Indian Journal of Animal Sciences **95** (2): 159–162, February 2025/Article
https://doi.org/10.56093/ijans.v95i2.158882

Measuring dairy progressiveness across the districts of Karnataka state

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Received: 24 October 2024; Accepted: 27 March 2025

ABSTRACT

This study evaluated regional disparities in Karnataka's dairy development, despite its robust cooperative structure and significant milk procurement. A Dairy Development Index (DDI), comprising ten key indicators, was constructed and used with Principal Component Analysis (PCA) and Biplot techniques to categorize districts based on dairy progressiveness. Results revealed substantial regional disparity in dairy development. Southern districts exhibited higher dairy progressiveness compared to Northern and Malnad and Coastal regions. The study identified the key indicators, artificial insemination coverage, veterinary service availability, cooperative membership, and average daily milk yield as determinants of dairy development. The study advocates for proper planning and prioritization of indicators that determine the regional dairy progressiveness to reduce the variability and regional imbalances for additional milk production. The developed DDI indicating the dairy progressiveness at district level will be useful for proper micro level planning, prioritization, policy formulation to reduce the regional imbalances and leading to balanced dairy development across the Karnataka State.

Keywords: Dairy development index, Principal component analysis, Regional disparity

The Livestock sector is a crucial part of India's agricultural economy, contributing 5.5% of the total GVA and 30.23% to agricultural Gross Value Added (GVA) in 2022-23. India remains the world's top milk producer, with 239.30 million tonnes in 2023-24, marking a 3.78% increase from the previous year and accounting for 24% of global production. Per capita milk availability rose to 471 grams per day from 351 grams in 2016-17 (DAH&D, 2024). The 20th Livestock Census (2019) recorded 536.76 million livestock, with dairy farming sustaining 80 million farmers and empowering women economically (DAH&D 2019). Karnataka is a key contributor to India's dairy sector, with an annual milk production of approximately 12.83 million tonnes, representing 5.62% of the national output (NDDB 2023, DAH&D 2024). The state's cattle and buffalo population are estimated at 12.2 million, with a rising proportion of indigenous breeds due to government interventions aimed at enhancing livestock health and productivity (DAH&D 2019). Karnataka's per capita milk availability stands at 543 grams per day, surpassing the national average of 471 grams, underscoring its well-established dairy infrastructure and cooperative network (DAH&D 2024). The Karnataka Milk Federation (KMF), the largest dairy cooperative in South India and the second-largest nationwide, operates across 15 districts, sourcing milk from over 2.6 million farmers. In April 2024, KMF reported an average daily milk collection of 80.89 lakh litres, reflecting significant growth compared to the previous year (Vivan 2024). The state's dairy sector not only enhances economic stability but also contributes to social empowerment, particularly among women and youth (IMARC Group 2023). However, Karnataka's dairy industry exhibits pronounced regional disparities driven by geographical, agro-climatic, socio-economic, and resource-based differences (Khalandar *et al*. 2019). Factors such as herd size, access to veterinary services, availability of quality fodder, and the presence of organized dairy cooperatives significantly influence regional variations in milk yield and value chain efficiency (Khan *et al*. 2021). Against this backdrop, the present study aims to assess dairy progressiveness across Karnataka's regions using selected indicators, providing insights into the sector's development dynamics and regional imbalances.

MATERIALS AND METHODS

Data Sources: To assess dairy progressiveness at the district level, a composite Dairy Development Index (DDI) was developed using secondary data from 2014-2020. The index construction began with identifying 35 relevant variables across five dimensions of dairy development through a literature review. These variables were validated by 60 field extension functionaries based on Relevancy Weightage (RW > 0.80) and Mean Relevancy Score (MRS > 2.40) (Panjaitan 2018). A final set of 17 variables were selected, with time-series data available for 30 districts. Data on milk production, dairy animal population, yields, and per capita milk availability were sourced from

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the 19th and 20th Livestock Census. Additional data on veterinary institutions, artificial insemination services, dairy cooperatives, and area under fodder crops were obtained from the Integrated Sample Survey and Annual Administrative Reports of the Department of Animal Husbandry & Veterinary Services, Government of Karnataka, and Karnataka Cooperative Milk Producers' Federation Limited.

Statistical Analysis

Multicollinearity Assessment & Normalization of Data: Collected data were tabulated and normalized to ensure comparability across different measurement scales. Correlation analysis was conducted to examine the linear relationship among variables, removing five highly correlated variables ($r > 0.8$), retaining 12 for analysis. Indicators were normalized to ensure comparability despite their varying scales of measurement by using followed equations:

- For a positive relationship:

$$\text{Normalization of data} = \frac{(\text{Actual value}–\text{Minimum value})}{(\text{Maximum value}–\text{Minimum value})}$$

- For a negative relationship:

$$\text{Normalization of data} = \frac{(\text{Maximum value}–\text{Actual value})}{(\text{Maximum value}–\text{Minimum value})}$$

Principal Component Analysis (PCA): PCA was performed on normalized data using varimax rotation with Kaiser normalization in SPSS 19. Indicators with factor loadings ≥ 0.6 under the two major principal components (PC1 & PC2) were retained. Ten dairy development indicators were selected, while two variables viz., ATB and MDC, loaded under PC3 and PC4 were excluded. The final index was computed using weighted indicators derived from PCA.

Biplot Analysis: Biplot analysis (Gabriel 1971, Mahida *et al*. 2018a) was employed to extract maximum information, visually representing two principal components explaining multi-dimensional data variation. Four principal components with eigenvalues >1 accounted for 80% of the variability.

Assignment of Weights: Weights were assigned to indicators based on PCA using the equation:

$$W_i = \Sigma|L_{ij}|E_j$$

Where,

W_i represents the weight of the i^{th} variable

L_{ij} represents the loading value of the i^{th} variable on j^{th} factor

E_j represents the Eigen value of the j^{th} factor

Construction of the Index: The weighted Dairy Development Index (DDI) was constructed using the formula:

$$\text{index} = \frac{\sum_{i=1}^{n} X_i W_i}{\sum_{i=1}^{n} W_i}$$

Where,

X_i represents the normalized value of i^{th} variable

W_i is the weight of i^{th}variable

$$DDI = \frac{0.8(VIA+FOD+DCM+PMA+MYC)+1.2(AIP+SCB+MPS+MYI+MYB)}{10}$$

with values ranging from 0 to 1, where higher values indicate better dairy development.

Categorization of Districts: Based on DDI values, districts were classified into three categories: progressive, moderately progressive, and less progressive in dairy development. The selected indicators reflect key aspects of dairy development, including productivity (MYI, MYC, MYB), veterinary infrastructure (VIA, AIP, ATB), crossbred cattle share (SCB), fodder availability (FOD), milk availability (PMA), and cooperative strength (MDC, MPS, DCM). These indicators provide a comprehensive assessment of dairy sector performance at the district level.

RESULTS AND DISCUSSION

The summary statistics of variables influencing dairy development (Table 2) indicate that, on an average, the share of indigenous cattle (42.47%) in the total bovine stock was higher than that of crossbred (36.27%) and buffalo (21.27%). Milk yield was found to be highest for crossbred cows (6.34 kg/day), followed by buffalo (2.93 kg/day) and indigenous cows (2.45 kg/day). The PCA results, as depicted in Table 1, illustrate the variability contributed by all principal components, with key factors influencing dairy development being average daily milk yield, artificial insemination coverage, veterinary service availability, and cooperative membership. Hence, concerted efforts need to be placed on these important factors for sustaining the dairy development.

Table.1. Factor loadings of corresponding principal components

Indicator	Principal Component (PC)			
	PC1	PC2	PC3	PC4
MYI	-0.100	0.829	0.061	0.075
MYC	0.381	0.657	0.194	-0.074
MYB	-0.158	0.869	-0.118	0.018
VIA	0.695	-0.015	0.532	-0.071
AIP	0.933	0.066	0.204	0.041
ATB	0.181	0.093	0.802	0.054
SCB	0.911	0.002	0.235	0.048
PMA	0.678	0.220	-0.437	0.087
FOD	0.730	0.078	0.049	-0.108
MDC	0.037	0.041	0.027	0.984
MPS	0.877	-0.115	0.019	0.010
DCM	0.783	-0.252	0.150	0.139

MYI-Average Per Day Milk Yield of Indigenous Cattle (Kg/day); MYC-Average Per Day Milk Yield of Cross Bred Cattle (Kg/day); MYB-Average Per Day Milk Yield of Buffalo (Kg/day); VIA-Veterinary. Institutions per 10000 Bovine Population; AIP-AI done per 1000 Adult Female Bovine Population; ATB-Number of Animals Treated per 1000 Bovine Population; SCB-Share of productive cross bred cattle in productive bovine stock - %; PMA-Per capita milk availability (grams); FOD-Area under fodder per 1000 total Bovine (hectare); MDC-Number of members per dairy cooperative society; MPS-Milk procurement per day per dairy cooperative society (Kgs); DCM-No. of DCS per 1000 tonnes of milk production.

Table.2. Summary statistics of variables influencing dairy development

Indicator	Average	Standard Deviation	Maximum	Minimum	Range
MYI	2.45	0.49	4.20	1.00	3.21
MYC	6.34	0.99	9.08	2.82	6.26
MYB	2.93	0.63	4.56	0.71	3.86
VIA	7.00	3.00	13.0	3.00	10.0
AIP	701	433	2223	70	2152
SCB	36.27	25.01	82.37	0.53	81.85
PMA	341	169	974	36.0	938
FOD	6.31	8.12	36.12	0.04	36.07
MPS	419	165	741	108	633
DCM	2.00	1.00	5.00	1.00	4.00

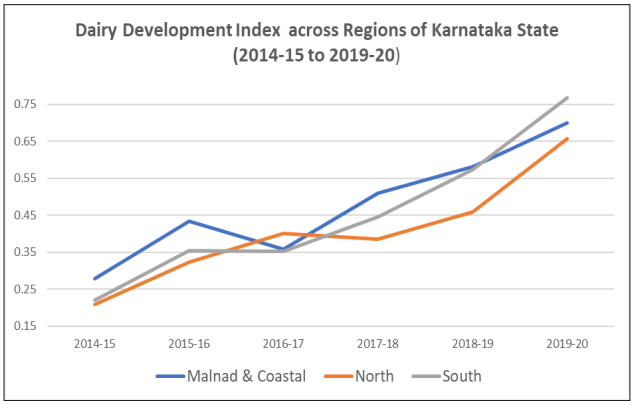

Fig. 2. Dairy Progressiveness across regions of Karnataka State

The biplot analysis (Figure 1) categorized districts based on dairy progressiveness, highlighting significant regional disparities. The most progressive districts, including Hassan (0.92), Tumkur (0.84), Kolar (0.83), and Ramanagara (0.82), belonging to Southern region, benefiting from favorable agro-climatic conditions, well-developed dairy infrastructure, a higher proportion of crossbred cattle, abundant water resources, fodder availability, and organized dairy cooperatives, allowing it to contribute majority of the state's milk production. Conversely, districts such as Bagalkote (0.43), Gadag (0.47), and Dakshina Kannada (0.59) belonging to both Northern and costal region of Karnataka exhibit lower dairy progressiveness, primarily due to semi-arid conditions, inadequate infrastructure, a lower prevalence of high-yielding breeds inadequate fodder and poor market access. The presence of the KMF also varies across the state, with Southern Karnataka benefiting from stronger cooperative support and higher membership, while Northern and Coastal Karnataka lag behind (KEA and KMF 2017, NDDB 2020, Rebasiddanavar 2021). The PCA further reveals that factors such as artificial insemination coverage, veterinary treatment per 1,000 bovine population, cooperative membership, and milk procurement per dairy society were critical determinants of regional dairy development (Mastuti *et al*. 2019, Mahinda *et al*. 2018b). The biplot analysis also indicates a strong association between progressive dairy districts and higher artificial insemination rates, cooperative efficiency, and veterinary care, which significantly contribute to productivity enhancement (NDDB 2023).

Figure 2 illustrates the dairy progressiveness trend across Karnataka from 2014 to 2020, demonstrating steady growth in the Southern region, where crossbred cattle dominated production. The South region benefits from superior market access, organized dairy cooperatives, and abundant fodder resources, positioning it as a key contributor to the state's dairy sector (Kolekar *et al*. 2024). In contrast, Northern Karnataka faces structural challenges, including erratic rainfall, insufficient veterinary services, and limited cooperative presence, resulting in lower milk production. Despite these constraints, targeted interventions, such as increasing artificial insemination

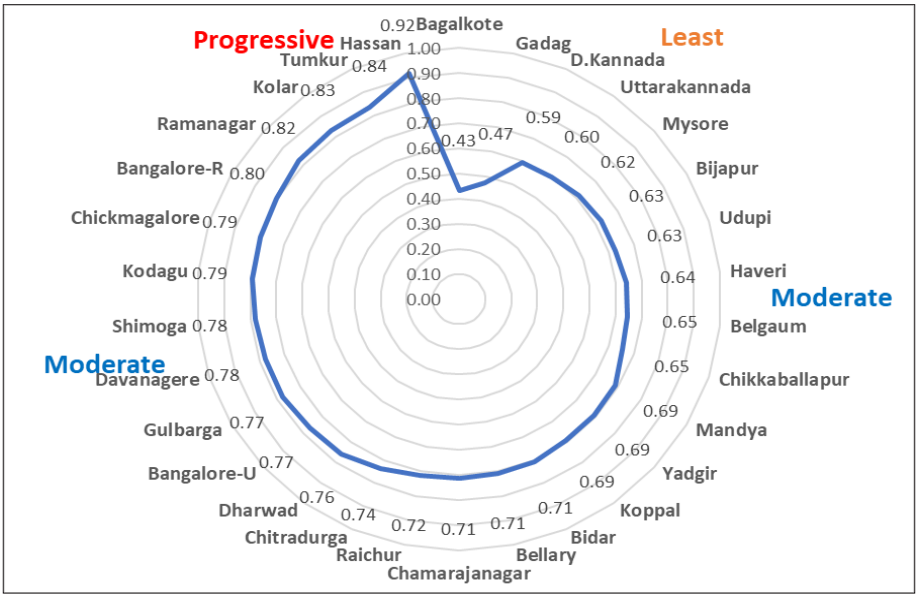

Fig. 1. Categories of Districts based on dairy progressiveness

coverage and strengthening veterinary infrastructure, could enhance dairy productivity in this region (KEA and KMF 2017). The Malnad and Coastal regions, characterized by humid conditions and diversified livelihoods, contribute less to dairy development, as evident from their lower progressiveness indices. The prevalence of indigenous cattle in these areas' further limits productivity, underscoring the need for genetic improvement programs and extension services to boost milk yields (Rebasiddanavar 2021).

The regional disparities can be minimized through micro level policy planning focused to genetic upgradation indigenous cattle, improving the veterinary infrastructure, improving the milk procurement by dairy cooperatives, increasing the area under improved fodder crops and improved access to extension services of developmental departments in the less progressive regions will enhance the milk production leading faster and overall dairy development across the regions of Karnataka State (Sathisha *et al*. 2018).

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