

Marketing Dynamics and Resource Use Efficiency of Maize Fodder in the Himalayan Region

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ABSTRACT

Maize fodder plays a vital role in sustaining livestock productivity, particularly in regions facing chronic fodder deficits such as India. The present study evaluates the economic viability, marketing dynamics, and resource use efficiency of maize fodder cultivation across three agro-climatic zones – temperate, intermediate, and sub-tropical – of the Jammu region of Jammu and Kashmir. The study was conducted during the agricultural year 2024–25 using a multistage random sampling technique, covering 120 farmers, and primary data were collected through structured surveys and analysed using cost-benefit analysis, marketing efficiency measures, and the Cobb–Douglas production function. The findings revealed that maize fodder cultivation is economically viable across all zones, with cost-benefit ratios ranging from 1:2.39 in the intermediate zone to 1:3.09 in the sub-tropical zone, indicating higher profitability in the latter owing to lower cultivation costs and higher yields. The marketing analysis identified two channels, of which the direct channel (Producer → Consumer) was more efficient, being characterised by lower marketing costs, reduced price spread, and a higher producer's share in the consumer's rupee. Resource use efficiency analysis showed that seed was consistently under-utilised across all three zones, while farmyard manure (FYM), irrigation, and plant protection were over-utilised; fertilizer and labour were under-utilised in the temperate and intermediate zones but over-utilised in specific contexts of the sub-tropical zone. All three zones exhibited decreasing returns to scale ($\Sigma\beta_i < 1$). The study highlights the need to reallocate inputs – increasing use of the under-utilised inputs and rationalising the over-utilised ones – while promoting direct marketing channels to enhance farmers' income. However, the findings are limited to selected districts of the Jammu region and are based on cross-sectional data for a single agricultural year, which may restrict their generalisability.

Keywords: Maize fodder, Resource use efficiency, Cobb–Douglas production function, Marketing efficiency, Price spread, Cost-benefit analysis, Jammu region.

Agriculture and livestock farming are deeply intertwined and serve as major income sources for rural populations globally (Dagar, 2017). Animal nutrition relies on green fodder, dry crop residues, and concentrates; a deficiency in any of these

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drastically reduces animal productivity (Zakirova *et al.* 2020). Optimising fodder supply is critical, as feed accounts for 55–60 per cent of cattle-rearing expenses (Aligazieva *et al.* 2020).

Developed nations manage this challenge effectively. The United States concentrates production, with just five states accounting for 75 per cent of grain corn revenue in order to reduce transport costs (Wolf *et al.* 2021), while the European Union derives 25 per cent of its feed from food-sector by-products, including imported corn gluten (9%) and citrus waste (2%) (Gaillard *et al.* 2020). Globally, feed production reached 1187.7 million tonnes in 2021 (+1%), with the top ten nations accounting for 63 per cent of the supply. China leads at 240 million tonnes (+5%), followed by the USA (215.9 Mt), Brazil (77.6 Mt), and India (39.3 Mt).

Despite leading the world in total milk production, India's per-animal productivity is 20–60 per cent below the global average of 2238 kg/year – a gap primarily caused by severe malnutrition and feed shortages (Vijay *et al.* 2018). India houses 17.5 per cent of the world's human population and nearly 20 per cent of the world's livestock on just 2.3 per cent of the planet's land area. Furthermore, the area under fodder farming has stagnated at 4 per cent (8.5 million hectares) for decades. Consequently, India faces massive national shortfalls: 35.6 per cent in green fodder, 10.5 per cent in dry crop leftovers, and 44 per cent in concentrate feed ingredients (IGFRI, 2015). By 2050, India is projected to require 1012 million tonnes of green fodder and 631 million tonnes of dry fodder, leaving anticipated deficits of 18.4 and 13.2 per cent, respectively (Halli *et al.* 2018).

Against this backdrop, understanding the economics of maize fodder – one of the most widely cultivated summer fodder crops in the Himalayan region – assumes strategic importance. The Jammu region of Jammu and Kashmir, with its distinct temperate, intermediate, and sub-tropical agro-climatic zones, offers an ideal setting to examine zone-specific patterns of production economics, marketing dynamics, and resource use efficiency. Accordingly, the present study was undertaken with the following objectives: (i) to evaluate the economic viability of maize fodder cultivation across different agro-climatic zones of the Jammu region; (ii) to analyse the marketing dynamics of maize fodder, including

price trends, marketing channels, and associated constraints; and (iii) to assess the resource use efficiency of maize fodder production by estimating the relationship between inputs and output using an econometric approach.

LITERATURE REVIEW

Economics of fodder cultivation

Singh *et al.* (2016) identified maize as a stable and adaptable fodder crop with consistent returns across agro-climatic regions of India, reporting cost-benefit ratios that established fodder maize as an economically remunerative crop. Halli *et al.* (2018) reviewed agronomic advances for fodder security in semi-arid zones of India and emphasised the growing gap between fodder demand and supply, arguing for productivity-enhancing interventions. Singh *et al.* (2019) documented that crop diversification, including inclusion of fodder crops in the rice-wheat system, improved sustainability and livelihood security of farm households.

Fodder, animal nutrition, and livestock productivity

Dagar (2017) highlighted the potential of degraded lands for fodder production, particularly to reduce pressure on cropped area. Zakirova *et al.* (2020) demonstrated that balanced nutrition through appropriate fodder is critical for improving livestock productivity, and Vijay *et al.* (2018) reported that quality seed and vegetative multiplication innovations in forage grasses can substantially raise dry-matter output. Aligazieva *et al.* (2020) underscored the economic importance of feed in livestock production systems, noting that feed constitutes the largest cost component in cattle rearing.

Global feed economics

Wolf *et al.* (2021) analysed the regional concentration of grain-corn production in the United States and its transport-cost implications, while Gaillard *et al.* (2020) documented the growing role of food-industry by-products in the European feed supply chain. These studies collectively suggest that feed supply optimisation is central to the economics of livestock systems worldwide.

Marketing dynamics and efficiency

Acharya and Agarwal (2004) proposed the widely-used marketing efficiency framework based on net price received by the producer, marketing margin, and marketing cost. This framework has been extensively applied in Indian agricultural marketing studies to compare channels on the basis of producer's share, price spread, and overall efficiency. The consistent finding across such studies is that direct marketing channels enhance producer welfare by curtailing intermediaries.

Resource use efficiency and the Cobb–Douglas approach

The Cobb–Douglas production function, originally proposed by Cobb and Douglas (1928), remains the most widely used functional form for estimating input elasticities and returns to scale in agricultural production research. Resource use efficiency is conventionally evaluated by comparing the marginal value product (MVP) of each input with its marginal factor cost (MFC), following the neoclassical rule of profit-maximisation. A ratio greater than unity indicates under-utilisation, while a ratio less than unity indicates over-utilisation. Despite this well-established framework, zone-specific evidence on resource use efficiency in maize fodder cultivation in the Himalayan Jammu region remains scarce — a gap the present study seeks to address.

METHODS

Study area and sampling

The study was conducted in the Jammu region of the Union Territory of Jammu and Kashmir during the agricultural year 2024–25. To capture climatic diversity, three agro-climatic zones — sub-tropical, intermediate, and temperate — were purposively selected. A multistage random sampling technique was employed: two blocks per zone, two villages per block, and ten farmers per village, resulting in a total sample of 120 respondents. Farmer lists were prepared with the assistance of the Department of Agriculture, Jammu.

Data collection

Primary data were collected through structured

surveys and personal interviews using a pre-tested questionnaire. Secondary data were obtained from official publications such as the Economic Survey, Digest of Statistics, and Annual Reports of the Department of Agriculture, Jammu and Kashmir.

Data Analysis

Cost concepts and profitability measures

The Commission for Agricultural Costs and Prices (CACP) cost concepts were applied to estimate and compare costs across zones:

- ♦ Operational paid-out costs (Cost A_1): hired labour, seeds, fertilizers, machinery use, pesticides, depreciation, irrigation, and miscellaneous expenses.
- ♦ Implicit and fixed costs (Cost B_1, B_2, C_1, C_2): interest on fixed capital, rental value of owned land, and imputed family labour.
- ♦ Comprehensive total cost (Cost C_3): Cost C_2 plus a managerial input of 10 per cent of Cost C_2 .

Profitability was assessed using the following income measures:

- ♦ Farm Business Income = Gross income – Cost A_1
- ♦ Farm Labour Income = Gross income – Cost B_1
- ♦ Net Income = Gross income – Cost C_3

Analysis of marketing dynamics

Marketing dynamics were analysed using marketing cost, marketing margin, price spread, producer's share in consumer's rupee, and marketing efficiency across the identified channels.

Marketing cost: $C = C_p + \sum C_{mi}$, where C is the total marketing cost, C_p is the cost incurred by the producer and C_{mi} is the cost incurred by the i^{th} intermediary.

Marketing margin (absolute): $A_{mi} = P_{ri} - (P_{pi} + C_{mi})$.

Percentage margin: $P_{mi} = [(P_{ri} - (P_{pi} + C_{mi})) / P_{ri}] \times 100$.

Price spread: Price Spread = $[(P_c - P_f) / P_c] \times 100$.

Producer's share in consumer's rupee: $PS (\%) = (P_f / P_c) \times 100$.

Marketing efficiency (Acharya and Agarwal, 2004):
 $ME = NPP / (MM + MC)$, where NPP is the net price received by the producer, MM is the marketing margin, and MC is the marketing cost.

Cobb–Douglas production function and resource use efficiency

Resource use efficiency in maize fodder production was estimated separately for each zone using the Cobb–Douglas production function, specified as:

$$Y = a \cdot X_1^{b_1} \cdot X_2^{b_2} \cdot X_3^{b_3} \cdot X_4^{b_4} \cdot X_5^{b_5} \cdot X_6^{b_6} \cdot e^u$$

In log-linear form:

$$\ln Y = \ln a + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 \ln X_6 + u$$

where:

Y = Output of maize fodder (q/ha);

X_1 = Seed (kg/ha);

X_2 = Labour (man-days/ha);

X_3 = Fertilizer (kg/ha, nutrient basis);

X_4 = FYM (q/ha);

X_5 = Irrigation (number of irrigations);

X_6 = Plant Protection (₹/ha);

b_i = Output elasticity of the i^{th} input.

Resource use efficiency (RUE) was estimated as:

$$RUE = MVP / MFC$$

where the marginal value product was computed as:

$$MVP = b_i \times (\bar{Y} / \bar{X}_i) \times P_y$$

with b_i the estimated regression coefficient, $\bar{Y}$ the geometric mean of output, $\bar{X}_i$ the geometric mean of the i^{th} input, and P_y the price of the output.

Decision criteria for input use were:

- ♦ $RUE > 1 \rightarrow$ Under-utilisation of the resource (scope to increase use);
- ♦ $RUE < 1 \rightarrow$ Over-utilisation of the resource (use should be reduced);
- ♦ $RUE = 1 \rightarrow$ Optimal utilisation.

RESULTS

Socio-economic profile of respondents

The descriptive statistics for the sampled farmers are summarised in Table 1. The average landholding was 0.38 ha, and the mean age of respondents was 47.57 years with a family size of 4.98 members. The average education attained was 5.59 years and mean farming experience was 37.57 years, with respondents' distance from the market averaging 9.31 km and the average number of milch cows per household being 2.78.

Economics of maize fodder cultivation

Table 2 presents the block-wise cost structure, yield, and returns of maize fodder cultivation in the Bhaderwah and Kishtwar blocks of the temperate zone. Cost A_1 , comprising all paid-out costs, was ₹ 35439.24/ha in Bhaderwah and ₹ 35470.91/ha in Kishtwar; since no land was leased in, Cost A_2 remained the same. Cost B_1 , incorporating interest on fixed capital, was ₹ 40010.66/ha and ₹ 40173.04/ha respectively, while Cost B_2 , which includes the rental value of owned land, rose to ₹ 48008.37/ha and ₹ 48423.75/ha. Cost C_1 (B_1 plus imputed family labour) was ₹ 46005.56/ha in Bhaderwah and ₹ 48152.12/ha in Kishtwar, whereas Cost C_2 stood at ₹ 54003.27/ha and ₹ 56402.83/ha. After adding a 10 per cent managerial cost, the total cost (C_3) reached ₹ 105409.16/ha in Bhaderwah and ₹ 110195.23/ha in Kishtwar, with an overall average of ₹ 107802.19/ha. The overall yield averaged 536.38 q/ha, generating gross returns of ₹ 134094.57/ha. The cost-benefit ratio of 1:2.42 indicates that maize fodder cultivation is economically viable in the temperate zone.

Table 3 depicts the block-wise cost structure, yield, and returns of maize fodder cultivation in the Reasi and Chenani blocks of the intermediate zone. Cost A_1 , representing all paid-out costs, amounted to ₹ 37977.24/ha in Reasi and ₹ 40882.46/ha in Chenani; as no land was leased in, Cost A_2 remained unchanged. Cost B_1 was ₹ 42761.33/ha and ₹ 45833.07/ha respectively. Inclusion of the rental value of land raised Cost B_2 to ₹ 50102.24/ha in Reasi and ₹ 53417.44/ha in Chenani. Cost C_1 was ₹ 51189.36/ha in Reasi and ₹ 54886.57/ha in Chenani, while Cost C_2 stood at ₹ 58530.27/ha and ₹ 62470.93/ha.

Table 1: Descriptive statistics of respondents' socio-economic characteristics

Particular	Average	Std. Dev.	S.E.	Kurtosis	Skewness	Minimum	Maximum
Total land (ha)	0.38	0.17	3.00	-0.94	0.82	0.20	0.75
Age (years)	47.57	10.76	3.00	-0.29	0.04	25.00	71.00
Family size	4.98	1.06	3.00	-0.62	-0.23	3.00	7.00
Education (years)	5.59	5.14	3.00	-1.01	0.37	0.00	15.00
Farming experience (years)	37.57	10.76	3.00	-0.29	0.04	15.00	61.00
KCC holders	0.36	0.48	3.00	-1.69	0.58	0.00	1.00
Soil health card holder	0.21	0.41	3.00	0.15	1.47	0.00	1.00
Distance from market (km)	9.31	3.00	3.00	-0.83	0.15	3.00	16.00
No. of cows	2.78	1.59	3.00	2.92	1.66	1.00	8.00

Source: Primary data collected through survey.

Table 2: Block-wise cost structure, yield, and returns of maize fodder in the temperate zone (₹/ha)

Particular	Bhaderwah (<i>n</i> =20)	Kishtwar (<i>n</i> =20)	Overall (<i>n</i> =40)
Hired labour	4185.37	4228.72	4207.05
Seed cost	3821.43	3946.81	3884.12
FYM	1364.80	1409.57	1387.19
Fertilizer	3684.95	3841.76	3763.35
Plant protection	909.86	939.72	924.79
Irrigation	539.55	557.25	548.40
Tools	11428.57	11914.89	11671.74
Interest on working capital	1037.38	1073.55	1055.47
Depreciation	8012.39	7088.78	7550.59
Miscellaneous	454.93	469.86	462.40
Total Cost A ₁	35439.24	35470.91	35455.08
Total Cost A ₂ (A ₁ + Rent LI)	35439.24	35470.91	35455.08
Interest on fixed capital @10%	4571.43	4702.13	4636.78
Total Cost B ₁	40010.66	40173.04	40091.86
Rental value of owned land	7997.70	8250.71	8124.21
Cost B ₂ (B ₁ + ROL)	48008.37	48423.75	48216.06
Imputed value of family labour	5994.90	7979.08	6986.99
Total Cost C ₁ (B ₁ + IVFL)	46005.56	48152.12	47078.84
Cost C ₂ (B ₂ + IVFL)	54003.27	56402.83	55203.05
C ₃ (C ₂ + 10% managerial)	5400.33	5640.28	5520.31
Total cost	105409.16	110195.23	107802.19
Total yield (q/ha)	527.72	545.04	536.38
Gross return (₹/ha)	131930.27	136258.87	134094.57
Return over variable cost	26521.12	26063.64	26292.38
Cost-benefit ratio	1:2.44	1:2.42	1:2.42

Source: Primary data collected through survey.

Table 3: Block-wise cost structure, yield, and returns of maize fodder in the intermediate zone (₹/ha)

Particular	Reasi (<i>n</i> =20)	Chenani (<i>n</i> =20)	Overall (<i>n</i> =40)
Hired labour	4153.41	4291.15	4222.28
Seed cost	4056.82	4191.36	4124.09
FYM	1448.86	1496.91	1472.89
Fertilizer	3911.93	7372.80	5642.37
Plant protection	965.91	997.94	981.93
Irrigation	572.78	591.78	582.28
Tools	12613.64	12345.68	12479.66
Interest on working capital	1074.06	1123.02	1098.54
Depreciation	8683.02	8791.14	8737.08
Miscellaneous	496.81	480.76	488.79
Total Cost A ₁	37977.24	40882.46	39429.85
Total Cost A ₂ (A ₁ + Rent LI)	37977.24	40882.46	39429.85
Interest on fixed capital @10%	4784.09	4950.61	4867.35
Total Cost B ₁	42761.33	45833.07	44297.20
Rental value of owned land	7340.91	7584.36	7462.64
Cost B ₂ (B ₁ + ROL)	50102.24	53417.44	51759.84
Imputed value of family labour	8428.03	9053.50	8740.77
Total Cost C ₁ (B ₁ + IVFL)	51189.36	54886.57	53037.97
Cost C ₂ (B ₂ + IVFL)	58530.27	62470.93	60500.60
C ₃ (C ₂ + 10% managerial)	5853.03	6247.09	6050.06
Total cost	115572.65	123604.60	119588.63
Total yield (q/ha)	569.89	588.79	579.34
Gross return (₹/ha)	142471.59	147196.50	144834.05
Return over variable cost	26898.94	23591.90	25245.42
Cost-benefit ratio	1:2.43	1:2.36	1:2.39

Source: Primary data collected through survey.

ha. With the 10 per cent managerial cost, total Cost C₃ reached ₹ 115572.65/ha in Reasi and ₹ 123604.60/ha in Chenani. The overall average yield was 579.34 q/ha, generating gross returns of ₹ 144834.05/ha. The cost-benefit ratio of 1:2.39 indicates economic viability in both blocks.

Table 4 depicts the block-wise cost structure, yield, and returns of maize fodder cultivation in the Samba and Satwari blocks of the sub-tropical zone. Cost A₁ was ₹ 32104.31/ha in Samba and ₹ 33364.10/ha in Satwari; as no land was leased in, Cost A₂ remained the same. Cost B₁ increased to ₹ 35302.84/ha and ₹ 36547.44/ha, while inclusion of the rental value of land raised Cost B₂ to ₹ 42691.73/ha and ₹ 44393.73/ha respectively. Cost C₁ was ₹ 40756.27/ha in Samba and ₹ 41026.60/ha in Satwari, while Cost C₂ was ₹ 48145.16/ha and ₹ 48872.90/ha. Including the

10 per cent managerial cost, total Cost C₃ was ₹ 93715.94/ha in Samba and ₹ 94786.79/ha in Satwari, with an overall average of ₹ 94251.37/ha. The average yield was higher in Satwari (619.44 q/ha) than in Samba (583.33 q/ha), producing higher gross returns. The overall cost-benefit ratio of 1:3.09 confirms that maize fodder cultivation is highly profitable in both blocks of the sub-tropical zone.

Maize fodder was economically viable across all three zones, with cost-benefit ratios ranging from 1:2.39 in the intermediate zone to 1:3.09 in the sub-tropical zone. Higher profitability in the sub-tropical zone was due to a lower cultivation cost (₹ 94251.37/ha) and a higher average yield (601.39 q/ha). This finding aligns with Singh *et al.* (2016), who identified maize as a stable and adaptable fodder crop with consistent returns across agro-climatic regions.

Table 4: Block-wise cost structure, yield, and returns of maize fodder in the sub-tropical zone (₹/ha)

Particular	Samba (n=20)	Satwari (n=20)	Overall (n=40)
Hired labour	6416.67	6659.03	6537.85
Seed cost	4083.33	4336.11	4209.72
FYM	1458.33	1548.61	1503.47
Fertilizer	3546.67	3766.22	3656.45
Plant protection	972.22	1032.41	1002.32
Irrigation	486.11	516.20	501.16
Tools	8161.76	8354.17	8257.97
Interest on working capital	1005.00	1048.51	1026.76
Depreciation	5488.10	5586.64	5537.37
Miscellaneous	486.11	516.20	501.16
Total Cost A ₁	32104.31	33364.10	32734.21
Total Cost A ₂ (A ₁ + Rent LI)	32104.31	33364.10	32734.21
Interest on fixed capital @10%	3198.53	3183.33	3190.93
Total Cost B ₁	35302.84	36547.44	35925.14
Rental value of owned land	7388.89	7846.30	7617.60
Cost B ₂ (B ₁ + ROL)	42691.73	44393.73	43542.73
Imputed value of family labour	5453.43	4479.17	4966.30
Total Cost C ₁ (B ₁ +IVFL)	40756.27	41026.60	40891.44
Cost C ₂ (B ₂ + IVFL)	48145.16	48872.90	48509.03
C ₃ (C ₂ + 10% managerial)	4814.52	4887.29	4850.91
Total cost	93715.94	94786.79	94251.37
Total yield (q/ha)	583.33	619.44	601.39
Gross return (₹/ha)	145833.33	154861.11	150347.22
Return over variable cost	52117.39	60074.32	56095.86
Cost-benefit ratio	1:3.03	1:3.17	1:3.09

Source: Primary data collected through survey.

Marketing dynamics of maize fodder

Table 5 presents the zone-wise marketable and marketed surplus of maize fodder. The marketable surplus was highest in the sub-tropical zone (360.83 q/ha), followed by the intermediate (260.70 q/ha) and temperate (187.73 q/ha) zones, indicating that farmers in the sub-tropical zone retained proportionally less produce for home consumption.

Table 6 shows the marketing channels adopted by sample farmers. Channel-I (Producer → Consumer) was most preferred in the temperate zone, where 30 farmers (75%) adopted direct marketing, followed by the intermediate zone (65%). In contrast, the sub-tropical zone showed greater reliance on Channel-II, with 26 farmers (65%) marketing through village agents. The findings suggest that intermediary involvement was more pronounced in the sub-tropical zone, whereas direct producer-

consumer linkages dominated in the intermediate and temperate zones.

Table 7 presents channel-wise marketing costs across the three zones. At the producer level, marketing costs were higher in Channel-I than in Channel-II in all zones, driven by greater expenditure on loading and unloading, transportation, and weighing. Producer-level costs rose from ₹ 31.00 in the sub-tropical zone to ₹ 39.00 in the temperate zone under Channel-I. At the village-agent level, costs were incurred only in Channel-II in the form of commissions, which rose from ₹ 10.00 in the sub-tropical zone to ₹ 14.00 in the temperate zone. Retailer-level marketing costs were also incurred only in Channel-II, due to packaging and transportation. Consequently, total marketing costs were higher in Channel-II than in Channel-I across all zones, indicating that intermediary involvement significantly increases the marketing cost burden.

Table 5: Zone-wise marketable and marketed surplus of maize fodder

Sl. No.	Zone	Marketable Surplus (q/ha)	Marketed Surplus (q/ha)
1	Sub-tropical Zone	360.83	354.00
2	Intermediate Zone	260.70	253.00
3	Temperate Zone	187.73	174.00

Source: Primary data collected through survey.

Table 6: Marketing channels of maize fodder in the sub-tropical, intermediate, and temperate zones ($n = 120$)

Channel	Marketing Pathway	Sub-tropical Zone		Intermediate Zone		Temperate Zone	
		No. of Farmers	Percentage	No. of Farmers	Percentage	No. of Farmers	Percentage
Channel-I	Producer → Consumer	14	35%	26	65%	30	75%
Channel-II	Producer → Village agent → Consumer	26	65%	14	35%	10	25%

Source: Primary data collected through survey.

Table 7: Channel-wise marketing costs of maize fodder in the sub-tropical, intermediate, and temperate zones (₹/quintal)

Sl. No.	Functionary / Cost item	Sub-tropical		Intermediate		Temperate	
		Ch-I	Ch-II	Ch-I	Ch-II	Ch-I	Ch-II
1	<i>Marketing cost at producer level</i>						
	(i) Loading & unloading	10.00	7.00	12.00	8.00	14.00	10.00
	(ii) Cost of gunny bag	4.00	3.00	4.00	3.00	4.00	3.00
	(iii) Transportation	16.00	10.00	18.00	12.00	20.00	14.00
	(iv) Weighing	1.00	2.00	1.00	2.00	1.00	2.00
	Sub-total (A)	31.00	22.00	35.00	25.00	39.00	29.00
2	<i>Marketing cost at village agent level</i>						
	(i) Commission	0.00	10.00	0.00	12.00	0.00	14.00
	Sub-total (B)	0.00	10.00	0.00	12.00	0.00	14.00
3	<i>Marketing cost at retailer level</i>						
	(i) Packaging, loading & unloading	0.00	6.00	0.00	7.00	0.00	8.00
	(ii) Transportation	0.00	15.00	0.00	17.00	0.00	19.00
	Sub-total (C)	0.00	21.00	0.00	24.00	0.00	27.00
	Total Marketing Cost (A+B+C)	31.00	53.00	35.00	61.00	39.00	70.00

Source: Primary data collected through survey.

Table 8 presents the price spread across marketing channels. In Channel-I, direct sales resulted in the absence of intermediaries and marketing margins; the net price received by the producer was ₹ 249.00, ₹ 255.00, and ₹ 256.00 in the sub-tropical, intermediate, and temperate zones respectively. In Channel-II, the involvement of village agents and retailers led to higher marketing costs and margins, ultimately widening the price spread. Consequently, the price

paid by consumers was higher in Channel-II across all zones.

The zone-wise marketing efficiency, margins, and costs are presented in Table 9. In Channel-I, where producers sold directly to consumers, marketing margins were nil and marketing costs were comparatively lower (₹ 31.00, ₹ 35.00, and ₹ 39.00 in the sub-tropical, intermediate, and

Table 8: Price spread of maize fodder across marketing channels in the sub-tropical, intermediate, and temperate zones (₹/quintal)

Sl. No.	Particulars	Sub-tropical		Intermediate		Temperate	
		Ch-I	Ch-II	Ch-I	Ch-II	Ch-I	Ch-II
1	Producer's sale price	280.00	260.00	290.00	270.00	295.00	280.00
2	Marketing cost at producer level	31.00	22.00	35.00	25.00	39.00	29.00
3	Net price received by producer	249.00	238.00	255.00	245.00	256.00	251.00
4	Purchase price of village agent	0.00	260.00	0.00	270.00	0.00	280.00
5	Marketing cost at village agent level	0.00	10.00	0.00	12.00	0.00	14.00
6	Village agent sale price	0.00	290.00	0.00	295.00	0.00	310.00
7	Village agent margin	0.00	20.00	0.00	13.00	0.00	16.00
8	Purchase price of retailer	0.00	290.00	0.00	295.00	0.00	310.00
9	Marketing cost at retailer level	0.00	21.00	0.00	24.00	0.00	27.00
10	Retailer sale price	0.00	323.00	0.00	334.00	0.00	347.00
11	Retailer margin	0.00	12.00	0.00	15.00	0.00	10.00
12	Price paid by consumer	280.00	323.00	290.00	334.00	295.00	347.00
13	Total marketing margin	0.00	32.00	0.00	28.00	0.00	26.00

Source: Primary data collected through survey.

Table 9: Marketing efficiency, marketing margin, and marketing cost of maize fodder across zones (₹/quintal)

Sl. No.	Particulars	Sub-tropical		Intermediate		Temperate	
		Ch-I	Ch-II	Ch-I	Ch-II	Ch-I	Ch-II
1	Producer sale price (₹/q)	280.00	260.00	290.00	270.00	295.00	280.00
2	Marketing margin (₹/q)	0.00	32.00	0.00	28.00	0.00	26.00
3	Marketing cost (₹/q)	31.00	53.00	35.00	61.00	39.00	70.00
4	Marketing efficiency	8.03	2.80	7.29	2.75	7.56	2.61
5	Price spread (%)	11.07	26.32	12.07	26.65	13.22	27.67

Source: Primary data collected through survey.

temperate zones respectively). This resulted in high marketing efficiency values of 8.03, 7.29, and 7.56 in the respective zones. In contrast, Channel-II involved intermediaries, leading to higher marketing margins (₹ 32.00, ₹ 28.00, and ₹ 26.00) and marketing costs (₹ 53.00, ₹ 61.00, and ₹ 70.00). Consequently, marketing efficiency declined to 2.80, 2.75, and 2.61 respectively. The higher price spread observed in Channel-II confirms lower marketing efficiency due to the intermediation.

Resource use efficiency of maize fodder production

The Cobb–Douglas production function was estimated separately for the temperate, intermediate, and sub-tropical zones to capture zone-specific

input–output relationships (Table 10). The coefficient of multiple determination (R^2) was 0.870, 0.758, and 0.850 for the temperate, intermediate, and sub-tropical zones respectively, indicating that the specified set of six explanatory variables jointly explained 87.0, 75.8, and 85.0 per cent of the total variation in maize fodder yield. The F-statistics were highly significant ($p < 0.01$) across all three zones, confirming the overall goodness-of-fit and the joint significance of the estimated models.

In the temperate zone, all six inputs were positive and statistically significant, with labour ($\beta = 0.263$) and fertilizer ($\beta = 0.211$) emerging as the most responsive factors. The intermediate zone showed significant elasticities for seed, labour, fertilizer, and FYM, while irrigation was statistically non-

Table 10: Estimated Cobb–Douglas Production Function for maize fodder across agro-climatic zones of Jammu & Kashmir

Independent Variable	Temperate Zone	Intermediate Zone	Subtropical Zone
Intercept	1.708*** (0.168)	2.321*** (0.213)	1.416*** (0.234)
Seed (X_1)	0.184*** (0.037)	0.155*** (0.044)	0.090** (0.037)
Labour (X_2)	0.263*** (0.040)	0.231*** (0.040)	0.020 ns (0.031)
Fertilizer (X_3)	0.211*** (0.027)	0.087*** (0.028)	0.329*** (0.039)
FYM (X_4)	0.110*** (0.024)	0.074** (0.034)	0.194*** (0.034)
Irrigation (X_5)	0.056*** (0.015)	0.009 ns (0.020)	0.048*** (0.012)
Plant Protection (X_6)	0.062** (0.027)	0.061* (0.030)	0.095*** (0.029)
R^2	0.870	0.758	0.850
Adjusted R^2	0.847	0.714	0.823
F -statistic	36.91***	17.19***	31.12***
$\Sigma\beta_i$ (Returns to Scale)	0.887	0.619	0.776
Nature of Returns	DRS	DRS	DRS
No. of Observations (N)	40	40	40

Note: Figures in parentheses are standard errors. ***, **, * indicate statistical significance at 1%, 5%, and 10% probability levels respectively; *ns* = not significant. DRS = Decreasing Returns to Scale ($\Sigma\beta_i < 1$). Dependent variable: log of maize fodder yield (q/ha).

Table 11: Resource use efficiency of inputs in maize fodder cultivation across agro-climatic zones

Panel A: Temperate Zone

Input	Mean X_i	MPP	MVP (₹)	MFC (₹)	MVP/MFC	Decision
Seed	2.68	2.229	245.18	110	2.23	Under-utilized
Labour	4.24	2.013	1207.89	600	2.01	Under-utilized
Fertilizer	4.66	1.468	73.41	50	1.47	Under-utilized
FYM	255.47	0.014	0.08	6	0.014	Over-utilized
Irrigation	3.32	0.549	353.88	645	0.549	Over-utilized
Plant Protection	51.40	0.039	0.08	2	0.039	Over-utilized

Panel B: Intermediate Zone

Input	Mean X_i	MPP	MVP (₹)	MFC (₹)	MVP/MFC	Decision
Seed	1.98	3.046	304.63	100	3.05	Under-utilized
Labour	5.57	1.608	964.86	600	1.61	Under-utilized
Fertilizer	5.88	0.577	23.09	40	0.58	Over-utilized
FYM	422.70	0.007	0.03	4	0.007	Over-utilized
Irrigation	2.95	0.124	61.77	500	0.124	Over-utilized
Plant Protection	54.50	0.043	0.04	1	0.043	Over-utilized

Panel C: Sub-tropical Zone

Input	Mean X_i	MPP	MVP (₹)	MFC (₹)	MVP/MFC	Decision
Seed	2.99	1.248	99.83	80	1.25	Under-utilized
Labour	3.64	0.223	111.62	500	0.22	Over-utilized
Fertilizer	6.14	2.216	110.79	50	2.22	Under-utilized
FYM	421.55	0.019	0.11	6	0.019	Over-utilized
Irrigation	2.02	0.977	488.72	500	0.977	Over-utilized
Plant Protection	57.65	0.068	0.07	1	0.068	Over-utilized

Note: MPP (Marginal Physical Product) = $\beta_i \times (\bar{Y}/\bar{X}_i)$; MVP (Marginal Value Product) = $MPP \times P_y$, where P_y is the output price of maize fodder; MFC (Marginal Factor Cost) = per-unit input price (P_{xi}). Decision rule: $MVP/MFC > 1 \rightarrow$ resource is under-utilised (scope to increase use); $MVP/MFC < 1 \rightarrow$ resource is over-utilised (use should be reduced); $MVP/MFC = 1 \rightarrow$ resource is optimally utilised. Units – Seed: kg/ha; Labour: man-days/ha; Fertilizer: kg/ha (nutrient basis); FYM: q/ha; Irrigation: number of irrigations; Plant Protection: ₹/ha.

significant – plausibly reflecting the moisture-adequate rainfed conditions of this belt. In the sub-tropical zone, fertilizer recorded the highest and most significant elasticity ($\beta = 0.329$), followed by FYM ($\beta = 0.194$) and plant protection ($\beta = 0.095$), while labour turned non-significant – indicative of labour-surplus conditions in the plains-adjacent belt. The sum of production elasticities ($\Sigma\beta$) was less than unity in all three zones (0.887, 0.619, and 0.776), confirming decreasing returns to scale – meaning that a proportional increase in all inputs would lead to a less-than-proportional increase in fodder output, a pattern consistent with the intensive cultivation practices prevailing in the study area.

The resource use efficiency of each input across the three zones is presented in Table 11. Efficiency was assessed by comparing the ratio of Marginal Value Product (MVP) to Marginal Factor Cost (MFC) for each input. Across all three zones, seed was consistently under-utilised (MVP/MFC ratios of 2.23, 3.05, and 1.25 in the temperate, intermediate, and sub-tropical zones respectively), suggesting that farmers could profitably raise seed rates within the recommended agronomic range. Fertilizer was under-utilised in the temperate (1.47) and sub-tropical (2.22) zones but over-utilised in the intermediate zone (0.58), pointing to zone-specific fertilisation gaps that call for site-specific nutrient management. Labour was under-utilised in the temperate (2.01) and intermediate (1.61) zones – where hilly terrain and small holdings constrain hired-labour markets – but over-utilised in the sub-tropical zone (0.22), reflecting labour abundance in the plains. FYM, irrigation, and plant protection chemicals were over-utilised in all three zones, with MVP/MFC ratios well below unity, consistent with the widely observed farmer tendency to apply organic manure and irrigation in excess of economically optimal levels and to use plant-protection chemicals prophylactically. Reallocation of expenditure from the over-utilised inputs towards the under-utilised ones would enhance overall profitability.

DISCUSSION

Farmer-level implications

The findings offer important insights for farmers seeking to improve the profitability and efficiency

of maize fodder cultivation. The consistently under-utilised status of seed suggests that farmers can raise productivity by adopting recommended seed rates and higher-yielding cultivars – a low-cost intervention with potentially high marginal returns. Rationalising the use of over-utilised inputs – particularly FYM, irrigation, and plant protection – can lower production costs without compromising output. Farmers can also improve their income by adopting direct marketing channels (Producer → Consumer), which reduce marketing costs, minimise the price spread, and increase their share in the consumer's rupee. Collective action through farmer producer organisations or cooperatives can further strengthen bargaining power and reduce dependence on intermediaries, particularly in the sub-tropical zone where reliance on village agents is high.

Societal implications

At the societal level, the study contributes to improving fodder availability and livestock productivity – both critical for enhancing rural livelihoods and ensuring nutritional security. Efficient maize fodder production can help address the persistent fodder deficit, thereby supporting the dairy sector and increasing overall agricultural sustainability. Promoting direct marketing systems can lead to fairer price distribution, benefiting both producers and consumers by reducing supply-chain inefficiencies. Improved resource use efficiency also reduces environmental pressure by minimising the excessive application of chemical inputs and irrigation water, thereby aligning with the wider goal of sustainable agriculture.

Policy recommendations

Balanced input use should be promoted through farmer awareness programmes and site-specific extension advisories that address zone-specific inefficiencies – notably raising seed rates while curbing the over-application of FYM, irrigation, and plant-protection chemicals. Strengthening extension services and farmer-training programmes is essential to ensure the scientific and efficient use of inputs, particularly plant-protection practices. Encouraging direct marketing channels (Producer → Consumer) can help reduce marketing costs,

minimise price spread, and increase the producer's share in the consumer's rupee. The development of local fodder markets, along with basic infrastructure such as transport, storage, and weighing facilities, can significantly improve market access and overall efficiency. In addition, supporting the formation of farmer producer organisations (FPOs) can reduce dependence on intermediaries and enhance farmers' bargaining power, ultimately leading to improved income and market efficiency.

CONCLUSION

The study concludes that maize fodder cultivation in the Jammu region is economically viable across all three agro-climatic zones, with the highest profitability observed in the sub-tropical zone due to lower cultivation costs and higher productivity. The marketing analysis reveals that direct marketing channels are more efficient – involving lower marketing costs, a narrower price spread, and a higher producer's share in the consumer's rupee – whereas the involvement of intermediaries widens the price spread and reduces efficiency. The resource use efficiency analysis indicates that seed is consistently under-utilised across all zones, while FYM, irrigation, and plant protection are consistently over-utilised; fertilizer and labour show zone-specific patterns of use. All three zones exhibit decreasing returns to scale ($\Sigma\beta_i < 1$), implying that gains from further proportional input intensification are limited. Overall, the findings highlight the presence of inefficiencies in both production and marketing systems, and suggest that improving input allocation and promoting efficient marketing channels can significantly enhance productivity, reduce costs, and raise farmers' income from maize fodder cultivation.

Limitations and Future Studies

The study is based on primary data collected from a sample of 120 farmers across selected districts of the Jammu region, which may limit the generalisability of the findings to other regions with different agro-climatic and socio-economic conditions. The analysis relies on cross-sectional data for a single agricultural year (2024–25) and therefore does not capture year-to-year variations in costs, yields, prices, or climatic factors. Additionally, the study focuses on the major inputs – seed, labour, fertilizer,

FYM, irrigation, and plant protection – and does not fully account for other factors influencing productivity, such as soil variability, mechanisation intensity, and technological adoption. The marketing analysis is confined to the two identified channels within the study area and may not reflect broader market structures or emerging digital marketing platforms. Furthermore, the estimation of resource use efficiency using the Cobb–Douglas production function assumes a specific functional form that may not fully capture complex input–output relationships.

Future studies could extend this work in several directions. First, panel data spanning multiple agricultural years would allow analysis of temporal dynamics in costs, yields, and prices, and enable robust identification of trends and shocks. Second, alternative functional forms – such as the translog production function – could be tested to relax the parametric assumptions of the Cobb–Douglas specification. Third, comparative studies across other fodder crops (oats, berseem, sorghum) and across the wider Himalayan region would strengthen the external validity of the findings. Finally, examining the role of digital marketing platforms, farmer producer organisations, and government procurement in reshaping the maize fodder value chain would provide timely evidence for policy formulation.

GENERATIVE AI DECLARATION

The author(s) confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript, and no images were manipulated using AI. The authors developed and verified all scientific content, data analysis, interpretation of results, and conclusions. The authors take full responsibility for the accuracy, integrity, and originality of the work presented, and no AI tool was listed as an author.

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