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An economic analysis of performance and efficiency in dairy farming

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Abstract
Dairy farming plays a crucial role in enhancing rural livelihoods, nutritional security and farm income in India. Improvement in the performance and efficiency of dairy enterprises is essential for ensuring their economic sustainability, particularly in the context of rising input costs and resource constraints. The present study aims to examine the performance and economic efficiency of dairy farming at the farm level. The analysis is based on primary data collected from sample dairy farmers through a structured survey, covering information on herd size, input use, costs, milk yield, and returns. Standard cost and return analysis was employed to assess the economic performance of dairy farms, while efficiency measures such as technical, allocative, and economic efficiency were estimated using appropriate frontier or ratio-based techniques. The results reveal significant variation in milk productivity, cost of production, and profitability across different farm size categories. Feed and fodder costs emerged as the major component of total production cost, followed by labour expenses. Efficiency analysis indicates that considerable scope exists for improving resource use efficiency, particularly among small and marginal dairy farmers. Factors such as herd size, access to veterinary services, adoption of improved feeding practices, and management skills were found to significantly influence the efficiency levels of dairy farms. The study concludes that enhancing managerial efficiency, promoting scientific dairy practices, and improving access to extension and institutional support can substantially improve the performance and economic efficiency of dairy farming. The findings provide useful policy insights for strengthening the dairy sector and promoting sustainable income growth among rural households.

Keywords: Dairy farming, economic efficiency, farm-level performance, cost and returns

1. Introduction
The Indian agricultural sector is undergoing a rapid structural transformation driven by rising incomes, urbanization, population growth, changing consumer preferences, and integration with the global economy. Traditionally focused on food grain production, Indian agriculture has been steadily diversifying towards high-value enterprises such as horticulture, livestock, and fisheries. Among these, livestock particularly dairying has emerged as a key growth engine due to its high income elasticity of demand, consistent growth in per capita income, and changing dietary patterns. Dairy farming plays a critical role in enhancing farm income, generating employment, and ensuring nutritional security, especially for small, marginal, and landless farmers. The crop livestock integrated farming system remains central to sustainable agriculture, wherein livestock efficiently utilize crop residues and by-products while contributing organic manure, draught power, and additional income to farming households.

India possesses one of the largest livestock populations globally, reflecting the sector's economic and social significance. As per the 20th Livestock Census (2019), the total livestock population stood at 535.78 million, showing an increase of 4.6 per cent over 2012. The bovine population alone accounted for 302.79 million, with notable growth in female cattle and crossbred animals, indicating a gradual shift towards productivity-oriented dairy farming. Milch animal population has increased substantially, underscoring the growing importance of dairying as a livelihood option. However, despite this numerical strength, wide variations persist in productivity, cost structures, and profitability across regions and farm sizes, highlighting the need for systematic assessment of performance and efficiency at the farm level.

While livestock significantly contributes to rural livelihoods and food security, concerns regarding environmental externalities particularly greenhouse gas emissions have gained prominence. Livestock contributes substantial share of methane emissions from agriculture, mainly through enteric fermentation and manure management, which represent energy losses and inefficiencies in production. These impacts, however, vary across production systems, with mixed crop-livestock systems being relatively benign and offering positive environmental services such as nutrient recycling and reduced dependence on fossil fuels. Improving the performance and efficiency of dairy farming not only enhances farm profitability but also reduces environmental stress per unit of output. In this context, a comprehensive evaluation of the economic performance and efficiency of dairy farms becomes essential for promoting sustainable and climate-resilient dairy development in India.

2. Review of Literature

Chandrasekar and Gopal (2015) [1] applied Data Envelopment Analysis (DEA) to assess resource use efficiency in ring seiner-operated farms. Under the constant returns to scale (CRS) assumption, they found that the mean technical efficiency was 0.53, allocative efficiency was 0.76 and economic efficiency was 0.40. These results indicate that while input allocation was relatively better, both technical and overall economic efficiencies were low, suggesting significant scope for improving input utilization and cost-effectiveness in these fishing operations.

Czyzewski and Ambrozy (2015) [2] applied Data Envelopment Analysis (DEA) to compare resource use efficiency between diversified and specialized farms. Their findings showed that specialized farms demonstrated higher economic efficiency compared to diversified ones. However, this efficiency came at the cost of reduced environmental sustainability, suggesting that while specialization boosts profitability, it may compromise ecological balance compared to diversified farming systems.

Singh *et al*. (2015) [10] found that only 14 per cent of all fish farms were technically efficient, with efficiency scores of 0.90 or above. Large farms had a higher proportion of efficient operations compared to small and medium ones. Factors significantly influencing technical efficiency included fish farm area, sole fish farming, involvement in other occupations and combining fish farming with agriculture, highlighting the role of scale and diversification in improving efficiency.

Kumawat and Singh (2016) [3] conducted study on economic analysis of cost and returns of milk production in Bikaner district of Rajasthan. The results from the study revealed that among total cost, feed and fodder cost accounted for the major share (59.52%) followed by labour cost (33.95%), fixed cost (25.31%) and miscellaneous expenses (1.15%) on sample dairy farms. The total cost was ₹1867599.61 per dairy farm per year and ₹333449.99 per milch animal per year and the net income was ₹1053011.60 per dairy farm per year and ₹18803.77 per animal per year. The average milk production per lactation was 129374 litres per dairy farm and 4173 litres per animal. The average cost of production and net return per liters of milk was ₹14.27 and ₹8.28, respectively.

Mevlut Gul *et al*. (2016) estimated the technical efficiency of goat rearing in the province of Isparta in Turkey using Data Envelopment Analysis (DEA). The data used were collected from 92 goat farmers using the stratified sampling method by means of a questionnaire. The technical efficiency of the goat farming varied widely between 0.13 and 1.00. The mean efficiency of 92 goat farms was calculated to be 0.44 and 0.66 for constant and variable returns to scale assumptions, respectively. The greatest slacks were in feedstuff concentrates and labour used. The most significant factors affecting efficiency of goat production were farmer experience, cooperative membership, milk yield per goat and family and hired labour. Technical efficiency should be improved by providing farmers with well-organized education, an extension program and research and development programs on goat rearing.

Sunil *et al*. (2016) conducted a study on economics of milk production in Mandya district of Karnataka and reported that per day maintenance cost was found to be highest for crossbred cows (98.66) followed by buffalo (76.52) and local cows (64.26). Among total maintenance costs feed and fodder costs accounts highest followed by labour cost, total fixed costs and miscellaneous costs, respectively. The return per litre of milk was highest for crossbred cows (5.57) followed by buffalo (4.03). However negative return was found in case of local cow. The net return from crossbred cow was more than that from buffalo and local cows indicating higher profitability in rearing crossbred cow in the area.

Mustafa *et al*. (2017) measured technical, allocative and economic efficiencies of dairy farms in western Turkey. The study was conducted to determine the input efficiencies of 43 dairy cattle farms. Data envelopment analysis was used. The technical, allocative and economical efficiencies were found to be as 0.66, 0.43 and 0.23 respectively. The analysis results showed that only 23.26 per cent of the farms were efficient with constant returns to scale with respect to the usage of major inputs while the remaining 76.74 per cent had the increasing return to scale indicating that these farms could maintain the current output with decreasing current inputs.

Sarathbabu (2017) used Data Envelopment Analysis (DEA) to assess technical efficiency and found that farmers' education level, farming experience and training attendance were positively significant at the 1 per cent level. Conversely, human labour and irrigation hours showed a negative and significant effect on technical efficiency at the 1 per cent level, indicating inefficiencies in labour and water use.

Sirohi*et al*. (2017) carried out the study on cost and returns from dairying in Malwa region of Madhya Pradesh. They estimated the cost and returns of about 300 milk producers. They reported that, in the case of crossbred cattle, the overall gross maintenance cost / animal / year was high, while same was least for local cows. Among total cost, feed and fodder cost accounted for major share (37.50%) followed by fixed cost (36.83%), labour cost (24%) and miscellaneous expenses (1.67%). The overall cost per litre of milk production for crossbred cow was lowest and the highest for buffalo. The net economic margins were fairly good for buffalo, higher for crossbred cow and almost negligible in local cow.

Amit and Thakur (2022) studied resource use efficiency in milk production among 60 households in Shimla, Himachal Pradesh, using 2020-21 data from three blocks: Masobra, Rampur and Rohru. The Cobb-Douglas production function best fit the data. Green feed and concentrate were key determinants of milk output, but both were underutilized, suggesting potential for increased milk production through improved input use.

Kaur and Toor (2022) examined resource use efficiency in milk production across milch breeds in rural Punjab. For crossbred cows, concentrates significantly affected milk yield, while buffalo yield was influenced by both green fodder and concentrates. No input was statistically significant for local cow milk. Marginal value productivity was positive for buffalo and crossbred cow milk, but negative for local cows, indicating inefficient resource utilization.

Dharpal *et al*. (2023) assessed resource use efficiency in crossbred cow milk production among 120 milk producers across eight villages in Amravati district, Maharashtra, including 32 with crossbred cows. Using a Cobb-Douglas function, they found positive regression coefficients for dry fodder, medicines, watering charges, input transport and veterinary costs highest for input transport (1.3353). Negative coefficients were reported for green fodder, concentrate, grazing, breeding, cleaning, interest on working capital and family labour. Interest on working capital had the lowest elasticity, highlighting input inefficiencies in milk production.

3. Methodology

The primary data was obtained directly from dairy farmers using pre-tested schedules designed to capture key aspects of their farming practices, economic conditions, and other relevant factors.

3.1 Data Collection

The primary data was collected through personal interviews with dairy farmers using a well-structured and pre-tested interview schedule. This schedule is designed to ensure consistency and accuracy in the responses, covering a wide range of topics pertinent to dairy farming. The data included economic features, such as the income sources of the farmers, expenditure on feed and healthcare, and overall profitability from dairy farming.

Additionally, the interview gathered information on the types of livestock raised by the farmers, including breed types (indigenous, crossbred cows, and buffaloes), herd size, and milk yield per animal. The farming practices followed by the respondents were also recorded, including breeding practices (natural vs. artificial insemination), feed and fodder management (types of feed used, sources of fodder, and feeding schedules), as well as health and veterinary care practices. The schedule also collected details about the labour force involved in dairy operations, including gender-specific roles and time allocation for milking, cleaning, feeding, and other farm-related tasks.

3.2 Analytical tools

1. Partial budgeting technique
2. Budgeting techniques was used to estimate cost and returns. The budgeting technique was specifically use gross margin analysis through which the Net Farm Income was obtained, the model is stated thus:
3. GM = GI-TVC…………………………………… (1)
4. Where,
5. GM = Gross Margin
6. GI = Goss Income
7. TVC = Total Variable Cost
8. NFI = GM-TFC…………………………………… (2)
9. Where,
10. NFI = Net Farm Income
11. GM = Gross Margin
12. TFC = Total Fixed Cost
13. 3.5.2.a. Technical efficiency analysis

DEA was applied by using both classic models CRS (constant returns to scale) and VRS (variable returns to scale) with input orientation, in which one seeks input minimization to obtain a particular product level. Under assumption of constant returns to scale, the linear programming models for measuring the efficiency of farmers are (Coelli *et al.* 1998),

Min $\theta\ \lambda\ \theta$

Subject to $-yi + Y\lambda \geq 0$

$\theta Xi - X\lambda \geq 0$

$\lambda \geq 0$ ………………………………………………………… (9)

Where,

yi is a vector ($mx1$) of output of the i*th* TPF Farmers

xi is a vector ($kx1$) of inputs of the ith TPF Farmers

Y is an output matrix (nxm) for n TPF Farmers

X is an input matrix ($n\ x\ k$) for n TPF Farmers

θ is the efficiency score, a scalar whose value was the efficiency measure for the i*th* TPF farmers. If θ=1, TPF (Total productivity factor) was efficient; otherwise, it was inefficient.

λ is a vector ($nx1$) whose values are calculated to obtain the optimum solution. For an inefficient TPF, the λ values was the weights used in the linear combination of other efficient TPFs, which influence the projection of the inefficient TPF on the calculated frontier.

The specification of constant returns is only suitable when the firms are working at optimum scale. Otherwise, measures of technical efficiency can be mistaken for scale efficiency, which considers all types of returns to production, i.e., increasing, constant and decreasing. Therefore, the CRS model is reformulated by imposing a convexity constraint. The measure of technical efficiency obtained in the model with variable returns is also named pure technical efficiency as it is free of scale effects, and the following linear programming model estimates it:

Min $\theta\ \lambda\ \theta$

Subject to $-yi + Y\lambda \geq 0$

$\theta Xi - X\lambda \geq 0$

$N1\lambda = 1$

$\lambda \geq 0$…………………………………………………. (10)

Where

N1 is a vector ($n\ x1$) of ones.

When there are differences between the values of the efficiency scores in the models CRS and VRS, scale inefficiency is confirmed, indicating that the return to scale is variable, i.e., it can be increasing or decreasing (Fare and Grosskopf,1994). The scale efficiency values for each analyzed unit can be obtained by the ratio between the scores for technical efficiency with constant and variable returns as follows.

$\theta s = \theta CRS\ (Xk, Y_k)/\theta VRS\ (Xk, Y_k)$…………… (11)

Where,

$\theta CRS\ (Xk,\ Y_k)$ is the technical efficiency for the model with constant returns

$\theta VRS\ (Xk,\ Y_k)$ is the technical efficiency for the model with variable returns

θs is scale efficiency

It was pointed out that model (9) makes no distinction as to whether TPF is operating in the range of increasing or decreasing returns (Coelli *et al.*1998). The only information that one has is that if the value obtained by calculating the scale efficiency in (10) is equal to one, the TPF was operating with constant returns to scale. However, when θs is smaller than one, increasing or decreasing returns can occur. Therefore, to understand the nature of scale inefficiency, it is necessary to consider another problem of linear programming i.e., the convexity constraint of model (9), N1λ=1, is replaced by N1λ≤1for the case of non-increasing returns, or by N1λ≥1, for the model with non-decreasing returns. Therefore, in this work the following models were also used for measuring the nature of efficiency.

Non-increasing returns

Min θ λ θ

Subject to -yi + Yλ ≥ 0

θXi - Xλ ≥ 0

N1λ ≤ 1

λ ≥0 ………………………………………….(12)

Non-decreasing returns

Min θ λ θ

Subject to -yi + Yλ ≥ 0

θXi - Xλ ≥ 0

N1λ ≥ 1

λ ≥ 0 …………………………………………………….….(13)

It is to state here that all the models presented above should be solved n times, i.e., the model is solved for each TPF in the sample. Gross yield (Q) was used as a output(Y) in the present case and seeds (kg), human labour (man days), bullock labour (₹), farm yard manure (t), fertilizers (kg), plant protection chemicals (₹). The models were solved using the DEAP version 2.1taking an input orientation to obtain the efficiency level.

4. Results and Discussion

Table 1: Daily cost and returns analysis of milk production in the study area (₹ / day / animal)

Sl. No.	Particulars	Belagavi	Hassan	Kalaburagi	Overall
A	**Fixed cost**				
1	Depreciation on farm buildings	23.78	19.26	14.75	17.56
2	Depreciation on animal cost	4.26	3.36	3.73	3.58
3	Depreciation on farm equipment	20.51	19.75	19.33	19.84
4	Interest on investment @ 9%	4.37	3.81	3.40	3.69
i	Sub total	52.92	46.18	41.21	44.67
B	**Variable cost**				
1	Green fodder/grazing	75.29	84.99	65.11	82.00
2	Dry fodder	22.61	21.02	39.72	28.67
3	Concentrates	105.00	116.87	105.26	108.91
4	Total feed cost	202.90	222.88	210.09	219.58
5	Medicine and veterinary care	4.78	4.93	4.83	4.81
6	Insurance	2.74	2.74	1.92	2.47
7	Miscellaneous expenses	1.62	1.56	1.53	1.58
8	Labour cost	46.05	42.40	50.59	49.08
9	Interest on working capital @ 11%	28.39	30.19	29.58	30.52
ii	Sub total	286.48	304.70	298.54	308.04
	Total cost (i+ii)	339.40	350.88	339.75	352.71
C	**Returns**				
iii	From milk	565.28	577.07	539.33	568.92
Iv	From dung	17.30	18.76	17.68	17.94
1	Gross return	582.58	595.83	557.00	586.85
2	Net return	243.18	244.95	217.25	234.14
3	Returns per rupees invested	1: 1.72	1: 1.70	1: 1.64	1: 1.67

Note: Average milk price (/liter) 35₹

The daily cost of milk production per animal was ₹339.40 in Belagavi, ₹350.88 in Hassan, and ₹339.75 in Kalaburagi, with an overall average of ₹352.71. Variable costs constituted the major share of total cost, accounting for more than 80 per cent across all districts, with feed cost alone contributing around 62 per cent. Gross returns from milk production were highest in Hassan (₹595.83/day), followed by Belagavi (₹582.58/day) and Kalaburagi (₹557.00/day). Net returns were positive across districts, ranging from ₹217.25 in Kalaburagi to ₹244.95 in Hassan. The returns per rupee invested varied from 1.64 to 1.72, indicating profitability of dairy farming in the study area.

The dominance of feed cost highlights its critical role in determining profitability of dairy enterprises. Higher daily returns in Hassan may be attributed to better feeding practices and higher milk yield. Lower net returns in Kalaburagi suggest inefficiencies in input use or lower productivity. Overall positive net returns and favourable benefit-cost ratios indicate that milk production is economically viable across regions, though scope exists for improving efficiency through optimized feed and labour use.

On a monthly basis, the total cost per animal was ₹10,185.69 in Belagavi, ₹10,529.47 in Hassan, and ₹10,195.60 in Kalaburagi, with an overall average of ₹10,584.12. Variable costs accounted for nearly 85 per cent of total cost, with feed expenses being the largest component. Gross monthly returns ranged from ₹16,710.30 in Kalaburagi to ₹17,874.90 in Hassan. Net returns were highest in Hassan (₹7,345.43), followed by Belagavi (₹7,291.71) and Kalaburagi (₹6,514.70). Returns per rupee invested remained consistent across districts.

The results reiterate the importance of feed and labour management in reducing production costs. The higher profitability observed in Hassan reflects better resource utilization and possibly superior animal productivity. Despite regional variations, dairy farming provides steady monthly income, making it a reliable livelihood option for farm households

Table 2: Monthly cost and return analysis of milk production of sample respondent in study area (₹/month/animal)

Sl. No.	Particulars/size of herd	Belagavi	Hassan	Kalaburagi	Overall
A	**Fixed cost**				
1	Depreciation on farm buildings	713.40	577.80	442.50	526.80
2	Depreciation on animal cost	129.67	102.17	113.50	108.75
3	Depreciation on farm equipment	615.30	592.50	579.90	595.20
4	Interest on investment @ 9%	132.92	116.00	103.50	112.17
5	Total fixed cost	1,591.29	1,388.47	1,239.40	1,342.92
B	**Variable cost**				
1	Green fodder/grazing	2258.70	2549.70	1953.30	2460.00
2	Dry fodder	678.30	630.60	1191.60	860.10
3	Concentrates	3150.00	3506.10	3157.80	3267.30
4	Total feed cost	6,087.00	6,686.40	6,302.70	6,587.40
5	Medicine and veterinary care	143.40	147.90	144.90	144.30
6	Insurance	82.20	82.20	57.60	74.10
7	Miscellaneous expenses	48.60	46.80	45.90	47.40
8	Labour cost	1381.50	1272.00	1517.70	1472.40
9	Interest on working capital @11%	851.70	905.70	887.40	915.60
10	Total variable cost	8,594.40	9,141.00	8,956.20	9,241.20
11	Total cost	10,185.69	10,529.47	10,195.60	10,584.12
C	**Returns**				
1	From milk	16,958.40	17,312.10	16,179.90	17,067.60
2	From dung	519.00	562.80	530.40	538.20
3	Gross return	17,477.40	17,874.90	16,710.30	17,605.80
4	Net return	7,291.71	7,345.43	6,514.70	7,021.68
5	Returns per rupees invested	1: 1.72	1: 1.70	1: 1.64	1: 1.67

Table 3: Annual cost and return analysis of milk production of sample respondent in study area (₹/year/animal)

Sl. No.	Particulars	Belagavi	Hassan	Kalaburagi	Overall
A	**Fixed cost**				
1	Depreciation on farm buildings	8,680	7,030	5,384	6,409
2	Depreciation on animal cost	1,556	1,226	1,362	1,305
3	Depreciation on farm equipment	7,486	7,209	7,055	7,242
4	Interest on investment @ 9%	1,595	1,392	1,242	1,346
i	Sub total	19,317	16,857	15,043	16,302
B	**Variable cost**				
1	Green fodder/grazing	27,481	31,021	23,765	29,930
2	Dry fodder	8,253	7,672	14,498	10,465
3	Concentrates	38,325	42,658	38,420	39,752
4	Total feed cost	74,059	81,351	76,683	80,147
5	Medicine and veterinary care	1,745	1,799	1,763	1,756
6	Insurance	1,000	1,000	701	902
7	Miscellaneous expenses	591	569	558	577
8	labour cost	16,808	15,476	18,465	17,914
9	Interest on working capital @ 11%	10,362	11,019	10,797	11,140
ii	Sub total	1,04,565	1,11,216	1,08,967	1,12,435
	Total cost (i+ii)	1,22,187	1,26,735	1,22,527	1,27,312
C	**Returns**				
ii	From milk	2,06,327	2,10,631	1,96,855	2,07,656
iii	From dung	6,315	6,847	6,453	6,548
1	Gross return	2,12,642	2,17,478	2,03,305	2,14,200
2	Net return	88,760	89,405	79,295	85,463
3	Returns per rupees invested	1: 1.72	1: 1.70	1: 1.64	1: 1.67

Note: Average milk price (/liter) 35₹

The annual cost of milk production per animal was ₹1,22,187 in Belagavi, ₹1,26,735 in Hassan, and ₹1,22,527 in Kalaburagi, with an overall average of ₹1,27,312. Feed costs constituted nearly two-thirds of total cost. Gross annual returns were highest in Hassan (₹2,17,478), followed by Belagavi (₹2,12,642) and Kalaburagi (₹2,03,305). Net annual returns ranged from ₹79,295 in Kalaburagi to ₹89,405 in Hassan, while returns per rupee invested ranged from 1.64 to 1.72.

Annual analysis confirms that dairy farming is economically rewarding across all districts. However, variations in net returns indicate differences in productivity, cost structure, and management efficiency. Improving feed efficiency and reducing avoidable costs can further enhance profitability, particularly in relatively low-return regions.

Table 4: Profitability analysis of dairy farms in the study area (₹/animal/year)

Particulars	Belagavi	Hassan	Kalaburagi	Overall average
Gross Return (GR)	2,12,642	2,17,478	2,03,305	2,14,200
Total Variable Cost (TVC)	1,04,565	1,11,216	1,08,967	1,12,435
Total Fixed Cost (TFC)	19,317	16,857	15,043	16,302
Gross Margin (GM) = GR - TVC	1,08,077	1,06,262	94,338	1,01,765
Net Farm Income (NFI) = GM - TFC	88,760	89,405	79,295	85,463

Gross returns per animal per year ranged from ₹2,03,305 in Kalaburagi to ₹2,17,478 in Hassan. Total variable costs were highest in Hassan (₹1,11,216), while total fixed costs were highest in Belagavi (₹19,317). Gross margin was highest in Belagavi (₹1,08,077) and lowest in Kalaburagi (₹94,338). Net farm income varied from ₹79,295 to ₹89,405, with an overall average of ₹85,463 per animal per year.

Higher gross margins indicate better operational efficiency in Belagavi, whereas lower margins in Kalaburagi reflect relatively higher variable costs or lower productivity. The positive net farm income across all districts reinforces the role of dairying as a profitable enterprise and an effective means of income diversification.

Table 5: Parameter estimates of milk production

Sl. No.	Particulars	Parameter	Belagavi	Hassan	Kalaburagi	Overall
			Co-efficient (β)	Co-efficient (β)	Co-efficient (β)	Co-efficient (β)
1	Intercept	a	1.02 (1.53)	1.68 (2.12)	1.01 (1.24)	1.30(1.40)
2	Concentrates	X_1	0.21 (0.36)	0.32 * (0.09)	0.12 (0.41)	0. 25* (0.11)
3	Green Fodder	X_4	0.32* (0.09)	0.38* (0.08)	0.22 (0.36)	0.34* (0.10)
4	Dry Fodder	X_5	0.28 (0.55)	0.22 (0.18)	0.27 * (0.02)	0.22 (0.15)
5	Labour	X_6	0.18 (0.21)	0.21 (0.28)	0.16 (0.21)	0.18 (0.17)
6	Herd Size	X_7	0.65* (0.04)	0.81* (0.32)	0.57 * (0.02)	0.72* (0.08)
F value			137.78	238.22	95.04	165.59
Coefficient of determination (R^2)			0.78	0.86	0.71	0.81
Adjusted R^2			0.75	0.83	0.68	0.77

Note: Dependent Variable: Milk yield; Figures in the parenthesis indicate standard errors of respective coefficient

Regression results revealed that concentrates, green fodder, and herd size significantly influenced milk yield in most districts. Herd size showed a strong positive and statistically significant effect across all regions, with coefficients ranging from 0.57 to 0.81. Green fodder had a significant impact in Belagavi and Hassan, while dry fodder was significant in Kalaburagi.

The model exhibited good explanatory power, with R^2 values ranging from 0.71 to 0.86. The findings emphasize the importance of herd size expansion and balanced feeding practices in enhancing milk productivity. Regional differences in significance of inputs suggest variability in management practices and agro-climatic conditions. Strengthening fodder availability and herd management can substantially improve production efficiency.

Table 6: Technical efficiency of dairy farms in Belagavi district

Sl. No.	Efficiency class	Belagavi (n=80)		Hassan (n=80)		Kalaburagi (n=80)		Overall (n=240)	
		CSR	VRS	CRS	VRS	CRS	VRS	CRS	VRS
1	< 0.50	3	2	2	1	3	2	8	5
2	0.51 to 0.60	6	5	5	4	8	6	19	15
3	0.61 to 0.70	9	7	8	6	14	10	31	23
4	0.71 to 0.80	15	14	19	17	16	14	50	45
5	0.81 to 0.90	21	23	21	24	20	18	62	65
6	>0.90	26	29	25	28	19	30	70	87
	Mean	0.794	0.865	0.821	0.874	0.755	0.835	0.790	0.860
	Minimum	0.446	0.462	0.457	0.479	0.401	0.437	0.401	0.437
	Maximum	0.957	0.978	0.965	0.985	0.945	0.960	0.965	0.985

Table 6 presents the distribution of technical efficiency scores of dairy farms across Belagavi, Hassan, and Kalaburagi, estimated through the Data Envelopment Analysis (DEA) framework. The analysis was carried out under two assumptions: Constant Returns to Scale (CRSTE) and Variable Returns to Scale (VRSTE). CRSTE assumes farms operate at an optimal scale, while VRSTE relaxes this assumption by accounting for scale inefficiencies. The efficiency scores, ranging from 0 to 1, represent the capacity of farms to convert available inputs into milk output, with values closer to 1 indicating better efficiency. The results show considerable variation across districts, highlighting differences in management practices, feed utilization, and resource allocation strategies among farmers.

The distribution across efficiency classes reveals that a higher proportion of farms in Belagavi and Hassan are concentrated in the top efficiency categories compared to Kalaburagi. For instance, in Belagavi, 26 farms under CRSTE and 29 farms under VRSTE achieved efficiency above 0.90, while Hassan recorded 25 and 28 farms, respectively, in this high-performing category. Kalaburagi, by contrast, had only 19 farms under CRSTE in this range, though VRSTE pushed the number slightly higher to 30. This indicates that while certain farms in Kalaburagi can perform efficiently when scale inefficiencies are accounted for, a substantial share still lags behind, pointing toward operational and technical constraints. Overall, Belagavi and Hassan demonstrate greater consistency in maintaining higher efficiency levels, while Kalaburagi shows wider disparities in farm performance.

The mean efficiency values provide further insights into regional differences. Hassan leads with average scores of 0.821 under CRSTE and 0.874 under VRSTE, reflecting strong performance in both scale-dependent and scale-adjusted efficiency. Belagavi follows closely with mean values of 0.794 and 0.865, suggesting good efficiency but slightly lower than Hassan. Kalaburagi records the lowest averages of 0.755 (CRSTE) and 0.835 (VRSTE), highlighting inefficiencies in resource use, possibly linked to lower feed availability, limited adoption of scientific management practices, and regional constraints such as semi-arid conditions. These results are consistent with earlier findings of higher input costs and lower profitability in Kalaburagi compared to Hassan's feed-intensive systems and Belagavi's mixed resource base.

The minimum and maximum scores highlight the range of efficiency across farms. Kalaburagi records the lowest observed values of 0.401 under CRSTE and 0.437 under VRSTE, showing that a subset of farms in this district struggle significantly with input management and scale adjustments. Hassan, on the other hand, reports the highest minimum scores of 0.457 (CRSTE) and 0.479 (VRSTE), demonstrating that even its least efficient farms perform better than the weakest performers in Belagavi and Kalaburagi. Maximum efficiency scores are very close to 1 across all districts, particularly under VRSTE, which suggests that certain farms operate near the frontier of efficiency. These highly efficient farms serve as potential benchmarks, offering lessons for others on optimal resource utilization and management practices.

Overall, the analysis highlights strong inter-district differences in technical efficiency, with Hassan emerging as the most efficient, followed by Belagavi, while Kalaburagi lags behind. The fact that several farms in all three districts achieve efficiency scores close to 1 show that improvements are possible for the less efficient farms if successful practices are shared and scaled. The results underscore the importance of addressing scale inefficiencies, improving feed and input management, and strengthening extension services to enhance performance in regions like Kalaburagi. Targeted interventions, such as better access to veterinary care, improved fodder supply systems, and training programs in scientific dairy practices, can help bridge the gap and raise overall efficiency levels across the study area.

Allocative efficiency of milk producers

The allocative efficiency results presented in Table 6 highlight the extent to which dairy farmers in Belagavi, Hassan, and Kalaburagi districts utilized resources in milk production relative to their marginal value product (MVP) and marginal factor cost (MFC). For concentrates, the MVP-MFC ratio was consistently above unity across all districts, with Hassan recording the highest ratio of 2.82, followed by Belagavi at 2.12 and Kalaburagi at 1.65. This clearly indicates underutilization of concentrates in all three regions, suggesting that farmers could enhance milk production and profitability by increasing concentrate feeding, particularly in Hassan where the returns to additional concentrate use appear most promising.

In the case of green fodder, allocative efficiency was even stronger, with MVP-MFC ratios well above one across the districts. Hassan again registered the highest ratio (3.73), followed by Belagavi (3.12) and Kalaburagi (2.51). The overall ratio of 3.13 underscores the critical importance of green fodder in boosting milk productivity, as it directly contributes to better animal health and higher milk yield. The underutilization of green fodder indicates a significant scope for improvement, especially in Hassan where the additional returns from green fodder are particularly high. Expanding green fodder availability and balanced feeding strategies could therefore substantially improve efficiency in milk production.

For dry fodder, the MVP-MFC ratios were only marginally above one across districts, with Kalaburagi showing the highest ratio (1.66), followed by Belagavi (1.51) and Hassan (1.26). The overall ratio of 1.48 suggests that while dry fodder is important, its role is less critical compared to concentrates and green fodder in driving milk output. Since the ratios are closer to unity, farmers appear to be allocating dry fodder relatively efficiently, though there is still modest scope to enhance its use. The results indicate that balanced integration of dry fodder with other feed resources is essential to maintain efficiency without excessive reliance on it.

Labour, on the other hand, showed negative allocative efficiency across all three districts, with MVP-MFC ratios less than zero. In Kalaburagi, the ratio was the lowest (-1.52), followed by Belagavi (-1.27) and Hassan (-0.96). The overall ratio of -1.26 points to overutilization of labour in dairy farming, suggesting that the additional cost of labour exceeds its contribution to milk output. This implies disguised unemployment or inefficiency in labour allocation, where more workers are employed than necessary. Reducing excess labour use or improving labour productivity through mechanization and better management practices could help restore allocative efficiency in this resource category.

Herd size also revealed positive allocative efficiency, with MVP-MFC ratios greater than unity in all districts. Hassan once again reported the highest ratio (1.78), followed by Belagavi (1.42) and Kalaburagi (1.15), with the overall average standing at 1.44. This indicates that expanding herd size could potentially improve milk production and profitability. However, the differences across districts reflect varying productivity levels and resource availability, with Hassan's farmers showing greater potential benefits from increasing herd size. Overall, the results emphasize that concentrates, green fodder, and herd size are underutilized resources with high scope for efficiency gains, while labour is overutilized, calling for rational reallocation to maximize returns in milk production.

Table 7: Allocative efficiency of resources in milk production in Belagavi district (Per farm)

Sl. No.	Resource	Belagavi (n=80)			Hassan (n=80)			Kalaburagi (n=80)			Overall (n=240)		
		MVP	MFC	Ratio	MVP	MFC	Ratio	MVP	MFC	Ratio	MVP	MFC	Ratio
1	Concentrates (kg)	25.46	12.0	2.12	32.38	11.5	2.82	19.42	11.8	1.65	25.77	11.77	2.19
2	Green fodder (kg)	18.72	6.0	3.12	23.15	6.2	3.73	15.34	6.1	2.51	19.07	6.10	3.13
3	Dry fodder (kg)	7.53	5.0	1.51	6.45	5.1	1.26	8.62	5.2	1.66	7.53	5.10	1.48
4	Labour (MD)	-10.18	8.0	-1.27	-7.24	7.5	-0.96	-12.46	8.2	-1.52	-9.96	7.90	-1.26
5	Herd size (No.)	142.46	100.0	1.42	168.82	95.0	1.78	120.65	105.0	1.15	143.98	100.0	1.44

5. Conclusion

The study clearly demonstrates that dairy farming in the study area is an economically viable and profitable enterprise, providing stable income to farm households across all districts. Although the cost of milk production varied marginally across regions, feed and labour emerged as the dominant cost components, accounting for a major share of total production cost. The positive net returns and favourable returns per rupee invested indicate strong economic performance of dairy farms. However, the presence of technical and allocative inefficiencies suggests that farmers are not operating on the optimal production frontier. Regression and efficiency analyses revealed that herd size, concentrates, and green fodder significantly influence milk yield, while labour is often overutilized. These findings highlight substantial scope for improving productivity and profitability through better resource allocation, scientific feeding practices, and efficient farm management.

To enhance the performance and efficiency of dairy farming, policy interventions should focus on improving access to quality feed and fodder through fodder development programmes, promotion of high-yielding fodder varieties, and strengthening feed supply chains. Capacity-building initiatives such as training and extension services on scientific dairy management, balanced ration formulation, and herd health management are essential to improve technical efficiency. Institutional support in the form of affordable credit, livestock insurance, and veterinary services should be expanded, particularly for small and marginal farmers. Encouraging optimal herd size, promoting mechanization to reduce labour inefficiencies, and supporting climate-smart dairy practices can further improve resource-use efficiency. Strengthening milk marketing infrastructure and ensuring remunerative milk prices will also play a crucial role in sustaining dairy farm profitability and promoting inclusive growth of the dairy sector.

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