Indian Journal of Agricultural Economics 79: 3 (2024):547-560
DOI:10.63040/25827510.2024.03.015

Comprehensive Evaluation of Fodder Deficits and Carrying Capacity in Livestock Sector of Jammu, Kashmir and Ladakh@

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ABSTRACT

The study addresses fodder scarcity in these regions, which rely heavily on livestock for their economy and livelihood. With Jammu having a fodder deficit of 18.6 per cent, Kashmir 40.6 per cent, and Ladakh 72.9 per cent, the research identifies an aggregate shortfall of 3066.2 thousand tonnes. The paper highlights the urgent need for strategic interventions, such as improving crop yields, adopting sustainable land management, and utilizing advanced technologies like remote sensing and GIS for better fodder management. The study also evaluates the carrying capacity of livestock, revealing a surplus population that exceeds available fodder, thus emphasizing the necessity for improved grazing practices, rotational farming, and silage technology. Furthermore, the findings suggest that leveraging high-yield fodder varieties, such as dual-purpose crops, and adopting hydroponic fodder systems, especially in arid regions like Ladakh, could be effective solutions. This research underscores the importance of interdisciplinary approaches to address fodder shortages and support sustainable livestock development in challenging terrains.

Keywords: Fodder deficit, livestock, carrying capacity, fodder budgeting

JEL codes: Q12, Q15, Q18, Q24

I

INTRODUCTION

With its diverse agricultural operations, India is home to approximately 15 per cent of the global livestock population despite holding only 2.29 per cent of the world's land area. According to the Indian Livestock Census (2019), the total livestock population was over 536 million, including 192.5 million cattle, 109.9 million buffaloes, 74.3 million sheep, 148.9 million goats, and 9.1 million pigs. Compared to the previous Census of 2012, the livestock population has increased by 4.8 per cent. Livestock rearing is predominantly rural, with 514.11 million animals, representing 95.78 per cent of the total livestock population, compared to 4.22 per cent in urban areas. However, India's livestock sector faces significant macro and micro challenges, with balanced fodder supply being a major issue. The sector is grappling with a net deficit of 35.6 per cent in green fodder, 10.95 per cent in dry crop residues, and 44 per cent in concentrate feeds. This deficit is expected to widen as the livestock population grows at an annual rate of 1.23 per cent. Fodder deficits are even more severe at regional levels, primarily due to the shift towards cash crops and the decline in pastoral lands.

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[@]The current study is a part of the research project titled "Ecosystems, Agribusiness and Institutions, component: Inclusive Agricultural Development (Hill and Arid Agriculture)" conducted at SKUAST-Kashmir and sponsored by the ICAR-NIAP.

In hilly and arid regions such as Jammu, Kashmir, and Ladakh, livestock rearing and trade are key economic activities within the agricultural sector. Livestock serves as an essential and quick asset for livelihood sustainability. The livestock population in Jammu, Kashmir, and Ladakh is approximately 12.9 million and is growing at a rate of 1.5 per cent annually, according to the 19th Livestock Census. The main livestock species in these regions include cattle, buffaloes, sheep, goats, and yaks. Cattle and buffaloes are primarily reared for milk production, while sheep and goats are significant for wool and meat. Yaks, predominantly found in the Ladakh region, are crucial due to their adaptability to high-altitude conditions and are valued for their milk, meat, wool, and use in transportation. The expansion of livestock populations in these regions underscores the urgent need for efficient fodder management strategies to meet the increasing demand.

The availability of fodder heavily constrains livestock management in these regions. Due to low per capita income and limited purchasing power within the farming community, fodder crops are primarily cultivated to feed livestock in the form of forage, silage, and hay. Farmers extensively use pastoral lands and local forest coverage to meet fodder requirements. The economic impact of technologies and practices to improve fodder production is significant, especially in regions like Jammu, Kashmir, and Ladakh, where geographic and climatic conditions heavily influence agricultural practices. The rise of the service sector, particularly in tourism, and the diversification into horticulture have adversely impacted fodder availability. Moreover, with the growth of tourism and rapid population increases, the demand for livestock also expands exponentially. This demand is further driven by using animals such as mules, horses, and donkeys to transport tourist goods during pilgrimages, adventure tours, and defence services across Jammu, Kashmir, and Ladakh.

In this context, it is imperative to investigate the current state of fodder resources in these regions, assess the nutritional requirements of livestock, and identify the gaps between fodder demand and supply. Fodder budgeting is critical in sustainable livestock farming and is central to profitability and cash management. This process involves systematic planning and the allocation of resources to ensure an adequate year-round feed supply for animals. It requires assessing available fodder resources, estimating livestock nutritional requirements, and developing strategies to bridge gaps between demand and supply.

Fodder budgeting is particularly significant in Jammu, Kashmir, and Ladakh regions due to their unique geographical and climatic conditions. The high-altitude terrain and extreme weather variations in these areas pose distinct challenges for livestock farming. Farmers in these regions rely heavily on fodder resources to sustain their animals through long winters and limited growing seasons. Research on fodder budgeting in these regions is crucial, given the scarcity of arable land and the dependence on traditional practices for fodder cultivation. This study delves into the intricate dynamics of fodder availability, local crop yields, indigenous forage species, and the impact of climate change on fodder production. By analyzing these factors, the

research aims to develop tailored strategies for efficient fodder management, ensuring the year-round sustenance of livestock in these challenging Himalayan terrains.

II

MATERIALS AND METHODS

Because of the growing livestock population and their significance in various other economic areas, the current study has examined the fodder supply and demand in the Jammu, Kashmir, and Ladakh regions of India. These regions are predominantly agriculture-driven economies and are witnessing drastic transformations in the rise of tourism and service sectors. Thereby, large disruptions are observed in these areas' livestock sector. The study has used secondary data at the regional level regarding land use, area & production under different crops and livestock populations from various livestock census reports from 1982-83 to 2018-19. Also, the pertinent data of livestock and land categories have been used from multiple reports of the Directorate of Economics and Statistics, Government of Jammu & Kashmir, Government of Indi

*Estimation of the Growth Rate***:** The compound annual growth rate (CAGR) for the time series data was calculated using the following log-linear regression model.

$$Y = a + b \log t$$

Where, Y is the dependent variable, t is the time, a is the intercept, and b is the slope coefficient.

Estimation of Availability of Livestock Feed**:** Livestock feed availability was estimated on a dry matter basis, utilizing the grain-to-straw ratio by adopting the methodology used by Wani *et al.* (2014). The availability of green fodder was assessed on various categories such as forage crops, grasses from forests, pastures and grazing lands, and cultivable wastelands.

*Estimation of Livestock Feed Requirement and Gap***:** Following the methodology used by Wani *et al.* (2014) and Chand *et al.* (2015), the livestock feed requirement on a dry matter basis was estimated using data from the Livestock Population Census (2019). Also, for estimation purpose, region-wise livestock populations were converted into adult cattle units (ACUs) following the methodologies outlined by Wani *et al.* (2014) and Chand *et al.* (2015).

III

RESULTS AND DISCUSSION

The current study employs a comprehensive methodology to address several critical aspects of livestock feed management in Jammu, Kashmir, and Ladakh. The study provides a detailed account of available fodder resources across the three regions' various categories by examining the region's inventory. Based on the estimates of the fodder supply in various categories, fodder budgeting has been used to assess the balance between fodder demand and supply, highlighting deficits and surpluses as well.

Besides, the carrying capacity of the livestock sector is evaluated to understand the sustainable limits of livestock populations while keeping available fodder resources in view. Lastly, it delves into the strategic interventions needed for bridging demand and supply gaps. A detailed description of these is provided below.

Trends and Growth in Livestock Population in the Region

The diverse climates of Jammu (Sub-tropical), Kashmir (Temperate), and Ladakh (Cold arid) support a rich array of livestock, including cattle, buffalo, sheep, goats, yaks, and camels, among others. The livestock sub-sector contributes about 5 per cent to J&K's GSVA and offers significant economic benefits, particularly in isolated hilly areas, aiding in poverty alleviation. To understand the livestock sector in the three regions, time series data from 1982-83 to 2017-18 was used to portray the sector's expansion. The livestock population data in aggregate for Jammu, Kashmir, and Ladakh region across several quinquennial census years depicted significant variations between 1982-83 and 2017-18. The total livestock population witnessed fluctuations, increasing to 10986 thousand in 2007-08, then decreasing to 8503 thousand in 2017-18. The cattle population dominated the total livestock population. However, the proportion declined from 39 per cent in 1982-83 to 30 per cent in 2017-18 (Table 1). In aggregate, the percentage share of sheep in the total livestock population increased from 32 per cent in 1982-83 to 38.7 per cent in 2017-18.

TABLE 1. LIVESTOCK POPULATION IN AGGREGATE ('000 NUMBERS) AT DIFFERENT CENSUS AND ITS SHARE IN THE TOTAL POPULATION (%)

Livestock (1)	1982-83 (2)	1988-89 (3)	1992-93 (4)	1997-98 (5)	2002-03 (6)	2007-08 (7)	2012-13 (8)	2017-18 (9)
Cattle	2325.2 (39.0%)	2765.7 (37.3%)	3055 (35.1%)	3177.4 (34.2%)	3083.9 (31.2%)	3443.1 (31.3%)	2798.3 (30.4%)	2550.7 (30.0%)
Buffalo	563.1 (9.5%)	595.3 (8.0%)	732.5 (8.4%)	787.8 (8.5%)	1039.5 (10.5%)	1050.3 (9.6%)	739 (8.0%)	690.82 (8.1%)
Sheep	1908.7 (32.0%)	2493 (33.6%)	2946.9 (33.8%)	3169.5 (34.1%)	3410.7 (34.5%)	4127.1 (37.6%)	3389.5 (36.8%)	3289.5 (38.7%)
Goats	1004 (16.9%)	1396 (18.8%)	1765.5 (20.3%)	1809.5 (19.5%)	2055 (20.8%)	2068.3 (18.8%)	2017.9 (21.9%)	1847.3 (21.7%)
Horses and ponies	97.3 (1.6%)	104 (1.4%)	121.5 (1.4%)	150.5 (1.6%)	171.7 (1.7%)	167 (1.5%)	144.5 (1.6%)	64.7 (1.8%)
Donkey mules	30.3 (0.51%)	34.9 (0.47%)	36.9 (0.42%)	43.3 (0.47%)	64.1 (0.65%)	66.5 (0.61%)	53.7 (0.58%)	26.3 (0.31%)
Camels	3.6 (0.06%)	2.7 (0.04%)	2.8 (0.03%)	3.7 (0.04%)	1.6 (0.02%)	1.5 (0.01%)	0.9 (0.01%)	0.5 (0.01%)
Pigs	2.6 (0.04%)	3.6 (0.05%)	11.9 (0.14%)	111.8 (1.20%)	1.7 (0.02%)	0.9 (1.20%)	2.4 (0.03%)	1.2 (0.01%)
Yaks	20.9 (0.35%)	21.4 (0.29%)	33.6 (0.39%)	33 (0.36%)	71.2 (0.72%)	61.9 (0.56%)	54.493 (0.59%)	32.3 (0.38%)
Total	5955.6	7416.6	8706.6	9286.5	9899.3	10986.7	9200.8	8503.4

Source: Authors Estimations Based on the Time Series Data of Livestock, Govt. of J&K

Similarly, goat populations increased from 16.9 per cent in 1982-83 to 21.7 per cent in 2017-18. Over the period, the equine population of horses and ponies experienced a notable decline in absolute numbers and proportion within the overall Livestock

Population. The yak populations in Jammu, Kashmir, and Ladakh regions have consistently increased from 20 thousand to 32 thousand.

Jammu, Kashmir, and Ladakh are quite diverse in their climate and geography, which creates a unique livestock population pool across the three regions. Cattle, buffalo, sheep, and goats dominate Jammu livestock. Kashmir has a high cattle and sheep population, whereas sheep, goats, and yaks dominate Ladakh. Population fluctuations of the various livestock categories between 1982-83 and 2017-18 across the three regions are given in Table 2.

TABLE 2. REGION-WISE LIVESTOCK POPULATION (000' NUMBERS) AND ITS SHARE IN TOTAL POPULATION (%)

	Jammu		Kashmir		Ladakh	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Livestock	1982-83	2017-18	1982-83	2017-18	1982-83	2017-18
Cattle	1181.7	1327.44	1105.4	1127.599	38.1	95.662
	(34.98%)	(25.55%)	(51.14%)	(43.78%)	(9.17%)	(13.05%)
Buffalo	525.7	676.813	19.5	14.016	17.9	
	(15.56%)	(13.03%)	(0.90%)	(0.54%)	(4.31%)	0
Sheep	843.4	1805.689	893.2	1243.313	172.1	240.506
	(24.96%)	(34.76%)	(41.32%)	(48.28%)	(41.41%)	(32.82%)
Goats	748.2	1328.48	97.2	161.632	158.5	357.2156
	(22.15%)	(25.57%)	(4.50%)	(6.28%)	(38.14%)	(48.75%)
Horses and ponies	45.9	34.814	43.5	23.91	7.9	6.0032
	(1.36%)	(0.67%)	(2.01%)	(0.93%)	(1.90%)	(0.82%)
Donkey mules	21.8	17.834	2.5	2.249	6	6.2296
	(0.65%)	(0.34%)	(0.12%)	(0.09%)	(1.44%)	(0.85%)
Camels	3.3	0.168			0.3	0.3162
	(0.098%)	(0.003%)	0	0	(0.072%)	(0.043%)
Pigs	2.6	1.215				
	(0.08%)	(0.023%)	0	0	0	0
Yaks	5.9	2.825	0.2	2.653	14.8	26.8688
	(0.17%)	(0.05%)	(0.01%)	(0.10%)	(3.56%)	(3.67%)
Total	3378.5	5195.27 8	2161.5	2575.372	415.6	732.8014

Authors Estimations Based on the Time Series Data of Livestock, Govt. of J&K

At aggregate levels, the compound annual growth rate (CAGR) across all livestock categories has been largely fluctuating positively up to 2002-07, followed by negative fluctuations in the CAGR. These trends in the CAGR suggest a complex interplay of factors influencing livestock populations, including economic shifts, changes in agricultural practices, environmental conditions, and shifts in consumer demands, impacting the diverse trends observed in the region's livestock composition over the studied period. In some categories, the fluctuations have been quite drastic compared to the base year, such as horse and ponies, camels, pigs, and yaks (Table 3).

TABLE 3. COMPOUND ANNUAL GROWTH RATE OF LIVESTOCK IN AGGREGATE

(*per cent*)

Livestock (1)	1982-1987 (2)	1987-1992 (3)	1992-1997 (4)	1997-2002 (5)	2002-2007 (6)	2007-2012 (7)	2012-2017 (8)
Cattle	3.53	2.01	0.79	-0.60	2.23	-2.51	-1.84
Buffalo	1.12	4.24	1.47	5.70	0.21	-6.79	-1.34
Sheep	5.49	3.40	1.47	1.48	3.89	-3.86	-0.60
Goats	6.82	4.81	0.49	2.58	0.13	-0.49	-1.75
Horses and ponies	1.34	3.16	4.37	2.67	-0.56	-2.84	-14.84
Donkey & mules	2.87	1.12	3.25	8.16	0.74	-4.16	-13.31
Camels	-5.59	0.73	5.73	-15.44	-0.21	-10.19	-12.14
Pigs	6.72	27.01	56.52	-56.71	-11.87	21.78	-12.88
Yaks	0.47	9.44	-0.36	16.63	-2.76	-2.52	-9.91
Total	4.49	3.26	1.30	1.29	2.11	-3.49	-1.56

Authors Estimations Based on the Time Series Data of Livestock, Govt. of J&K

Across regions and categories, the CAGR of the livestock population revealed interesting changes and patterns over the years (Table 4).

TABLE 4. REGION WISE COMPOUND ANNUAL GROWTH RATE (%) OF LIVESTOCK POPULATION

Livestock (1)	Region (2)	1982-92 (3)	1992-97 (4)	1997-2002 (5)	2002-07 (6)	2007-12 (7)	2012-17 (8)
Cattle	Jammu	2.31	1.81	1.04	1.9	-4.52	-2.31
	Kashmir	3.14	-0.29	-2.67	2.72	-3.83	-1.55
	Ladakh	5.27	1.43	2.34	1.06	1.47	1.89
Buffalo	Jammu	2.38	1.26	7.58	0.12	-6.77	-1.31
	Kashmir	4.81	5.2	-13.74	4.63	-7.63	-2.85
	Ladakh	7.33	1.76	-100	0	0	0
Sheep	Jammu	6.09	1.07	7.05	2.78	-4.96	-2.11
	Kashmir	2.69	2.23	-5.97	6.58	-2.63	1.55
	Ladakh	4.16	0.3	-5.65	2.54	0.67	0.9
Goats	Jammu	6.18	-0.17	1.67	0.79	-0.57	-2.18
	Kashmir	7.07	5.96	2.64	-1.78	-3.36	-6.45
	Ladakh	2.89	-0.89	7.91	-1.44	2.4	2.95
Horses and ponies	Jammu	0.72	1.84	11.68	-0.68	-1.96	-15.77
	Kashmir	3.92	6.17	-5.61	-0.49	-2.8	-15.25
	Ladakh	0.5	4.41	5.25	-0.06	-10.26	-4.9
Donkey mules	Jammu	0.14	3.7	5.72	4.93	-4.23	-13.04
	Kashmir	4	0.53	25.86	-10.43	-1.21	-19.15
	Ladakh	6.35	3.21	5.64	-2.52	-5.45	-11.35
Camels	Jammu	-1.99	5.92	-16.06	-0.79	-13.19	-25.06
	Kashmir	0	0	0	0	0	0
	Ladakh	-10.4	0	0	7.11	8.7	8.12
Pigs	Jammu	16.43	56.52	-56.71	-12.18	22.12	-12.82
	Kashmir	0	0	0	n/a	-10.87	-100
	Ladakh	0	0	0	0	0	0
Yaks	Jammu	7.27	1.15	6.79	0.91	-1.19	-30.36
	Kashmir	17.46	-16.74	22.42	34.97	-6.67	-5.33
	Ladakh	3.41	-0.69	21.34	-5.97	-2.68	-4.46
Total	Jammu	4.27	1.38	3.74	1.67	-4.03	-2.33
	Kashmir	3.21	1.37	-3.59	3.67	-3.29	-0.77
	Ladakh	3.91	0.19	1.13	-0.19	1.04	1.54

Source: Authors Estimations Based on the Time Series Data of Livestock, Govt. of J&K

*Region wise data for 1987-88 not available;

In the Jammu region, cattle and buffalo populations exhibited predominantly positive growth rates up to 2007, demonstrating stability with occasional modest variations. From 2007-08 to 2017-18, there was a decline in the growth rate in all livestock categories. The growth rates of cattle and buffalo in Kashmir exhibited fluctuations, sometimes even declining. Sheep and goats depicted varied growth, suggesting that the possible reasons may be changing preferences or economic factors. However, only sheep showed positive growth in recent years, which was majorly demand-driven. Significantly, horses, ponies, and donkey mules had varying growth rates. Ladakh region in cattle demonstrated decreasing growth rates over time, but the growth was still better than in the other two regions due to changes in consumer preferences. Sheep and goats displayed higher and more consistent growth rates, indicating a potential inclination towards these species due to their adaptability or economic feasibility.

Land Resources Allocated for Fodder Cultivation

Livestock feed is sourced from cultivated and uncultivated lands where private support lands for grazing include grasses from paddy field embankments, fallow lands, and orchards. In Jammu and Kashmir, the lush green forests are crucial support lands for the state's livestock. Table 5 describes the availability of different forms of land in three regions as a source of feed resources.

TABLE 5. AVAILABILITY OF LAND FOR FEED RESOURCES OF JAMMU & KASHMIR & LADAKH

(*'000 ha)*

Particulars	Source	Jammu	Kashmir	Ladakh	J&K
Common support lands	Forest (As per village papers)	638.68	5.25	0.11	644.04
	Barren and uncultivable land	248.48	46.84	27.64	322.96
	Cultivable waste land	116.23	38.71	3.60	158.54
	Land under tree groups	55.05	9.03	2.13	66.21
	Permanent Pastures	73.59	33.83	2.21	109.62
	Non-Agricultural land	174.02	39.58	7.90	221.50
Total		1306.05	173.23	43.59	1522.86
Private support land	Fallow lands	69.41	50.22	2.38	122.00
	Orchards	121.03	213.80	1.03	335.87
	Grass from bunds in paddy fields (5per cent of area)	6.71	6.66	0.00	13.38
Total		197.15	270.68	3.41	471.25
Cultivated fodder	Fodder crops	23.69	13.36	5.73	42.78
Residues from leguminous crops (straw I)	All pulses	10.98	5.16	1.01	17.14
Residues from Coarse grain crops (straw II)	Maize	220.06	69.12	0.00	289.18
Residues from Fine grain crops (straw III)	Millets	0.44	7.87	1.14	9.45
	Paddy straw	134.30	133.28	0.00	267.58
	Wheat straw	242.49	1.27	4.13	247.89
	Barley	9.10	0.02	0.00	9.12
Total		641.05	230.08	12.02	883.14
Forest	Area maintained by Forest dept.	1207.00	813.00	3.00	2023.00
Overall total		3351.2	1486.99	62.02	4900.25

Source: Digest of Statistics Year 2020-21, Govt. of J&K and Ladakh.

Under the common support lands category, around 1522.86 thousand hectares of area is available across the three regions. Similarly, under the private support lands category, which includes fallow lands, orchards, and grass from paddy field bunds, approximately 471.25 thousand hectares of land are available under feed resources. Moreover, cultivated fodder, consisting of fodder crops and residues from different grain crops, is a significant portion, aggregating to around 883.14 thousand hectares. This comprehensive data highlights the diverse sources of feed resources available in the region, which are crucial for assessing fodder availability and planning for livestock sustenance in Jammu, Kashmir, and Ladakh. Jammu has a high dominance of common support lands for feed resources, followed by Kashmir and Ladakh. However, Kashmir has a rich feed resource base from private land support, followed by Jammu and Ladakh.

Fodder Supply

Farmers analyse crop yields, pasture quality, and alternative feed options to create an adequate budget. By considering seasonal variations, weather patterns, and potential contingencies, fodder budgeting aims to provide optimal animal health and productivity while optimizing costs. It is a balancing act that requires foresight and adaptability, crucial for maintaining a sustainable and thriving agricultural ecosystem. Estimating forage yield involves assessing resources such as communal and private grazing lands, cultivated fodder, and crop residues based on the state's land use classification, as outlined in Table 6. The suggested forage yield per hectare has already been adapted from the study of Wani et al. (2014) for calculating fodder availability in terms of dry matter from these diverse resources. Forage yield from crop residues like straws from wheat, paddy & barley, stovers of maize, millet, and legumes are worked out based on extraction ratio, as suggested by Wani et al. (2014), of these cultivated crops and are presented in Table 6.

TABLE 6. FORAGE YIELD ON DRY MATTER BASIS

(*tonnes/ha*)

Source (1)	Yield (2)
Cultivated fodder	8
Grass from bunds in paddy fields	5
Permanent Pastures	3
Fallow Land	2
Arable waste land	1.5
Forest	1.5
Barren & non-arable waste land	1
Orchard	1
Land under tree groups	0.5
Pulses (Legumes)	1.8
Millets (Stovers)	3
Maize (Stovers)	3
Barley (Straw)	3
Wheat (Straw)	6.3
Paddy(Straw)	9

Source: Adapted from Wani et al., 2014.

Table 7 outlines the availability of fodder on a dry matter basis across Jammu, Kashmir, and Ladakh, categorized by various sources. Jammu notably exhibits a higher availability of fodder across multiple categories than Kashmir and Ladakh, which helps intensify livestock in the region. Common support lands contribute significantly to Jammu's fodder reserves, with 1650.01 thousand tonnes, overshadowing the 223.52 thousand tonnes in Kashmir and 41.84 thousand tonnes in Ladakh. Moreover, private support lands yield more in Kashmir, with 347.56 thousand tonnes compared to 293.42 thousand tonnes in Jammu and 5.79 thousand tonnes in Ladakh. Cultivated fodder also favours Jammu, amounting to 342.27 thousand tonnes, while Kashmir and Ladakh stand at 189.55 thousand tonnes and 45.87 thousand tonnes, respectively. Overall, Jammu leads in total fodder availability at 5577.9 thousand tonnes, followed by Kashmir at 2125.8 thousand tonnes and Ladakh at 124.8 thousand tonnes. This data emphasizes regional discrepancies in fodder resources, which are crucial for strategic livestock management, agricultural policies, and resource distribution across these regions.

TABLE 7. AVAILABILITY OF FODDER ON DRY MATTER BASIS FOR JAMMU & KASHMIR & LADAKH

('000 tonnes)

Particulars (1)	Source (2)	Jammu (3)	Kashmir (4)	Ladakh (5)	J&K (6)
Common support lands	Forest (As per village papers)	958.02	7.87	0.16	966.05
	Barren and uncultivable land	248.48	46.84	27.64	322.96
	Cultivable waste land	174.35	58.06	5.40	237.81
	Land under tree groups	27.53	4.51	1.06	33.10
	Permanent Pastures	220.76	101.49	6.62	328.86
	Non-Agricultural land	20.88	4.75	0.95	26.58
Total		1650.01	223.52	41.84	1915.37
Private support land	Fallow lands	138.82	100.43	4.75	244.00
	Orchards	121.03	213.80	1.03	335.87
	Grass from bunds in paddy fields (5 of area)	33.57	33.32	0.00	66.90
Total		293.42	347.56	5.79	646.77
Cultivated fodder	Fodder crops	189.55	106.85	45.87	342.27
Residues from leguminous crops (straw I)	All pulses	19.76	9.29	1.81	30.86
Residues from Coarse grain crops (straw II)	Maize	660.17	207.37	0.00	867.54
Residues from Fine grain crops (straw III)	Millets	1.31	23.61	3.42	28.34
	Paddy straw	1208.68	1199.54	0.00	2408.22
	Wheat straw	1527.67	7.98	26.03	1561.68
	Barley	27.29	0.06	0.01	27.37
Total		3634.44	1554.69	77.15	5266.28
Overall total		5577.9	2125.8	124.8	7828.4
Forest	Area maintained by Forest dept.	1810.50	1219.50	4.50	3034.50

Source: Authors Estimations

Fodder Demand

Livestock productivity relies heavily on feeding practices, feed quality, and fodder quality. Banerjee (1997) recommended fodder doses for the various animal species, forming the basis for calculating the requirements. Table 8 provides an estimation of the annual fodder requirement on a dry matter basis for major livestock categories across the regions of Jammu, Kashmir, and Ladakh,

TABLE 8. FODDER REQUIREMENT ON DRY MATTER BASIS

Livestock	Fodder requirement (kg/animal/day)	Jammu (tonnes/ year)	Kashmir (tonnes/ year)	Ladakh (tonnes/ year)	Aggregate (tonnes/ year)
(1)	(2)	(3)	(4)	(5)	(6)
Cattle/Yaks	8	3884374	3300336	357789	7542499
Buffalo	10	2470367	51158	0	2521526
Equines	8	154468	76384	37105	267957
Sheep/goat	1.5	343324	153841	65450	562616

Source: Authors Estimations

Fodder Deficit

Table 9 details the fodder budgeting on a dry matter basis and presents a comprehensive view of the demand and supply dynamics across three distinct regions: Jammu, Kashmir, and Ladakh. On a cumulative basis, three regions collectively face a feed deficit of 28 per cent. Jammu's elevated demand of 6852.5 thousand tonnes for fodder arises from its robust dairy industry and substantial cattle population, driving the need for a considerable supply. However, limitations in available arable land and water scarcity within the region impede fodder supply by about 5577.9 thousand tonnes, resulting in a noticeable deficit of 1274.7 thousand tonnes which is 18.6 per cent of the demand. Kashmir, characterized by a diversified livestock base, faces challenges such as harsh weather conditions and topographical constraints, leading to a significant deficit in meeting the demand for fodder of about 3581.7 thousand tonnes and supply of only 2125.8 thousand tonnes and thus creation of a deficit of 1456 thousand tonnes, or 40.6 per cent deficit. Ladakh, despite its smaller livestock population, exhibits a notable demand of 460.0 thousand tonnes due to traditional animal husbandry practices, yet supply is hindered by altitude-related challenges and extreme

TABLE 9. FODDER DEFICIT ON DRY MATTER BASIS (‘000 TONNES)

Region	Demand	Supply	Deficit	Deficit (%)
(1)	(2)	(3)	(4)	(5)
Jammu	6852.5	5577.9	1274.7	18.6
Kashmir	3581.7	2125.8	1456.0	40.6
Ladakh	460.3	124.8	335.6	72.9
Total	10894.6	7828.4	3066.2	28.1

Source: Authors Estimations

climatic conditions, while the fodder supply is even less (124.8 thousand tonnes) pegs a huge deficit of 335.6 thousand tonnes or 72.9 per cent of demand. The cumulative deficit of 3066.2 thousand tonnes in aggregate underscores the substantial disparities between demand and supply, influenced mainly by geographic, climatic, and agricultural factors and creating a total deficit of 3066.2 thousand tonnes, representing 28.1 per cent of the total demand on aggregate level. Addressing these discrepancies necessitates interdisciplinary approaches integrating agricultural innovations, climatic adaptation strategies, and livestock management practices to effectively bridge regional fodder deficits.

Carrying Capacity

Carrying capacity in the context of livestock and fodder refers to the maximum sustainable number of animals a particular area or ecosystem can support without depleting its resources, specifically fodder and forage. Table 10 provides a comprehensive overview of the fodder in all three regions. Kashmir region has 2125.768 thousand tonnes of fodder, which is the optimum amount for 833.635 thousand livestock. However, the livestock population is significantly higher at 1451.416 thousand, resulting in a surplus of 617.781 thousand animals, about 74.1 per cent higher than the carrying capacity. Similarly, in the Ladakh region, the available fodder can sustain an optimum of 48.931 thousand livestock. Yet, the actual population is much higher at 254.782 thousand, leading to a substantial surplus of 205.852 thousand. The available feed/fodder in the Jammu region can ideally support 2187.4 thousand livestock. The actual population stands at 2687.055 thousand, resulting in a surplus of 499.655 thousand, around 22.8 per cent more than the recommended. In aggregate, the available fodder can sustain an optimum of 3069.965 thousand livestock. The actual population exceeds this, standing at 4393.253 thousand, resulting in a surplus of 1323.288 thousand animals, about 43.1 per cent of the overshoot population.

TABLE 10. CARRYING CAPACITY OF FODDER CROPS

Region	Total availability of feed and fodder (000t)	Optimum Livestock population (000no.)	Actual Population (000no.)	Surplus population (000no.)	Overshoot population (per cent)
(1)	(2)	(3)	(4)	(5)	(6)
Jammu	5577.9	2187.4	2687.1	499.6	22.8
Kashmir	2125.8	833.6	1451.4	617.8	74.1
Ladakh	124.8	48.9	254.8	205.8	420.7
Total	7828.4	3069.9	4393.2	1323.3	43.1

Source: Authors Estimations.

Overall, the results highlight the divergence between the available fodder resources and livestock populations in different regions. It indicates instances where the current number of livestock exceeds the sustainable capacity supported by available feed and fodder. It emphasizes the need for better management practices or adjustments

in livestock numbers to maintain sustainable agricultural ecosystems. In regions where the livestock population exceeds the carrying capacity dictated by available fodder crops, orchestrating sustainable livestock development necessitates a comprehensive and interdisciplinary approach. Enhanced grazing management practices, such as rotational grazing, offer a viable strategy to optimize pasture utilization and facilitate natural regeneration, mitigating the detrimental impacts of overgrazing. Concurrently, incentivizing cultivating high-yield fodder crops and diversifying crop varieties tailored to the region's climatic conditions can substantially strengthen fodder resources.

Strategic Interventions in Bridging Demand and Supply Gaps

Addressing fodder demand and supply disparities necessitates a holistic approach, acknowledging the diverse landscapes, climate variations, and traditional agricultural practices. By amalgamating innovation, adaptation, and local knowledge, sustainable solutions can be forged to bolster fodder availability, ensuring the thriving sustainability of livestock farming in these challenging Himalayan terrains. These initiatives aim to provide consistent fodder supply, essential not only for livestock sustenance but also for supporting the socio-economic fabric of these regions.

1. Crop improvement and variety development: Advanced approaches in fodder production are essential to bridge the demand-supply gap and enhance livestock nutrition. Utilizing biotechnology and genetic engineering tools is a significant approach in this direction. Studies have shown that high-yielding fodder varieties can increase biomass output significantly, leading to better livestock productivity and higher farmer income.
2. Sustainable cropping systems and Resource Management: Integrating fodder crops into existing cropping systems to maximize land utilization and promote agro-forestry and silvipasture systems can improve fodder production in the three regions. Studies such as Patel *et al.* (2023) and Kumar et al. (2018) have significantly demonstrated an impact on fodder cultivation due to the change in cropping systems and resource management.
3. Application of Remote Sensing & GIS: Technological advancements such as remote sensing and GIS can contribute significantly to effectively managing green pastures. These technologies can provide satellite imagery and aerial photography, provide accurate and timely data on vegetation cover, biomass production, and land use patterns, which can be integrated with GIS to create detailed maps & models for developing adaptive management strategies for the efficiency and sustainability of fodder production systems (Booth & Cox, 2008 and Maurya *et al.*, 2023).
4. Silage Technology: Using silage technology to preserve fodder can reduce losses during the dry season and increase the availability of quality feed. Implementing silage-making practices can help manage seasonal fodder

scarcity, especially in the harsh winters of these regions, ensuring continuous livestock nutrition.

5. Hydroponic Fodder Systems: Studies have evaluated the cost-effectiveness of hydroponic systems, finding them particularly beneficial in arid regions where water and arable land are limited. Hydroponics can produce fodder faster with less water and space, offering substantial cost savings and higher efficiency. In Ladakh, where water scarcity is a significant issue, hydroponic systems could provide a reliable method for fodder production without straining limited water resources.
6. Grassland Rejuvenation: Grassland rejuvenation, particularly in piospheres around water points that are heavily grazed and degraded, can be achieved through a combination of soil restoration techniques, erosion control measures, vegetation management, use of native grasses and legumes, water management, erosion control, and adaptive monitoring (Jones et al., 2015).

IV

CONCLUSION AND POLICY IMPLICATIONS

The study results provide advantageous insights for having a stable and nutritious fodder supply, thereby supporting the sustainability and productivity of livestock farming in the challenging environments of the hill economies of India. The research highlights a critical fodder deficit in Jammu, Kashmir, and Ladakh, which significantly impacts the sustainability of livestock farming in these regions. Jammu faces a deficit of 1274.7 thousand tonnes (18.6 cent), Kashmir 1456.0 thousand tonnes (40.6 cent), and Ladakh 335.6 thousand tonnes (72.9 per cent). This cumulative deficit of 3066.2 thousand tonnes underscores the pressing need for effective fodder management strategies to ensure the sustainability of livestock farming. Based on the results, the study advocates for sustainable fodder management strategies and leveraging innovative technologies. Key areas of focus include the development of dual-purpose crop varieties, such as sorghum, which can provide grain and fodder. The application of biotechnological tools to create genetically engineered varieties resistant to abiotic and biotic stresses. Additionally, integrating precision agriculture technologies, such as remote sensing and GIS, can optimize crop monitoring, irrigation, and nutrient management, enhancing forage production efficiency.

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