (%) 1990	House-holds Owning (%) 2024
Sheep	**28.4**	**14.6**	**-48.6**	**76**	**48**
Goats	**22.6**	**16.3**	**-27.9**	**84**	**66**
Cattle	**3.1**	**3.8**	**22.6**	**92**	**94**
Buffaloes	**0.8**	**1.4**	**75**	**28**	**42**
Horses / Mules	**0.9**	**1.9**	**88.9**	**34**	**56**
Total	**56.3**	**38**	**-32.5**	**100**	**100**

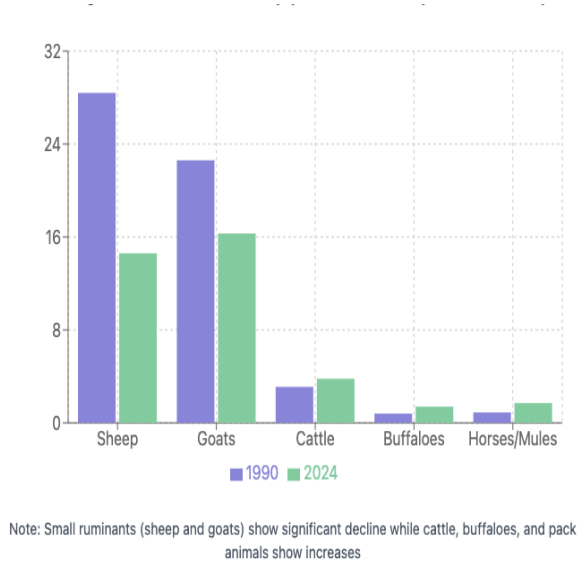

Figure 3: Livestock ownership per household,1990 and 2024. Source: Author.

3.3. *Changes in Livestock Management Practices*

Accompanying the changes in livestock ownership patterns, significant transformations were observed in livestock management practices among the surveyed households. The data reveal a notable shift away from long-distance transhumance, with the percentage of households practising migration of more than 50 km declining from 68% in 1990 to 36% in 2024. Concurrently, there was an increase in households practising short-distance transhumance (from 22% to 34%) and settled livestock keeping (from 10% to 30%), indicating a general trend toward reduced mobility. Traditional communal herding arrangements declined from 74% to 46% of households, while the use of hired herders increased from 12% to 38%, reflecting changes in labour allocation and social organisation. The practice of stall feeding (at least partial) doubled from 36% to 72% of households, indicating a move toward more intensive management systems. There was also a significant increase in the cultivation of fodder crops (from 18% to 54% of households) and the use of commercial feed supplements (from 8% to 46%), suggesting greater integration with market systems and adaptation to reduced access to natural pastures. Access to veterinary care improved considerably, with 82% of households reporting access in 2024 compared to 44% in 1990. Table 4 and Figure 4 summarise key changes in management practices between 1990 and 2024.

Table 4: Change in livestock management practices. Compiled by Authors.

Management Practice	1990 (% households)	2024 (% households)	Change
Long-distance transhumance (>50 km)	68	36	-32
Short-distance transhumance (<50 km)	22	34	12
Settled livestock keeping	10	30	20
Communal herding arrangements	74	46	-28
Hired herders	12	38	26
Stall feeding (at least partial)	36	72	36
Cultivation of fodder crops	18	54	36
Use of commercial feed supplements	8	46	38
Veterinary care access	44	82	38

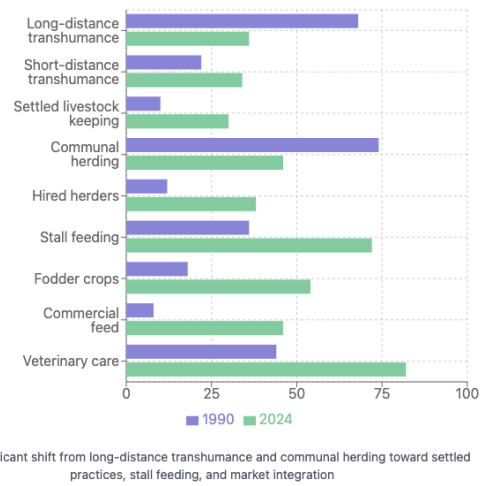

Figure 4: Livestock management practices.

3.4. *Drivers of Change in Livestock Ownership and Management*

The survey and interviews identified multiple, interrelated factors driving changes in livestock ownership and management practices. Climate change impacts on pastures emerged as the most widely recognised driver, with 88% of households rating it as important or very important. Respondents reported changes in vegetation patterns, water availability, and the timing of seasonal transitions in highland pastures, making traditional grazing systems less viable. Labour constraints due to outmigration, particularly of young men seeking education and employment opportunities elsewhere, were identified as a critical factor by 84% of households. With fewer family members available to participate in herding activities, many households have been forced to reduce herd sizes or alter management practices. The emergence of new income opportunities, especially in the tourism and hospitality sectors, was rated as important by 78% of households. The growing tourist influx to religious sites and trekking destinations in the region has created alternative livelihood options, reducing dependence on traditional livestock-based activities while simultaneously increasing demand for pack animals to support tourism infrastructure. Land use changes and access restrictions, including the creation of protected areas, hydropower development, and expansion of infrastructure, have affected traditional migration routes and grazing areas according to 76% of households. Changing market demand for livestock products, with increasing preference for cow and buffalo milk over sheep and goat products, was identified by 72% of households as influencing their livestock choices. Government policies and programs, including subsidies for improved cattle breeds, fodder development schemes, and restrictions on grazing in certain areas, were rated as important by 68% of households. Natural disasters, particularly the increased frequency of landslides and extreme weather events, were identified by 64% of households as affecting their livestock management decisions. Table 5 presents the perceived importance of different drivers of change based on households' ratings.

Table 5: Perceived importance of different drivers of change in livestock systems. Source: Compiled by Authors.

Drivers of Change	Percentage of Households Rating as Important/Very Important
Climate change impacts on pastures	88
Labor constraints due to outmigration	84
New income opportunities (tourism, etc.)	78
Land use changes and access restrictions	76
Market demand for livestock products	72
Government policies and programs	68
Natural disasters and extreme weather events	64
Increasing production costs	62
Predation and wildlife conflicts	58
Cultural and lifestyle preferences	56

3.5. *Socio-economic Implications of Changing Livestock Systems*

The transformations in livestock ownership and management practices have had far-reaching socio-economic implications for agro-pastoralist households. The study found a significant decline in the contribution of livestock products to household income, from 42.6% in 1990 to 28.3% in 2024. Similarly, income from crop agriculture decreased from 25.8% to 18.5%. Conversely, there were notable increases in the contribution of tourism and hospitality (from 8.7% to 19.4%), wage labour (from 12.4% to 16.8%), and remittances (from 6.5% to 10.2%), indicating a diversification of livelihood strategies and reduced

dependence on traditional agropastoral activities. Beyond changes in income composition, respondents reported several other socio-economic implications of the transitions in livestock systems. With men increasingly engaged in off-farm employment, women have taken on greater responsibility for livestock management, particularly for cattle and buffaloes kept near homesteads. Surveys indicated that women now perform more daily livestock management tasks compared to 1990. This has increased women's workload.

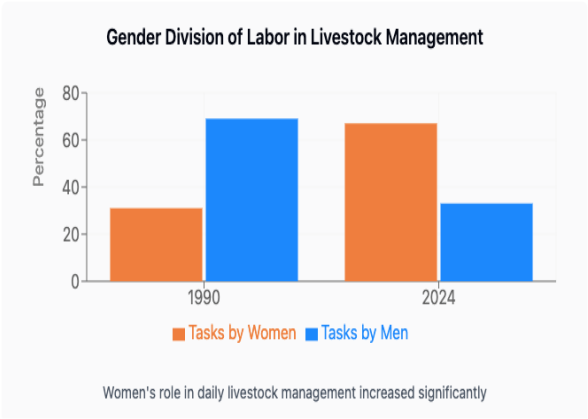

Figure 6: Gender division in livestock management, 1990-2024.

The decline in traditional agro-pastoralist practices has disrupted the transmission of indigenous knowledge about livestock breeds, pasture management, and environmental conditions. Many respondents expressed concern about the loss of specialised knowledge and skills among younger generations. Traditional communal herding arrangements provided a foundation for cooperation and reciprocity within communities. Their decline has weakened some social bonds while creating new forms of economic interdependence through hired herding and tourism-related activities. Changes in livestock systems have affected household consumption patterns, with reported reductions in the availability of traditional animal-source foods such as sheep and goat meat, milk products, and wool. However, increased cash income from alternative sources has improved access to market-purchased foods. Many respondents, particularly older individuals, expressed concern about the erosion of cultural practices, ritual observances, and community celebrations associated with agro-pastoralist pastoralism, which have traditionally been central to local identity. The transitions in livestock systems have contributed to increasing economic differentiation within communities. The average annual net return from sheep and goat production decreased. In contrast, the average annual net return from cattle and buffalo production increased.

These changes reflect both market factors (increased demand and prices for dairy products) and production factors (improved breeds, better veterinary care, and feeding practices). While traditional livestock (sheep and goats) still provided good returns, improved cattle breeds and horses and mules offered the highest absolute net returns. This explains the shift toward these livestock types among households with sufficient capital to invest in them, as horses and mules serve dual purposes for transportation and tourism activities, while improved cattle provide higher milk yields and better market prices compared to local breeds. Thus, the households are strategically diversifying their livestock portfolio based on available capital and market opportunities in the changing mountain economy. Households with better access to education, capital, and social networks have been more successful in capitalising on new opportunities in tourism and commercial livestock production. Changes in grazing patterns have altered human-environment interactions, with reduced grazing pressure in some high-altitude pastures leading to vegetation changes and increased grazing intensity in accessible areas closer to settlements. Table 6 and Figure 4 summarise key changes in income sources between 1990 and 2024, highlighting the declining relative contribution of livestock to household economies.

Table 6: Changes in household income sources. Source: Compiled by Authors.

Income Source	Avg. contribution to HH income%		
	1990	2024	Change
Livestock products	42.6	28.3	-14.3
Crop agriculture	25.8	18.5	-7.3
Wage labor	12.4	16.8	4.4
Tourism and hospitality	8.7	19.4	10.7
Remittances	6.5	10.2	3.7
Government service	3.2	4.6	1.4
Other	0.8	2.2	1.4

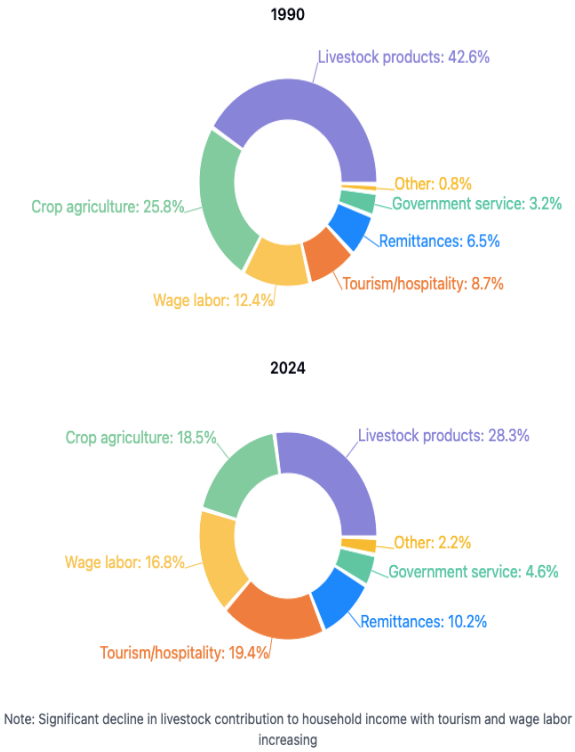

Figure 7: Gender division in livestock management, 1990-2024.

3.6. Adaptive Strategies to Changes

The land use and land cover map between 1990 and 2023 was prepared and analysed in order to understand the changing livelihood pattern of the agrarian community and the adoption of suitable adaptive practices. Substantial environmental shifts have been observed that provide context for understanding these adaptations. Snow cover decreased significantly from 344,127 hectares to 184,404 hectares (a reduction of nearly half). This decline aligns with findings that 88% of respondents consider climate impacts on pastures a critical concern and explains disruptions to traditional grazing patterns. Tree cover experienced remarkable expansion, growing from 28,137 hectares to 86,077 hectares over three decades. Simultaneously, barren lands increased from 30,881 to 112,249 hectares. These ecological shifts have necessitated fundamental changes in livestock management approaches. High-altitude pastures that previously supported seasonal grazing under snow conditions now offer reduced accessibility and productivity, forcing communities to seek alternatives to extensive grazing practices. The documented shift from small ruminants to larger livestock becomes clearer when viewed against expanding grasslands (46,186 to 60,563 hectares, especially at lower altitudes). Sheep and goats require access to high mountain pastures, while cattle and buffalo can utilise grassland areas closer to villages. Rural families surveyed across the region demonstrate this transition well. Traditional transhumant households have reduced sheep numbers while expanding horse ownership. These pack animals now generate income through tourist services and supply transport for trekking operations, capitalising on tourism infrastructure growth (built-up area expansion from 1,138 to 5,449 hectares). Table 7 and Figure 6 (base map from USGS) below show the changes observed in the region.

Table 7: Land use and land cover dynamics, 1990-2024. Source: Computed by Author.

Land use Classification	Area (Ha.) (1990)	Area (Ha.) (2024)
Water	1182	1144
Barren	30881	112249
Tree cover	28137	86077
Built-up	1138	5449
Grassland	46186	60563
Snow	344127	184404
Agricultural Land	2213	3978

Complete transformation characterises some household strategies. Certain families have abandoned sheep entirely and minimized goat production while concentrating on improved cattle breeds suited to available grasslands near settlements. Converting marginal cropland to fodder cultivation as supported by agricultural land increases from 2,213 to 3,978 hectares, enables intensive management systems. Traditional agro-pastoralists illustrate adaptive maintenance of customary practices. Rather than abandoning livestock entirely, few families reduced sheep holdings and goat numbers. Labour-sharing cooperatives among multiple households enable participation in off-farm employment during slack periods. Migration routes and seasonal timing have been modified to accommodate altered pasture conditions and

regulatory restrictions on grazing access. Tree cover and grassland expansion, and changing snow patterns have generated unexpected opportunities as well as certain challenges. Although livestock income proportions declined from 78% to 58%, traditional families have compensated through wool handicraft sales and community tourism participation, benefiting from improved infrastructure access. Agricultural land increases have facilitated fodder crop cultivation among few households, supporting the transition from extensive to intensive livestock systems better suited to current mountain conditions.

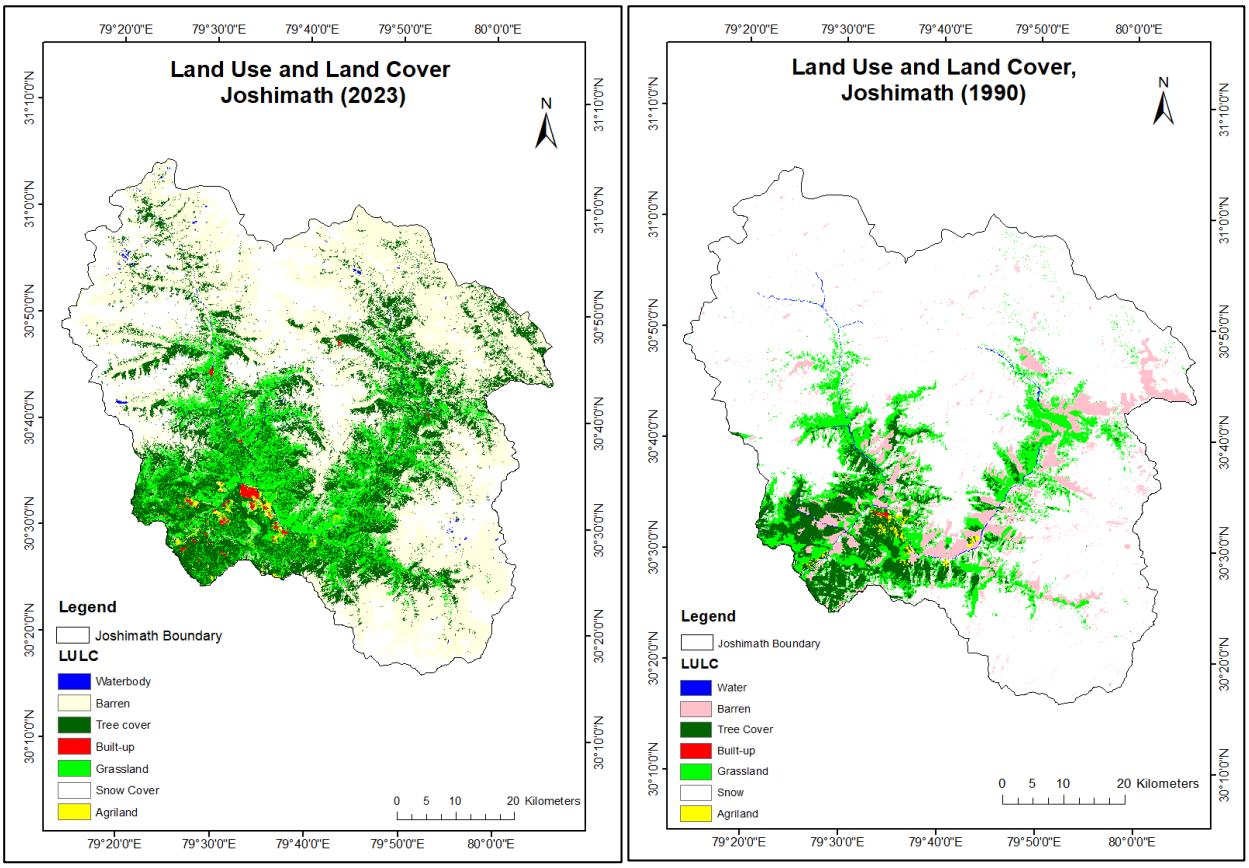

Figure 8: Land use land cover, 1990 and 2023. *Source: USGS, (Landsat 5 and 8).*

3.7. Comparative Analysis with Other Agropastoral Regions

The transformations observed in livestock ownership and management practices in the study region reflect broader patterns documented across mountain agropastoral systems globally. Research from the Ladakh region of India has revealed similar trends in livestock transitions, with studies documenting changes in grazing management practices and socio-environmental factors affecting traditional pastoral livelihoods (Dorjay et al., 2023). The Ladakh case demonstrates comparable patterns of reduced transhumance distances and increased settled livestock keeping, driven by similar combinations of climate change impacts, labor migration, and emerging economic opportunities in tourism. Studies conducted in the Nepal Himalayas have documented parallel changes in agropastoral systems, with researchers reporting climate change impacts on agricultural communities and livestock systems (Gentle & Maraseni, 2012; Paudel et al., 2019). Research in the Langtang valley has specifically examined how transhumance systems are being constrained by policy, land use, and socio-economic changes (Paudel et al., 2014). The Nepal case shows similar adoption of intensive management practices and climate adaptation strategies among farming communities, including changes in traditional grazing patterns and increased integration with market systems. The drivers of change identified in Nepal, particularly climate variability and outmigration of young people, closely mirror those documented in the present study.

The vulnerability of Himalayan transhumant communities to climate change has been

systematically documented across the region (Gentle & Thwaites, 2016), with pronounced warming predicted for high altitude areas affecting traditional lifestyles based on seasonal livestock rearing and subsistence agriculture. Studies from various Himalayan countries have shown that agriculture communities are disproportionately vulnerable due to emerging challenges from climatic and non-climatic stressors (Rasul et al., 2019). Comparative analysis with other agropastoral systems globally reveals both similarities and important regional differences. Research on livestock production systems demonstrates that climate change affects livestock through multiple pathways and that adaptation and mitigation actions can limit these effects (Bett et al., 2022). Studies from sub-Saharan Africa show that livestock transhumance represents a key adaptation strategy to environmental variability, though the specific patterns and challenges differ from those in mountain systems (Salam et al., 2018). Studies from various regions provide insights into agropastoral transitions in different contexts. Gender perspectives on climate change adaptation strategies in livestock farming have highlighted how females in developing countries are more vulnerable to climate change impacts, which affects adaptation strategies (Kumar et al., 2024). Research on transhumance routes demonstrates how seasonal mobility of livestock represents a critical survival strategy for populations dependent on pastoralism and agropastoral livelihoods (UNDP, 2023). The comparative analysis reveals several consistent patterns across diverse mountain agropastoral regions. These include declining overall livestock numbers, reduced long-distance transhumance practices, increased commercialisation of livestock management, and growing importance of non-livestock income sources. However, the specific magnitude and nature of these changes vary according to local ecological conditions, market access, government policies, and cultural factors. The universal presence of climate change impacts on pasture systems emerges as a critical driver across all regions, though the specific manifestations differ according to local climatic and ecological contexts.

3.8. Climate Change Impacts on Livestock Systems and Pasture Productivity

Climate change has emerged as a fundamental driver reshaping agropastoral systems in mountain regions, with livestock affected through temperature stress, altered precipitation patterns, and reduced forage quality (Bett et al., 2022). Rising temperatures and altered precipitation patterns have significantly affected the productivity and composition of high-altitude pastures that form the foundation of traditional livestock systems. Higher temperatures extend growing seasons at some elevations while creating heat stress conditions that reduce forage quality and quantity in others, while increased precipitation variability disrupts the predictable seasonal patterns that have traditionally guided transhumance schedules. The productivity of high-altitude pastures has shown particular vulnerability to climate change impacts, with research consistently documenting declining biomass production in the highest elevation grazing areas. Changes in species composition have been widely observed, with palatable and nutritious forage species often declining while less desirable or invasive species increase their dominance. These vegetation changes reduce the carrying capacity of traditional grazing areas and affect the nutritional quality of available forage. Water availability has become an increasingly critical constraint, with reduced and more variable snowfall affecting the timing and quantity of snowmelt that traditionally provides water for both livestock and pasture vegetation. Traditional water sources, including springs and seasonal streams, have become less reliable in many areas, forcing changes in grazing routes and watering schedules. Extreme weather events have increased in frequency and intensity, with drought conditions affecting forage production while extreme precipitation events damage grazing areas through erosion and flooding. Different livestock species exhibit varying vulnerabilities to climate change impacts, which helps explain the shifts in herd composition observed across mountain regions. Small ruminants like sheep and goats face particular challenges from heat stress and reduced forage diversity, while larger livestock species may be better adapted to some climate changes but require more water and can cause greater damage to degraded pastures. The adaptive capacity of agropastoral households varies significantly depending on their access to resources, alternative livelihood opportunities, and social networks, with those having limited resources often facing difficult choices between maintaining traditional practices and making costly adaptations. Climate projections for mountain regions suggest continued warming and increased precipitation variability, indicating that the pressures on traditional agropastoral systems will likely intensify. Understanding these climate impacts provides crucial context for interpreting the livestock transitions.

4. DISCUSSION

The transformations documented in livestock ownership and management practices among agro-pastoralist communities in Chamoli district reflect broader patterns of change occurring across pastoral systems in the Himalayan region and globally. The substantial decline in overall livestock numbers (32.5%) over a decade, with particularly pronounced reductions in sheep (48.6%) and goats (27.9%), accompanied by increases in cattle, buffaloes, and pack animals, represents a fundamental shift in the pastoral economy of the region. This transition from extensive, mobile production systems based on small ruminants toward more intensive, settled systems focused on larger livestock aligns with patterns observed in other mountain regions worldwide (Dong et al., 2011; Kreutzmann, 2013).

The drivers of these changes reveal the complex, multidimensional pressures affecting pastoral communities in the Himalayas. Climate change impacts on highland pastures, reported by 88% of respondents as important or very important, appear particularly significant in this high-altitude environment. This finding resonates with research by Aryal et al. (2017), who documented increased vulnerability of Himalayan agro-pastoralist communities to climate variability, and Pandey et al. (2021), who highlighted changing precipitation patterns and vegetation dynamics in high-altitude pastures. The climate sensitivity of these pastoral systems may be heightened by their location, which Singh and Thadani (2015) described as one of the world's most rapidly warming mountain regions. Labour constraints due to outmigration, identified by 84% of households as a critical factor, reflect broader demographic transitions occurring across rural mountain regions. This finding aligns with studies by Barua et al. (2013) and Suryawanshi et al. (2019), who have documented the impacts of educational expansion and changing aspirations on pastoral labour availability. The current study's finding that 54% of surveyed households have at least one migrated member underscores the magnitude of this demographic shift and its implications for traditional labour-intensive herding practices. The emergence of tourism as both a driver of livestock system change (reported by 78% of households) and an increasingly important income source (increasing from 8.7% to 19.4% of household income) represents a significant new dynamic in the regional economy. The dual role of tourism, creating alternative livelihood opportunities while simultaneously generating demand for pack animals, illustrates the complex ways in which new economic activities can both displace and transform traditional pastoral practices. This parallels findings from other Himalayan regions where tourism development has created both opportunities and challenges for pastoral communities (Kreutzmann, 2012; NITI Aayog, 2018).

Land use changes and access restrictions, identified by 76% of households as important drivers, reflect the institutional dimensions of pastoral transformation. This aligns with research by Agrawal (2014) and Shrestha et al. (2019) on changing common property regimes and resource governance in Himalayan regions. The specific impacts of protected area creation, hydropower development, and infrastructure expansion, as documented in this study, illuminate how broader development processes and conservation imperatives are reconfiguring the spatial dimensions of pastoral mobility. The economic analysis presented in this study offers valuable insights into the rational calculations underlying pastoral decision-making. The finding that improved cattle breeds and horses or mules now offer the highest returns helps explain the shift toward these livestock types among households with sufficient capital. At the same time, the continued high returns on investment from traditional livestock (96.2% for sheep and 111.6% for goats) suggest that these species remain economically viable for households with appropriate labour arrangements and access to pastures. This economic complexity cautions against simplistic narratives of pastoral decline or inevitable modernisation. The socio-economic implications of changing livestock systems documented in this study are particularly revealing. The shifting composition of household income, with declining contributions from livestock products (from 42.6% to 28.3%) and agriculture (from 25.8% to 18.5%), alongside increases in tourism, wage labour, and remittances, indicates a broader diversification of livelihood strategies. This parallels findings by Jodha (2005) and Sharma et al. (2020) on adaptation strategies employed by mountain communities facing environmental and socioeconomic change. The gendered dimensions of these transformations, with women taking on greater responsibility for livestock management, particularly for cattle and buffaloes kept near homesteads, highlight how pastoral transitions can reconfigure intrahousehold labour allocations and power relations. The finding that women now perform 67% of daily livestock management tasks compared to 31% in 1990 suggests significant changes in gender roles within these communities. These findings are

consistent with Bhasin's (2011) research on the evolving gender dynamics in Himalayan pastoral societies. Of particular concern are the results highlighting the decline of traditional ecological knowledge and cultural practices linked to pastoral livelihoods. The difference in fodder species identification between younger and older community members (7 and 8, respectively) suggests a rapid loss of specialised environmental knowledge. Similarly, the 42% decline in a cultural practices index comprising traditional pastoral activities indicates significant cultural transformation. These findings raise concerns similar to those expressed by Nautiyal et al. (2019) and Singh et al. (2015) regarding the loss of traditional ecological knowledge systems in Himalayan communities.

The diverse adaptive strategies documented through case studies illustrate both the agency of pastoral households and the differentiated nature of their responses to changing conditions. The contrasting pathways exemplified by the three case households—one shifting toward tourism services, another toward intensive dairy production, and a third modifying traditional transhumance through cooperative arrangements highlight the heterogeneity of adaptation processes. This diversity of responses aligns with observations by Mishra et al. (2003) on risk mediation strategies among trans-Himalayan agropastoral and Joshi et al. (2020) on differential response capacities within pastoral communities. The transitions documented in this study suggest the emergence of new socio-ecological systems in the Chamoli district, characterised by modified livestock compositions, altered mobility patterns, increased market integration, and new forms of resource governance. While these changes reflect the adaptive capacity of pastoral communities, they also raise important questions about long-term sustainability, cultural continuity, and environmental management. As Nüsser et al. (2012) and Gergan (2017) have argued, the reconfiguration of traditional human-environment relationships in mountain regions carries both opportunities and risks that require careful evaluation. The policy implications of these findings suggest the need for more nuanced approaches to pastoral development that recognise the continuing importance of livestock in mountain economies while supporting sustainable adaptations to changing conditions. Rather than viewing pastoral transformation as either an inevitable decline or necessary modernisation, policies should seek to maintain the ecological knowledge, economic flexibility, and cultural values embedded in traditional systems while addressing legitimate aspirations for improved livelihoods and wellbeing among mountain communities.

5. CONCLUSION

The significant transformations in livestock systems among agro-pastoralist communities in Joshimath block of Chamoli district, Uttarakhand (India) represent a decline in overall livestock numbers and a shift from sheep and goats toward cattle, buffaloes, and pack animals. The socioeconomic implications are multifaceted, affecting household income composition, gender roles, and cultural practices. Critical concerns include the erosion of specialised ecological knowledge and cultural practices, evidenced by younger generations' limited identification of traditional fodder species. However, diverse adaptive strategies demonstrate remarkable resilience among pastoral households. This study proposes establishing community-based fodder banks, cooperative herding models, and value-addition training programs to address labour constraints and knowledge erosion while enhancing economic returns. Future research should focus on longitudinal knowledge transmission studies, integrated pastoral-tourism economic modelling, and climate vulnerability assessments for livestock species. The research purpose is to provide evidence-based guidance for sustainable pastoral development in mountain regions facing environmental and socioeconomic change. The findings support developing integrated policies that recognize pastoral systems as dynamic entities capable of sustainable transformation while maintaining cultural heritage and supporting resilient mountain communities.

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