RESEARCH PAPER

# DECLINE IN TRADITIONAL FODDER AVAILABILITY AND SHIFT TO ALTERNATIVE FODDER SUPPLEMENTS FOR LIVESTOCK IN CHAMOLI DISTRICT, UTTARAKHAND, INDIA

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ABSTRACT. The Himalayan region's traditional fodder systems are under increasing strain from socioeconomic shifts and environmental change. This study examines the changing dynamics of fodder availability and livestock management in Chamoli district, Uttarakhand (India). The study was conducted in five blocks of the district (Joshimath, Pokhari, Karnaprayag, Tharali, and Dewal). These covered different elevation zones: lower (800–1,500 m), middle (1,500–2,500 m), and higher (>2,500 m). The research employed household surveys (n=150) to examine trends in traditional fodder resources, adaptation strategies, and associated challenges. Findings reveal a 37% decline in overall fodder availability since 1990, with the highest reduction (45%) in higher regions due to climate change and decreasing snowfall. Mid-altitude areas experienced a 38% decline, largely due to restricted forest access and invasive species. The lower zones reported a 29% decrease, which was driven by agricultural expansion and deforestation. The study highlights a 105% increase in fodder collection (from 2.1 to 4.3 hours daily) as well as a doubling of collection distances (from 1.8 to 3.6 km) over three decades. Periods of acute shortage extended from 2.3 to 4.7 months annually. This increase disproportionately impacts women's workloads. Households have responded by adopting alternative strategies, including commercial feed (63% adoption), increased reliance on crop residues (88%), and herd reduction (97%). Household income, market access, and education significantly influence adaptation capacity. These findings underscore the urgent need for targeted interventions, such as improved fodder cultivation, integrated fodder development programs, enhanced forest management policies, and economic support for dependent populations. This research contributes to understanding social-ecological transitions in mountain systems.

KEYWORDS: fodder, Himalayas, livestock, high altitude, agriculture

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## INTRODUCTION

Livestock rearing forms an integral component of rural livelihoods in the Himalayan region of Uttarakhand. The traditional agro-pastoral systems have sustained Himalayan communities for generations (Singh et al. 2015). Despite the significance of livestock rearing in the region, forage cultivation has received minimal attention. Instead, grazing in forest areas, subalpine pastures, and alpine pastures remains the primary source of fodder for animals (Aryal et al. 2014). Historically, forests and natural grasslands have provided the bulk of fodder for livestock, with well-established seasonal variations in fodder collection strategies (Wrobel et al. 2025). In addition to natural grazing, fodder trees and shrubs play a crucial role in meeting livestock dietary needs, particularly during periods of scarcity. These traditional fodder sources have long supported rural livelihoods and livestock productivity. However, their availability is increasingly challenged by environmental and socioeconomic changes (Saeed et al. 2022). In recent, significant transformations have occurred in fodder availability patterns, forcing farmers to adapt their livestock management practices. The Central Himalayan landscape of the Chamoli district presents diverse

geographical features ranging from valleys to high-altitude meadows, supporting an economy that is predominantly agrarian, with animal husbandry contributing significantly to household income and food security (Kumar et al. 2025a).

Traditional fodder resources in this region include forest leaf litter, tree fodder, grasses from community lands, and crop residues from agricultural fields (Katoch 2022; Khan et al. 2025). These resources have not only supported livestock but have also played important roles in enhancing human health and nutrition through the livestock products they enable. Several studies, such as Katoch et al. 2022, Ahmad et al. 2018, Kumar et al. 2025b, and Kumar et al. 2026 have documented how changing environmental and socioeconomic conditions are affecting fodder availability in the Himalayan regions. The decline in traditional fodder availability has become a serious issue in many livestock-dependent regions. This has prompted a shift toward alternative fodder supplements for livestock. Climate change, environmental degradation, land-use changes, and policy restrictions have contributed to the depletion of natural fodder sources (Pandey et al. 2014). The variability in precipitation patterns, reduced snowfall, and shifting vegetation zones have affected the natural regeneration and productivity of fodder species. Studies on fodder plants in the Joshimath area of Chamoli district have reported significant declines in several important species. These have raised concerns about their availability and ecological implications (Tiwari & Rawat 2017). Similar trends have been observed in neighboring regions, where studies have reported a rapid decline in forest-based fodder availability. These studies attribute the decline to climate change, forest degradation, and policy restrictions (Negi et al. 2019). The socioeconomic dimensions of these changes are equally significant. The adaptation strategies to resource scarcity are strongly influenced by socioeconomic status, landholding size, and market accessibility (Mohamed et al. 2020). Research indicates a reduction in traditional fodder resources in the Garhwal region of Uttarakhand, highlighting a broader trend across the Central Himalayas. This decline has been further intensified by outmigration, shifting livelihood patterns, and reduced labor availability for fodder collection (Sharma et al. 2023; Islam et al. 2023). In response to these challenges, farmers have increasingly turned to cultivated fodder crops, commercial feed, and agro-industrial by-products to sustain livestock. While these alternatives offer short-term relief, concerns remain about their long-term sustainability, particularly for small-scale farmers with limited financial resources (Kumar et al. 2025b). Households with improved cattle breeds are more likely to purchase commercial feed, while those with traditional livestock varieties attempt to maximize the use of available natural resources. This suggests a relationship between livestock breed selection and fodder management strategies that merits further investigation in the Chamoli context.

Critical perspectives on these transitions emphasize concerns about the sustainability of current adaptation trends, particularly regarding increasing economic vulnerability among resource-poor households and the potential long-term ecological impacts of intensive fodder cultivation systems. These concerns are especially significant in the context of social-ecological resilience and sustainability. Despite these advances in understanding, significant knowledge gaps remain regarding the complex interactions between climate change, forest management policies, socioeconomic transformations, and fodder availability (Katoch 2022). Most existing studies have either focused on broader regional patterns or on specific aspects of the fodder system. There is a lack of information on how much traditional fodder sources have actually declined in Chamoli and how people are adjusting to feed their livestock. The mitigation strategies and challenges adopted by poorer households and wealthier households may also differ. This study fills these gaps in several ways. It documents changes in traditional fodder availability and identifies which alternative feeding practices households have started using. It examines how households have adopted each approach from buying commercial feed to growing their own fodder. Since not all households have the same resources, the study compares how deprived and well-off households differ in strategies. In addition to wealth, the study examines additional variables that may facilitate or impede adaptation, such as the number of livestock kept by a family, their educational attainment, the distance from markets, etc. Together, these provide a more comprehensive understanding of the problem and the many approaches being used by households. Understanding these patterns can help design inclusive programs that work for mountain communities.

## STUDY AREA

The study was conducted in Chamoli district, Uttarakhand, which covers an area of approximately 8,030 km2 in the Central Himalayan region. The district has elevations ranging from 800 to 7,817 meters above sea level. The research encompassed five distinct blocks within the district (Joshimath, Pokhari, Karnaprayag, Tharali, and Dewal), each representing different ecological characteristics and farming systems. The Joshimath block is situated in the higher elevational zone. It is characterized by alpine meadows, influencing seasonal livestock migration patterns. The Pokhari block is located in the middle elevational zone and features mixed oak and rhododendron forests that serve as important fodder sources for local communities. The Karnaprayag block represents transitional ecology between lower and middle zones, with terrace farming being predominant. The Tharali block in the middle zone is known for its extensive community-managed forest areas that play a crucial role in regulated fodder collection. The Dewal block has subtropical vegetation and more intensive agricultural practices with crop residues forming a significant portion of livestock feed. These blocks were strategically selected to represent the full spectrum of fodder management systems practiced across different ecological niches in the Himalayan region.

## METHODOLOGY

### Sampling Design and Data Collection

The study covered five different blocks in the district (Joshimath, Pokhari, Karnaprayag, Tharali, and Dewal). Fifteen villages were selected across three elevational zones: lower (800-1,500 m), middle (1,500-2,500 m), and higher (above 2,500 m) to capture the diversity of fodder conditions and livestock management practices (Table 1). The study employed a multi-stage sampling approach to ensure a representative selection of participants. Specific study areas were purposively selected to capture variations across different elevational zones. Afterwards, a random selection of villages was conducted within these areas to ensure geographical diversity. Then, systematic random sampling was used to select households, ensuring that the sample accurately reflected the local community's

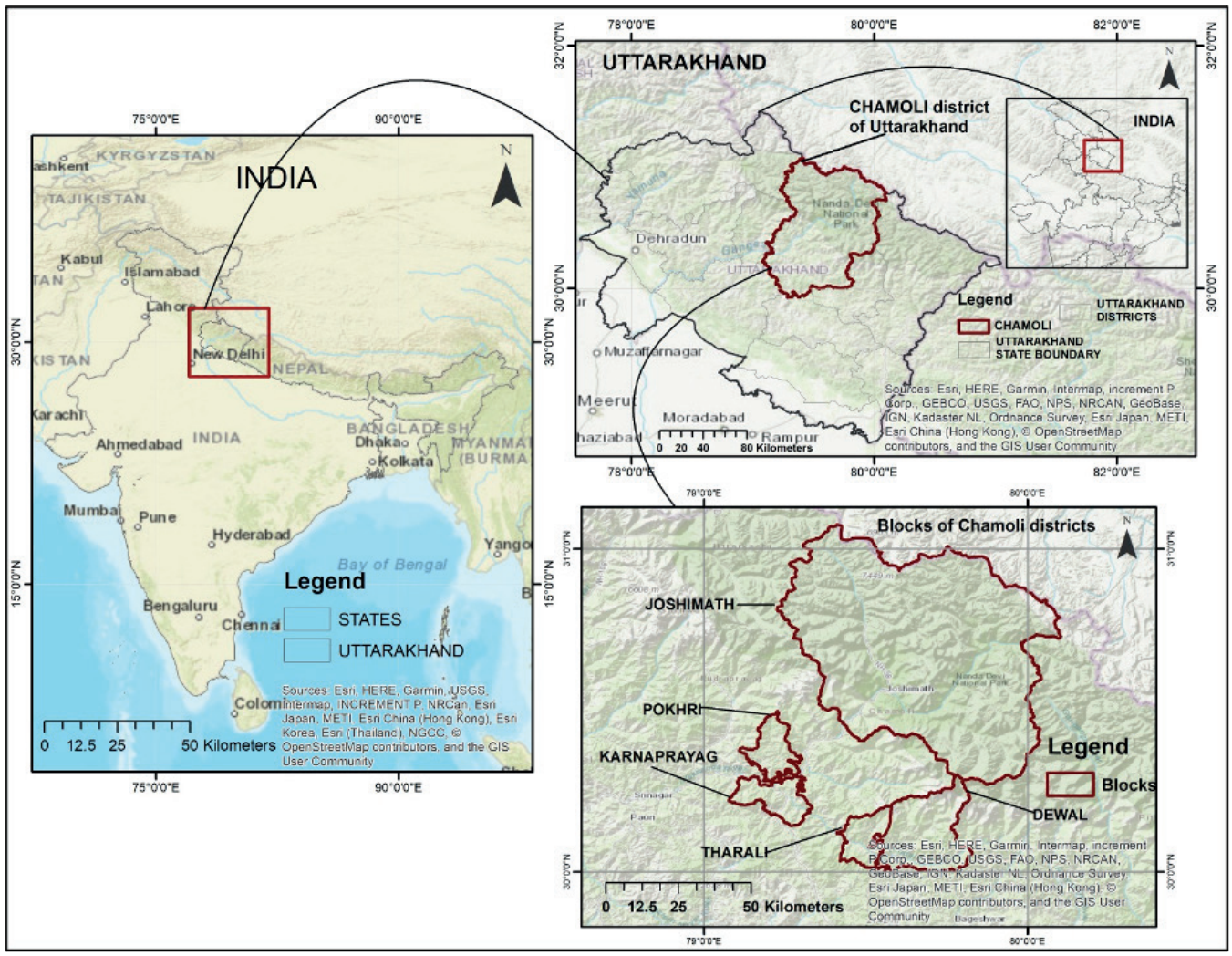


**Fig. 1. Study Area**

demographic and landholding patterns. Surveys were conducted with 150 households (10 households from each village and 50 households in each elevation zone). The data were collected on family demographics, livestock ownership, land use, fodder collection practices, alternative feeding methods, and the costs of maintaining livestock. For comparative analysis of adaptive strategies across socioeconomic strata, sampled households were classified into two economic categories based on total annual household income. Households were categorized as deprived if their annual household income fell below ₹60,000 (approximately ₹5,000 per month or ₹1,000 per capita per month for an average household of 5.3 members). This threshold was determined based on the rural poverty benchmarks for mountainous regions of Uttarakhand, approximating the per capita monthly consumption expenditure of ₹1,632 reported for rural areas in India (Ministry of Statistics and Programme Implementation, 2024). Households with annual income at or above ₹60,000 were classified as well-off.

Fodder use was measured using standard units, such as head loads for forest fodder and other fodder types. The amount of fodder, fuelwood, or other agricultural products balanced on the head in a single journey is referred to as the head load. This method of manual transportation is common in rural communities (Singh et al. 2021). One head load typically weighs 20-25 kg for fresh green fodder, representing the standard unit of measurement for quantifying fodder collection (Heglund & Willems 1995). This study estimates the fodder reduction using a single head load of 15 kg. Time taken by the households to collect fodder was tracked and estimated based on observation. In addition to surveys, the research included in-depth discussions with elderly individuals and group discussions with 8-10 participants in each of the blocks with local communities. Direct observation of fodder collection practices further validated survey responses and provided a deeper understanding of the challenges faced by villagers. This mixed-method approach enabled gathering both quantitative data and detailed qualitative insights into local practices.

## Data Analysis

Statistical analysis was performed using SPSS and STATA software. Descriptive statistics were calculated to characterize the sample and summarize key variables to compare current fodder availability with retrospective data from 1990 (based on respondent recall). Chi-square tests examined the association between household socioeconomic characteristics (economic status, education level, landholding size) and adoption of alternative fodder sources. Pearson correlation coefficients were calculated to determine relationships between key variables such as fodder availability, collection time, household income, and livestock numbers. Qualitative data were analyzed using thematic content analysis. Triangulation of quantitative and qualitative data strengthened the validity of findings. The integration of these analytical approaches enabled a comprehensive assessment of the decline in traditional fodder availability and the transition to alternative feeding strategies in the study area.

**Table 1. Sampling Framework and Village Selection**

| Elevation Zone | Block | Selected Villages | Altitude (m asl) | Total per Zone |
|---|---|---|---|---|
| Higher (>2,500 m) | Joshimath | Mana | 3,200 | 50 |
| | | Tapovan | 2,650 | |
| | | Lata | 2,550 | |
| | | Malari | 3,170 | |
| | | Niti | 3,200 | |
| Middle (1,500-2,500 m) | Pokhari | Pokhari | 2,200 | 50 |
| | | Dungar | 1,950 | |
| | Karnaprayag | Nauti | 2,100 | |
| | Tharali | Gwaldam | 2,050 | |
| | | Tharali | 1,900 | |
| Lower (800-1,500 m) | Pokhari | Choundi | 1,450 | 50 |
| | Karnaprayag | Simli | 1,350 | |
| | Dewal | Devsari | 1,250 | |
| | | Choting | 1,150 | |
| | | Chaud | 950 | |
| Total | | | | 150 |

## Statistical Techniques Used in the Study

To assess changes in fodder availability and other indicators over time, the study used descriptive statistics to calculate mean reductions, percentages, and other descriptive measures. Fodder availability in 1990 was determined based on respondent recall (head load), while 2024 availability was measured directly during the survey period. We acknowledge that recall data may be subject to recall bias, though we attempted to minimize this by triangulating with community elders and focus group discussions. For each household in all three different elevation zones, we calculated the absolute reduction by subtracting current availability from the 1990 baseline. The mean reduction across all households was then computed by averaging these individual reductions. This means absolute reduction was converted to a percentage. For each zone, the formula was applied separately (where n=50 in each of three elevation zones). This decline in fodder availability across different zones was calculated using the mathematical expression as follows (Eq. 1):

$$\text{Mean Reduction} = \frac{\sum (\text{Fodder Availability in 1990} - \text{Fodder Availability in 2024})}{\text{Total Number of Observations}} \quad (1)$$

The chi-square test was used to determine whether there is a statistically significant relationship between variables, such as the relationship between household economic status and adoption of various fodder strategies. This test was applied to determine the significance of differences in the adoption rates of alternative fodder strategies between poor and well-off households. All tests had 1 degree of freedom with the significance level set at $\alpha = 0.05$ before data analysis to maintain consistency. P-values below 0.001 are reported as such to indicate particularly strong evidence against the null hypothesis, the fundamental decision criterion remained whether $p < 0.05$ (Eq. 2) is as follows:

$$X^2 = \frac{\sum E(O-E)^2}{E} \quad (2)$$

where $O$ – observed frequency in each category,
$E$ – expected frequency in each category.

To investigate the relationships between key variables (such as fodder availability, collection time, household income, education level, etc.), Pearson correlation coefficients were computed. This allowed the study to assess how strongly related different factors are to each other. This test was used to measure the strength and direction of the relationships between fodder availability, collection time, income, and other variables. Correlation strength was interpreted using standard conventions: $r < 0.3$ as weak, $0.3 \leq r < 0.7$ as moderate, and $r \geq 0.7$ as strong. The same $\alpha = 0.05$ threshold was applied, with graduated significance levels (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$) reported to indicate varying degrees of evidence against independence. Eq. (3) is as follows:

$$r = \frac{\sum (X-\bar{X}) \sum (Y-\bar{Y})}{\sqrt{\sum (X-\bar{X})^2 \sum (Y-\bar{Y})^2}} \quad (3)$$

where $X$ and $Y$ – variables being compared, $\bar{X}$ and $\bar{Y}$ – means of $X$ and $Y$, r – Pearson correlation coefficient

## RESULTS

### Household and Livestock Characteristics

The demographic data reveals a traditional agricultural society in transition. The 150 sampled households exhibited diverse socioeconomic characteristics (Table 2). The average household size was 5.3 members, with 42% of households reporting at least one member who had migrated for work, likely working-age males seeking employment in urban areas. This underscores animal husbandry's importance in the regional economy. Agriculture remained the primary occupation for 68% of households, while 22% reported livestock rearing as their main livelihood activity. The remaining 10% primarily depended on wage labor, government service, or private employment. Regarding livestock holdings, cattle (68%) and goats (61%) were the most commonly kept animals, followed by cows (42%) and sheep (18%). The average livestock holding was 4.2 livestock units per household, with significant variation based on economic status and landholding size, reflecting a balanced approach between larger, more resource-intensive animals and smaller, more resilient ones. Nearly all households (97%) reported a decline in their livestock numbers over the past decade, with a mean reduction of 36% across the sample. This represents a dramatic contraction of the livestock economy.

### Traditional Fodder Resources and Availability Trends

Local communities in the Chamoli district traditionally used many different types of fodder for their livestock (forest-based fodder, agricultural by-products, cultivated fodder, etc.). They gathered leaves, branches, and plants from forests that were either protected, community-owned, or considered sacred. Oak trees, rhododendron trees, and other leafy trees were especially important sources. People also collected grasses and herbs from shared grazing areas, mountain meadows called bugyals, and unused farmland. They gathered fresh green plants during the rainy season and dried grass for winter feeding. After harvesting crops like finger millet, barnyard millet, wheat, rice, and beans, farmers used the leftover stalks and stems as dry fodder when other food for animals was scarce. Some families also grew small amounts of fodder, mostly native grasses and useful trees along the edges of their fields. This diverse approach to fodder collection reflected the community's deep knowledge of local ecology and seasonal changes.

Villagers developed sophisticated harvesting schedules that followed natural cycles, carefully timing when to collect from different sources to ensure sustainability. This traditional system also had social dimensions, with unwritten community rules governing access to shared resources and mutual assistance during collection. Families would often cooperate to gather and transport larger quantities of fodder from distant meadows before winter set in. The variety of fodder sources also provided nutritional balance for livestock throughout the year, with different plants offering complementary nutrients. This traditional knowledge was passed down through generations, connecting cultural practices to the practical challenges of maintaining livestock in a mountainous region with distinct seasons. The findings reveal a significant decline in traditional fodder resources across all elevation zones over the past few decades (Table 3). Due to ecological variations in vegetation density and productivity, baseline values varied by elevation zone. The results showed that the lower zones (800–1500 m) reported a mean baseline availability of 127 head loads per household per month in 1990, declining to 90 in 2024 (29% reduction). The middle zones (1500–2500 m) reported 108, which decreased to 67 (38% reduction). Whereas the higher zones (>2500 m) reported 85, which decreased to 47 (45% reduction). The analysis indicates a mean reduction of 37% in overall fodder availability since 1990, with substantial variation across ecological zones. The data demonstrates a clear pattern of fodder reduction that varies by altitude, with the higher ecological zone (>2500 m) experiencing the most severe decline (45%), primarily attributed to climate change impacts and reduced snowfall. This suggests high-altitude ecosystems may be particularly vulnerable to changing climate conditions. The middle ecological zone

**Table 2. Demographic characteristics of sampled households (n=150)**

| Characteristics | Category | Percentage |
|---|---|---|
| Landholding Size | Landless (<0.1 ha) | 12 |
| | Marginal (<0.1-1 ha) | 48 |
| | Small (1-2 ha) | 27 |
| | Medium (2-4 ha) | 10 |
| | Large (>4 ha) | 3 |
| Economic Status | Deprived Households | 36 |
| | Well-off Households | 64 |
| Educational Status of Household Head | Illiterate | 23 |
| | Primary Education | 31 |
| | Secondary Education | 35 |
| | Higher Education | 11 |

Source: Primary Survey, 2024

(1500-2500 m) shows a 38% reduction, with key factors being reduced community forest access and invasive species encroachment, indicating both anthropogenic and biological factors affecting mid-altitude regions. Lower ecological zones (800-1500 m) recorded a 29% reduction, mainly due to agricultural land conversion and forest degradation, reflecting increasing pressure on lowland ecosystems from expanding human activities. The regional variation in fodder availability appears to correlate with different driving forces: land use change dominates in lower zones, access restrictions and invasive species in middle zones, and climate-related factors in higher zones. This ecological zonation of causal factors suggests that management strategies may need to be tailored specifically to each altitude range to effectively address fodder availability challenges.

The decline in fodder availability has several important implications on local communities (Table 4). People now spend much more time gathering fodder than they did in the past. In 1990, villagers typically spent about 2.1 hours each day collecting fodder, but by 2024, this had more than doubled to 4.3 hours daily (105% increase). Villagers also have to travel much farther to find enough fodder. The average distance they walk to gather fodder has doubled from 1.8 km to 3.6 km over the study period. Additionally, the times of year when fodder is especially hard to find have become longer and more difficult. In 1990, communities faced severe fodder shortages for about 2.3 months of the year, but by 2024, these difficult periods had stretched to nearly 5 months annually. These changes show how the decreasing availability of traditional fodder sources has created significant challenges for rural households that depend on livestock. Respondents identified multiple drivers of declining fodder availability (Fig. 2), with forest degradation (cited by 86% of households), changing rainfall patterns (78%), the reduced community access to forest resources (65%), invasive species proliferation (58%), and agricultural land abandonment (52%) being the most frequently mentioned factors. The drivers of declining fodder availability are shown in Fig. 2.

Focus group discussions and key informant interviews provided contextual insights into these changes. A 72-year-old local farmer from the Joshimath block stated:

"When I was young, we could collect a head load of oak leaves within an hour's walk from the village. Now, the same collection takes almost the entire day, and the quality of fodder has also deteriorated. This has affected our traditional livestock-based economy."

## Adoption of Alternative Fodder Supplements

Due to the declining traditional fodder resources, households have adopted various alternative feeding strategies to meet their livestock needs. Statistical analysis using chi-square tests examined relationships between economic status and feeding strategies. Table 5 shows the adoption of alternative fodder supplements by different household categories, including effect sizes to indicate the practical significance of relationships. Commercial feed supplements show a 63% overall adoption rate, with a

**Table 3. Changes in fodder availability by elevation zones, and head loads per household per month**

| Elevation Zone | Baseline 1990 (head loads/month) | Current 2024 (head loads/month) | Mean Reduction (%) | Primary Drivers |
|---|---|---|---|---|
| Lower (800-1500 m) | 127 | 90 | 29% | Agricultural land conversion and forest degradation |
| Middle (1500-2500 m) | 108 | 67 | 38% | Reduced access to community forests and invasive species |
| Higher (>2500 m) | 85 | 47 | 45% | Climate change impacts and altered precipitation patterns |
| Overall | 107* | 68* | 37% | Multiple interacting factors |

*Overall values represent the mean across all 150 households.

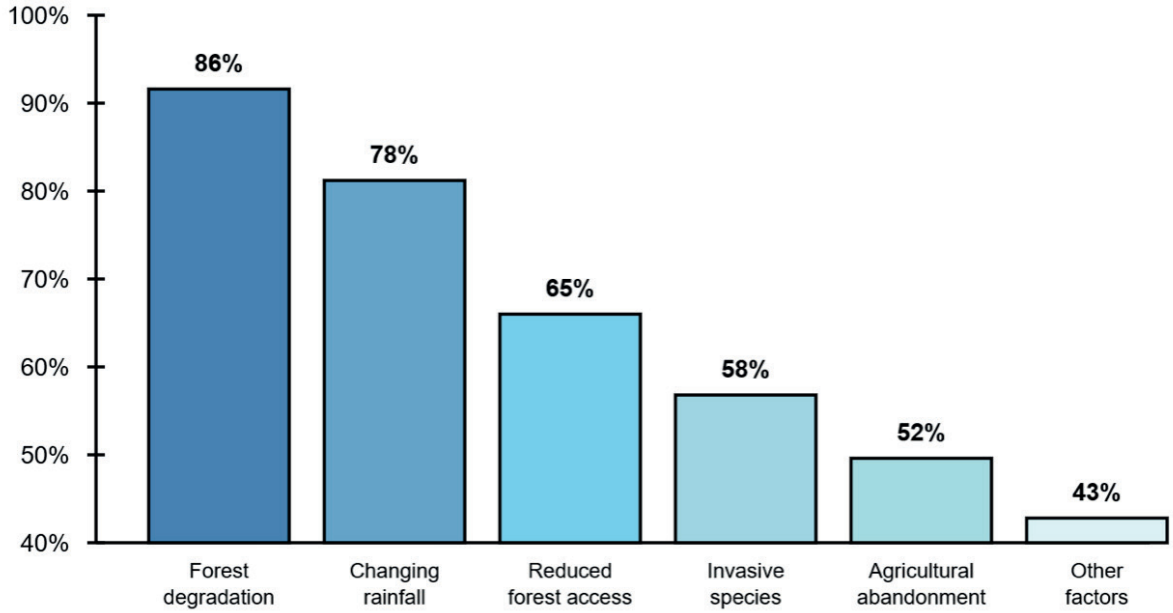


**Fig. 2. Drivers of declining fodder availability (percentage of household identifying each factor)**

**Table 4. Fodder availability decline indicators**

| S. No | Indicator | 1990 Value | 2024 Value | Change in Percentage | Participants Perception |
|---|---|---|---|---|---|
| 1 | Overall Fodder Availability | 106((head loads/ month) loads/month) | 68 (head loads/month) | -37 | Severe Decline Threatening Livestock Sustainability |
| 2 | Average Fodder Collection Time | 2.1 hours/day | 4.3 hours/day | 105 | Workload Increased for Women |
| 3 | Collection Distances | 1.8 km/day | 3.6 km/day | 100 | Increased Physical Burden |
| 4 | Period of Acute Fodder Shortages | 2.3 months/year | 4.7 months/year | 104 | Extended Vulnerability for Households |

Source: Computed by Author based on primary survey

**Table 5. Adoption of alternative fodder supplements by different household categories**

| Alternative Feeding Strategy | Overall (%) | Deprived (%) | Well-off (%) | $\chi^2$ | p-value |
|---|---|---|---|---|---|
| Commercial feed supplements | 63 | 39 | 77 | 18.7 | <0.001*** |
| Crop residues | 88 | 94 | 84 | 3.5 | 0.061 |
| Cultivated fodder | 42 | 24 | 52 | 12.4 | <0.001*** |
| Purchased forest fodder | 37 | 56 | 27 | 14.2 | <0.001*** |
| Reduced livestock numbers | 97 | 100 | 96 | 2.1 | 0.147 |
| Changed livestock composition | 72 | 65 | 76 | 2.8 | 0.094 |

Note: All chi-square tests conducted with df = 1. Significance level set at $\alpha = 0.05$. *** indicates $p < 0.001$.

stark contrast between poor households (39%) and well-off households (77%). The chi-square test indicates a very strong and statistically significant relationship ($\chi^2 = 18.7$, $p < 0.001$), demonstrating that commercial feeds are substantially more accessible to wealthier households, likely due to their higher purchasing power. The medium-to-large effect size confirms this is not only statistically significant but also practically meaningful. Crop residues are the most adopted strategy overall, with an 88% adoption rate. Poor households show slightly higher adoption (94%) compared to well-off households (84%). However, this difference is not statistically significant ($\chi^2 = 3.5$, $p = 0.061$), suggesting that crop residues are universally accessible regardless of economic status, as they are the most readily available local resource for both economic groups. Cultivated fodder has a moderate adoption rate of 42%, with only 24% of poor households using it compared to 52% of wealthier ones. This highly significant difference ($\chi^2 = 12.4$, $p < 0.001$) indicates a medium effect size, suggesting that cultivating fodder requires resources such as land, agricultural inputs, and technical knowledge that are substantially less available to economically disadvantaged households. Purchased forest fodder is adopted by 37% of households overall, used much more by poor households (56%) than well-off ones (27%). This statistically significant difference ($\chi^2 = 14.2$, $p < 0.001$) shows a medium effect size and may reflect the affordability of forest fodder and local availability for poorer households who cannot afford commercial feed alternatives.

Reduced livestock numbers are nearly universal (97% overall adoption), with 100% of poor households and 96% of well-off households reporting this practice. The small difference is not statistically significant ($\chi^2 = 2.1$, $p = 0.147$), indicating that reducing herd size is a universal response to feed scarcity across all economic groups, irrespective of household wealth. Changed livestock composition is adopted by 72% of households (65% of poor households and 76% of wealthier ones). This difference shows a trend toward higher adoption among wealthier households but is not statistically significant at the conventional 0.05 level ($\chi^2 = 2.8$, $p = 0.094$). This suggests that changing livestock type is a relatively accessible and flexible adaptation strategy for households across different economic levels. The analysis demonstrates that economic status has a pronounced influence on the adoption of resource-intensive feeding strategies like commercial feed and cultivated fodder, while poorer households show greater reliance on locally available resources like crop residues and forest fodder. Herd reduction appears to be a universal coping mechanism regardless of economic capacity. These findings emphasize the need for inclusive support mechanisms that address both financial constraints and knowledge barriers to improve fodder security for all households, particularly those with limited economic resources.

## Relationships Between Key Variables

Correlation analysis provided insights into the relationships between various factors affecting fodder availability and adaptation strategies (Table 6). The analysis revealed important relationships between variables affecting fodder availability and adaptation strategies in the study area. Fodder availability showed a strong negative correlation with collection time ($r = -0.78$, $p < 0.001$), indicating that when fodder is more readily available, households spend significantly less time gathering it. This suggests that fodder scarcity creates a substantial time

burden on rural families. Household income showed a weak but significant positive correlation with fodder availability ($r = 0.21$, $p < 0.05$), suggesting wealthier households have slightly better access to fodder resources, possibly due to their ability to invest in various fodder acquisition methods. More notably, household income had a moderately strong negative correlation with collection time ($r = -0.34$, $p < 0.01$), showing that higher-income households spend considerably less time collecting fodder, likely because they can afford alternative sources or have more efficient collection methods. Livestock numbers correlated positively with fodder availability ($r = 0.43$, $p < 0.01$), indicating a bidirectional relationship where better fodder access enables larger herds or households with more livestock prioritize securing adequate fodder resources. Education level proved significant, showing positive correlations with both commercial fodder use ($r = 0.48$, $p < 0.01$) and cultivated fodder adoption ($r = 0.45$, $p < 0.01$), demonstrating that more educated households are more likely to purchase commercial fodder and implement fodder cultivation practices, possibly reflecting greater awareness of improved agricultural techniques. Market distance negatively correlated with commercial fodder use ($r = -0.53$, $p < 0.01$) but positively correlated with cultivated fodder adoption ($r = 0.37$, $p < 0.05$), showing that geographical isolation limits access to purchased fodder but encourages self-sufficiency through home-grown alternatives. Household income strongly correlated with commercial fodder use ($r = 0.64$, $p < 0.001$), cultivated fodder adoption ($r = 0.57$, $p < 0.001$), and livestock numbers ($r = 0.36$, $p < 0.05$), highlighting how economic capacity enables households to diversify their fodder management strategies and maintain larger livestock holdings. Collection time was negatively associated with commercial fodder use ($r = -0.28$, $p < 0.05$), cultivated fodder adoption ($r = -0.31$, $p < 0.01$), and livestock numbers ($r = -0.39$, $p < 0.01$), suggesting that high time burdens for fodder collection may restrict households' ability to invest in alternative fodder strategies or maintain optimal herd sizes. These findings illustrate how socioeconomic factors interact with fodder management approaches and could inform targeted interventions to improve fodder availability, particularly for resource-constrained households in the study region.

## Economic Implications of Changing Fodder Practices

The scarcity of traditional fodder and transition to alternative fodder sources has not only reshaped livestock management practices but also had significant economic implications for households in the region. As communities have shifted from reliance on traditional fodder sources to other commercial feed and supplements, the economic burden on households has increased substantially. The average annual expenditure on purchased fodder and feed supplements has surged from 1990 to 2024. Based on household surveys, fodder-related expenditure varied substantially across economic groups. Poor households reported spending approximately 11% of their total income on fodder and feed supplements, compared to 5% among well-off households, indicating a disproportionate economic burden on vulnerable families. This gap reflects not just different spending levels but fundamentally different coping strategies. The wealthier households could afford commercial feeds and cultivated fodder, while poorer households relied more heavily on time-intensive collection of free resources or other alternatives like crop residues. The financial strain goes beyond direct costs. Many poor households have reduced their herd sizes or shifted to less productive but less demanding livestock simply because they could not sustain the feeding expenses. Women in these households face particular challenges, spending significantly more hours each day on fodder collection as traditional sources became scarcer and more distant from villages. Traditionally responsible for fodder collection, women now report spending an average of 2.2 additional hours daily on this task compared to a decade ago. This increased time commitment has implications for women's participation in other productive activities, affecting their overall workload and potentially limiting their opportunities for income generation or personal well-being. The growing economic burden of alternative fodder sources may have broader consequences for rural livelihoods, particularly for low-income households that may struggle to afford increasingly expensive feed. This economic burden of alternative fodder sources presents a critical challenge for rural mountain communities, particularly in regions like the Chamoli district where traditional livestock management practices are rapidly transforming. As a result, there is a need for sustainable, cost-effective alternatives that not only reduce the economic strain on families but also support ecological conservation. Agroforestry practices, improved fodder management, and community-based resource management may offer solutions to mitigate these economic challenges while ensuring fodder security for livestock. Further research into the long-term economic and social implications of changing fodder practices is essential for developing policies that balance the needs of rural communities with environmental sustainability.

**Table 6. Relationship between key variables**

| Variables | Fodder availability | Collection time | Household income | Education level | Market distance |
|---|---|---|---|---|---|
| Fodder availability | 1.00 | | | | |
| Collection time | -0.78*** | 1.00 | | | |
| Household income | 0.21* | -0.34** | 1.00 | | |
| Commercial feed adoption | 0.15 | -0.28* | 0.64*** | 0.48** | -0.53** |
| Cultivated fodder adoption | 0.12 | -0.31** | 0.57*** | 0.45** | 0.37* |
| Livestock numbers | 0.43** | -0.39** | 0.36* | 0.17 | -0.14 |

Note: All chi-square tests conducted with df = 1. Significance level set at $\alpha = 0.05$. Correlation coefficients are Pearson's r.

## DISCUSSION

The findings of this study underscore the significant challenges faced by rural communities in Chamoli district, Uttarakhand. The decline in traditional fodder resources is influenced by multiple environmental and socioeconomic factors. The reduction in livestock numbers, the shift in fodder collection patterns, and the increasing reliance on alternative feed sources represent a complex interplay of ecological, economic, and cultural changes. One of the most striking findings of this study is the significant decline in fodder availability, with a mean reduction of 37% since 1990. This trend is particularly pronounced in higher altitude zones (>2500 m), where climate change-induced factors like reduced snowfall and altered precipitation patterns have had the most severe impact (Aryal et al. 2014). The results align with broader trends observed in the Himalayas, where changes in seasonal weather patterns have led to the degradation of alpine ecosystems, which are critical for the fodder supply in these regions (Sati 2015). Similarly, the middle and lower ecological zones have faced significant pressures from human activities, such as land conversion for agriculture and the proliferation of invasive species, highlighting the multi-dimensional threats to traditional fodder resources (Korner 2004). These findings suggest that each ecological zone experiences distinct, but interconnected, drivers of fodder scarcity. The variation in fodder availability across altitude zones supports the need for tailored management strategies that account for these differential impacts. The shift from forest-based and agricultural by-product fodder collection to alternative feed sources has led to increasing financial and physical burdens for rural households. The doubling of time spent on fodder collection, from 2.1 hours per day in 1990 to 4.3 hours per day in 2024, reflects the increased scarcity of traditional fodder sources and the need for greater mobility to gather feed (Katoch 2022). The geographical pattern of fodder collection, especially the longer distances traveled, suggests that rural households are increasingly forced to rely on distant grazing areas, adding a logistical burden to already strained resources. This phenomenon is not isolated to Chamoli but reflects global patterns where traditional subsistence practices are disrupted due to climate change and resource degradation. Furthermore, the extension of the period of acute fodder shortages from 2.3 months in 1990 to 4.7 months in 2024 highlights the growing vulnerability of rural communities, who now face longer periods of fodder insecurity for their livestock, exacerbating the economic stress faced by these households (Ahmed et al. 2018). The adoption of alternative fodder strategies further exemplifies the socioeconomic divides within the region. Wealthier households, with higher income and better access to markets, are more likely to invest in commercial feeds. In contrast, poorer households rely more on crop residues and purchased forest fodder, often the most accessible and cost-effective options. This divide is consistent with research indicating that the adoption of innovative farming practices, such as purchasing commercial feed or cultivating fodder, is typically constrained by economic resources (Ghimire et al. 2015; Dhakal et al. 2022).

Moreover, while the adoption of crop residues remains widespread across all economic groups, the differences in commercial feed and cultivated fodder use underscore the economic barriers to accessing sustainable fodder solutions. Household income, market access, and education level are critical determinants of the adoption of alternative fodder sources. These factors are consistent with findings from other studies, which have emphasized the role of socioeconomic factors in shaping adaptation strategies to climate change and resource scarcity (Chettri et al. 2024). Specifically, the strong relationship between income and the adoption of commercial feed highlights the importance of economic capital in shaping rural resilience. Additionally, education emerged as a significant predictor of the adoption of both commercial feed and cultivated fodder. This suggests that knowledge and awareness of agricultural practices play a pivotal role in transitioning towards more sustainable fodder management systems (Bwalya et al. 2023; Tulu et al. 2023). Further, ecological changes influencing fodder availability and the fragmentation of forested areas and loss of dense forest are also reasons for this decline. This aligns with the findings of other studies (Kassa et al. 2017; Tripathy 2023), which have observed the encroachment of human settlements and infrastructure, such as roads, into traditionally forested areas, thereby limiting access to forest-based fodder. The fact that many villages are experiencing the most difficulty in accessing fodder is a critical finding and has been observed in various studies globally, such as Paterson et al. 1998; Maleko et al. 2018; Singh et al. 2022; and Dhamodharan et al. 2024. This highlights the tension between conservation goals and the livelihood needs of local communities globally. The economic implications of these changing fodder practices are significant. As households shift to purchasing commercial feeds, the economic burden on rural families has increased substantially, with annual fodder expenses rising. This increase in costs mirrors broader trends in agricultural economies where the growing reliance on external inputs increases household expenditure and reduces economic sustainability (Bist et al. 2024). The higher expenditure on fodder is particularly burdensome for economically disadvantaged households, where fodder-related costs account for a larger proportion of their total household expenditure. This disparity highlights the need for policies that address the financial constraints faced by these households while ensuring equitable access to sustainable fodder solutions. At the same time, the increased workload for women in fodder collection reflects broader socio-cultural dynamics. Women who traditionally bear the responsibility for livestock management are now spending more time on fodder collection (Maikhuri et al. 2011), which limits their ability to participate in other economic activities (Rocheleau 2019). This shift in gender dynamics could have long-term implications for women's empowerment and overall community well-being (Upadhyay 2005).

The findings of this study offer critical insights into the socioeconomic and ecological transformations occurring in the Chamoli district due to the decline of traditional fodder resources. The complex interaction between climate change, land use change, and socioeconomic factors has placed rural communities in a vulnerable position, with increasing pressure on both their time and financial resources. To address these challenges, it is essential to implement targeted policies that promote sustainable fodder management, improve market access, and provide educational and financial support to vulnerable households. Furthermore, future research should explore long-term solutions such as agroforestry, improved pasture management, and community-based resource management systems that can offer sustainable alternatives to the growing reliance on commercial feed and help safeguard the livelihoods of rural communities in the region.

## CONCLUSION

The problems that mountain people face across the Himalayas are reflected in the Chamoli fodder crisis. Environmental degradation, shifting policies, and economic difficulties have altered the once-stable balance of forests, grasslands, and farms that provided enough feed for cattle. The adaptation process to changing fodder conditions is not uniform or equitable. Wealthier households have the option to cultivate fodder crops or purchase commercial feed. In order to cope, poorer households may accept reduced livestock output, reduce herds, or spend more time gathering limited supplies. Since the alternatives accessible to low-income families sometimes include degrading commons or abandoning livestock that have supported families for generations, this imbalance poses a danger of widening inequality and raising environmental problems. From a conservation perspective, people turn to alternatives when established sources do not work, which might lead to new ecological stresses. Because of the close linkages between communities and forests, promoting sustainable fodder production serves both subsistence and conservation. Programs must recognize that fodder is linked to knowledge systems, economic opportunity, resource access, and land governance. These findings extend beyond Chamoli. They show how climate change, forest policies, and economic pressures combine to undermine traditional systems that have sustained Himalayan communities for generations. What is needed instead are approaches that strengthen community control over forests. These approaches must also make commercial inputs affordable for vulnerable households and value women's knowledge and time. In mountain areas, human well-being and ecosystem health cannot be separated. The goal should be sustaining not just livestock numbers but the social fabric and ecological foundations that make mountain life possible.

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