Indian Journal of Animal Sciences **95** (12): 1090–1094, December 2025/Article
https://doi.org/10.56093/ijans.v95i12.150708

Spatio-temporal dynamics of bovine population and milk production in Andhra Pradesh

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Received: 17 April 2024; Accepted:24 March 2026

ABSTRACT

Investigating inter-district variations in bovine population dynamics and milk production, and understanding their drivers, is essential for targeted interventions towards dairy development. This study analysed district-wise trends in bovine population dynamics and milk production in Andhra Pradesh from 2007 to 2019, using secondary data collected from various sources. Trend analysis was performed by estimating compound annual growth rate. All districts witnessed a considerably higher rate of increase in the population of crossbred females, indicating the substitution of low-yielding indigenous animals with high-yielding crossbred cattle. The results revealed significant inter-district variations in the level of dairy development, as reflected in bovine density, bovine composition, herd efficiency ratio (HER), and milk production. District-level determinants of HER were analysed by employing panel data regression. The density of veterinary institutions, tractor density, and rainfall were found to have a positive and significant influence on the HER.

Keywords: Breed preference, Bovine composition, Herd efficiency ratio Milk productivity and Aspirational districts, Panel data regression

Dairying is the most critical component of India's livestock sector, employing more than 8 crore rural households (GoI, 2022) with every second rural household owning at least one dairy animal (Kishore *et al*. 2016). Milk is the largest livestock commodity, and contributed 5% to the nation's Gross Value Added in 2023-24 (GoI, 2025). Among food commodity groups, milk and milk products have the highest income elasticity of demand. The per capita availability of milk in India was recorded as 485 grams/day in 2024-25. India has the world's largest bovine population (302.79 million) and was the largest milk producer (247.87 million tonnes), contributing about 15% and 25% to the global totals in 2024-25, respectively (GoI, 2025).

Andhra Pradesh, known for its thriving dairy sector, stands seventh in milk production (13.96 million tons), with a share of 5.63% of the total milk production in India (GoI, 2025). As per 20th Livestock Census (2019), Andhra Pradesh had 10.8 million bovine population, of which the share of buffaloes was highest (56.5%), followed by indigenous cattle (22%) and crossbred cattle (21.5%). The share of crossbred cattle to the total bovine population has increased while the share of indigenous cattle and buffaloes has decreased over the years. Ongole and Punganur cows and Godavari buffaloes are the dominant indigenous bovine breeds in the state.

Andhra Pradesh is broadly divided into Rayalaseema and Coastal Andhra regions. While the Rayalaseema region faces frequent droughts, coastal Andhra is often exposed to floods, leading to agricultural uncertainty. Over 4.6 million farmers depend on livestock farming in the state, and dairying could be a promising option for improving the livelihood security of farmers, especially resource-poor landless, marginal, and small farmers.

The proportion of in-milk bovines in the total bovine population is known as herd efficiency ratio (HER), and reflects the degree of specialization and intensification of dairying in a region (Kishore *et al*. 2016, Rajan and Shah, 2020). A higher HER implies a more efficient and productive dairy system, as it means that more bovines are producing milk rather than being kept for draught or breeding purposes. In this paper, we used HER as an indicator of dairy development. With this background, the study aims to assess the spatial and temporal variations in the bovine population and milk production in Andhra Pradesh.

MATERIALS AND METHODS

Data sources: This study mainly relied on district-level data from three quinquennial rounds of livestock census of India, conducted during the years 2007, 2012, and 2019. The data on district-level milk production from 2011 to

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2020 was collected from the integrated sample survey reports, published by the Animal Husbandry Department, Government of Andhra Pradesh.

The livestock census has district-level data on number of cattle (indigenous/non-descript and exotic/crossbred cattle) and buffaloes by sex (male, female), age group (less than one year, 1 to 2.5 years, more than 2.5 years), usage (agriculture, breeding, agriculture and breeding, other work) and lactation status (in-milk, dry, not calved once, others). The density of different bovine animals (number of animals per km^2 of geographical area) and their share in total bovine population and HER (ratio of number of in-milk animals to total animals) were analysed using these data.

The district-level information regarding the land utilization, veterinary infrastructure, tractor use, and road infrastructure was compiled from statistical abstract reports of various years from the Directorate of Economics and Statistics, Government of Andhra Pradesh (GoAP, 2021).

To analyze the trends in value of output from milk in Andhra Pradesh, the data was collected from the reports of state-wise estimates of the value of output from agriculture and livestock, published by Ministry of Statistics and Programme Implementation, Government of India.

Statistical analysis: Compound Annual Growth Rate (CGR)

The trend in species wise bovine population and milk production was estimated using CGR, as follows

$$Y_t = ab^t e^{u_t}$$

Where,, bovine population and milk production at time t; , intercept; regression coefficient; , an error term corresponding to t^{th} observation.

Panel data regression: Determinants of district level variations in HER were analyzed using panel data regression model. A balanced panel was constructed for 13 districts of Andhra Pradesh by combining variables on veterinary infrastructure, source-wise irrigated area, density of tractors, and road infrastructure from 2011 to 2019. The district-wise time series data on HER and other bovine demographic variables from 2011 to 2019 was constructed using the interpolation technique. The Hausman test was used to determine whether the fixed effect model (FEM) or random effect model (REM) is more appropriate for a given dataset.

The FEM had constant slopes but intercepts differed according to the cross-sectional (districts) unit. For *i* classes, *i–1* dummy variables were used for designating a particular district.

$$Y_{it} = \alpha_i + \beta^1 X_{1\,it} + \beta_2 X_{2\,it} + \beta_3 X_{3\,it} + \beta_4 X_{4\,it} + \beta_5 X_{5\,it} + \beta_6 X_{6it} + \beta_7 X_{7\,it} + \beta_8 X_{8\,it} + \beta_9 X_{9\,it} + e_{it}$$

$$e_{it} \sim IID(0,\sigma_e^2)$$

Where,

Y_{it} = HER in the i^{th} district (i=1 to 13) and t^{th} year (t=2011 to 2019)

X_1 = Share of crossbred cattle in total bovine population (%)

X_2 = Share of buffaloes in total bovine population (%)

X_3 = Groundwater irrigated area (% net sown area)

X_4 = Surface water irrigated area (% net sown area)

X_5 = Veterinary institutions (number per one lakh of bovine animals)

X_6 =Tractor density (number per100 ha of net sown area)

X_7 =Road density (km per km^2 of geographical area)

X_8 =Area under barren land and pastures (%)

X_9 = Actual rainfall (mm)

e_{it} =Error component

$\alpha_i, \beta_1, \beta_2, \ldots, \beta_9$ = Parameters to be estimated

REM assumed that district-specific coefficient, was fixed for each time-invariant and was expressed as follows,

$$\alpha_i = \alpha + \epsilon_i$$

$$\epsilon_i \sim IID(0,\sigma^2_{ei})$$

Therefore, REM was expressed as follows

$$Y_{it} = \alpha + \beta_1 X_{1\,it} + \beta_2 X_{2\,it} + \beta_3 X_{3\,it} + \beta_4 X_{4\,it} + \beta_5 X_{5\,it} + \beta_6 X_{6\,it} + \beta_7 X_{7\,it} + \beta_8 X_{8\,it} + \beta_9 X_{9\,it} + w_{it}$$

Where, was a composite error term, including a cross-section error component, and a combined time series and cross-section error component, .

RESULTS AND DISCUSSION

Bovine density: Bovine density was highest (106 bovines per km^2 of geographical area) in Srikakulam and West Godavari districts, followed by Vizianagaram (93) and Krishna (92) districts in 2019 (Fig. 1). Anantapur and YSR Kadapa districts had the lowest bovine density (41), accounting for one-fourth of that in Srikakulam. The cattle density was highest (98) in Srikakulam district, followed by Vizianagaram district (75), while the lowest density was observed in Prakasam district (4) (Supplementary Table S1). Between 2007 and 2019, all districts experienced a decline in the cattle density, mainly due to faster decline in the indigenous and non-descript cattle population, as bovine functions shifted from draught to dairying.

Buffaloes dominated the coastal districts of Andhra Pradesh, as high humidity, temperature and rainfall in these districts were favourable for rearing buffaloes. In 2019, buffalo density was highest in Krishna district (82), followed by Guntur district (78), while it was lowest in Chittoor district (6). The overall buffalo density in Andhra Pradesh declined from 54 in 2007 to 41 in 2019. This decline was attributed to culling of less productive non-descript and male buffaloes (Amaravathi and Reddy, 2020).

Traditionally, farmers kept indigenous cattle for agricultural and transportation needs, with milk as a by-product. However, over the years, the bovine functions shifted towards dairying due to rising farm mechanisation

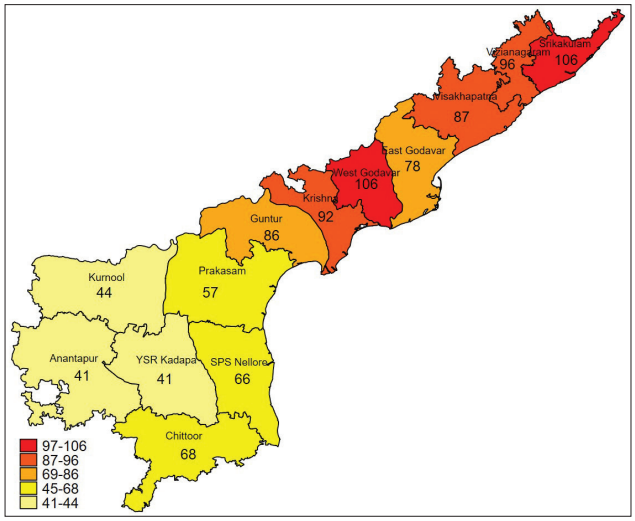

Fig. 1. Bovine density in Andhra Pradesh in 2019

and increased demand for milk and milk products driven by urbanisation and higher incomes (Birthal *et al*. 2014; Kishore *et al.* 2016, Rajan and Shah, 2020). Notably, Vizianagaram district, an aspirational district with a large tribal population and poverty, marked an increase in the proportion of crossbred cattle from 24 to 54% between 2007 and 2019 (Supplementary Table S2). It signified that the crossbred cattle adoption was concentrated among resource-poor landless and small landholders to generate stable income (Birthal *et al*. 2014, Kishore *et al*. 2016; Birthal *et al*. 2017, GoI, 2022).

Trends in bovine population: The cattle population declined across the districts, except in East Godavari and Visakhapatnam, as indicated by negative CGR (Table 1). The decline was restricted to indigenous cattle, mainly driven by a sharp decline in the male population following a considerable decline in their use for agricultural operations. The robust rental markets for tractors, power tillers, and threshers allowed even marginal and small farmers to mechanise agricultural operations. All the districts witnessed a positive CGR in the population of crossbred cows. These results indicated a structural transformation in the bovine composition across the districts of Andhra Pradesh, although at varying rates. All the districts of Andhra Pradesh, except SPS Nellore, experienced a decline in the buffalo population.

Patterns of HER: HER for crossbred cattle was highest in Chittoor district (0.42), followed by Anantapur (0.40%) (Fig. 2). In other districts, HER ranged from 0.33 to 0.39, except in Guntur (0.28) and Kurnool (0.25), which recorded lower values. HER for buffalo was also relatively high across districts, ranging from 0.31 in Vizianagaram to 0.38 in East Godavari.

In contrast, HER was lowest for indigenous cattle with

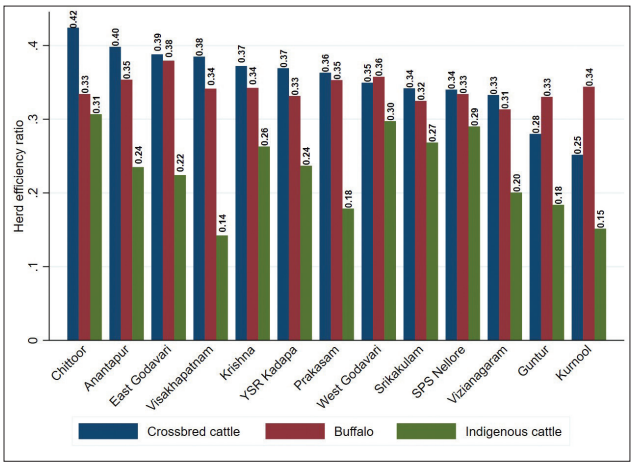

Fig. 2. Herd efficiency ratio in Andhra Pradesh in 2019

Table 1. CGRs of cattle and buffalo population in Andhra Pradesh from 2007 to 2019 (%)

Districts	Indigenous cattle		Crossbred cattle		Total cattle	Buffalo		
	Male	Female	Male	Female		Male	Female	Total
Anantapur	-9.98	-4.96	2.43	7.10	-3.76	-4.69	-8.38	-4.29
Chittoor	-12.53	-5.77	-5.92	1.41	-1.15	-3.61	-7.37	-3.07
East Godavari	1.52	4.33	-8.78	0.84	2.35	-1.20	-7.63	-0.56
Guntur	-4.79	-1.42	11.80	6.72	-2.46	-2.34	-7.55	-1.77
Krishna	-6.45	0.00	-1.53	-0.30	-2.14	-2.41	-6.76	-1.93
Kurnool	-4.01	-2.03	12.91	14.31	-2.84	-3.27	-9.31	-2.66
Prakasam	-7.53	-1.23	-1.69	18.09	-3.93	-2.42	-8.42	-1.69
SPS Nellore	-11.03	-0.95	0.04	2.41	-3.48	-0.24	-4.47	0.27
Srikakulam	-9.97	-5.97	-6.31	3.12	-2.63	-7.05	-10.89	-5.80
Visakhapatnam	1.05	0.09	-8.86	3.36	0.88	-3.09	-7.55	-2.13
Vizianagaram	-7.81	-2.18	-2.22	6.92	0.57	-4.82	-8.94	-3.84
West Godavari	-5.11	1.68	-2.52	1.47	-0.06	-0.73	-5.78	-0.19
YSR Kadapa	-9.76	-0.94	-2.99	8.75	-1.64	-0.33	-2.82	-0.02
Overall	-6.65	-1.49	-1.05	5.71	-1.56	-2.79	-7.37	-2.13

Source: Livestock Census data of various years, Department of Animal Husbandry and Dairying, Govt. of India

large inter-district variations. Chittoor had highest HER (0.31), followed by West Godavari (0.30). Visakhapatnam and Kurnool districts, where indigenous cattle accounted for 48% and 44% of the total bovine population, respectively, recorded lower HER values of 0.14 and 0.15. Kishore *et al*. (2016) also reported a lower HER in tribal districts of India, attributing it to greater dependence on draught power and cultural taboos associated with milk consumption

Determinants of HER: The determinants of district-level variations in HER in Andhra Pradesh were analyzed using panel data regression model (Table 3). REM was applied based on the results of Hausman specification test. The results showed that the districts with a higher share of crossbred cattle and buffaloes in the total bovine population had a significantly high level of HER. This was expected as crossbred cattle and buffaloes were mainly reared for milk production compared to indigenous cattle that were used for draught purposes, with milk as an adjunct product. There was no significant influence of groundwater and surface irrigated areas on HER. Kishore *et al.* (2016) also found no significant relationship between surface irrigation and HER. However, Birthal and Rao (2004) and Rajan and Shah (2020) reported that groundwater-irrigated areas had the most efficient and intensive dairying due to a positive effect on feed availability.

The districts with a high density of veterinary institutions had a significantly high level of HER. Well-equipped veterinary hospitals and clinics were essential for providing medical care to dairy animals. Tractor density had a significant and positive influence on HER. Reliance on male cattle or buffaloes for draught power was limited in the districts with a higher density of tractors and power tillers. Previous studies had also reported similar results (Birthal and Rao, 2004; Kumar and Singh, 2008; Kishore *et al*. 2016). Road density and barren land and pastures had no significant influence on HER. The districts with high rainfall had a positive and significantly higher HER. A similar positive relationship was reported by Birthal and Rao (2004).

Trends in milk production: Table 2 shows district-wise share of milk production in the total milk production of Andhra Pradesh during triennium ending (TE) 2019. Chittoor district contributed the largest share (11.39%) to the total milk production of Andhra Pradesh, followed by Krishna (11.05%), Guntur (10.36%), and Prakasam (10.19%) districts. Despite having a higher density of bovines, the tribal districts of Srikakulam and Vizianagaram districts had the lowest share in the milk production. Between 2007 and 2019, all the districts of Andhra Pradesh had registered a positive CGR in milk production. YSR Kadapa district registered the highest annual increase of 9.81%, followed by Anantapur (9.51%) and Chittoor districts (8.66%). Overall, milk production in Andhra Pradesh registered a CGR of 7.89%.

Figure 2 depicts the trends in the value of output from milk in Andhra Pradesh from 2011 to 2020 at 2011-12 constant prices. The value of output from milk increased from ₹ 206.89 billion in 2011 to ₹ 371.48 billion in 2019,

Table 2. District-wise trends in milk production in Andhra Pradesh from 2007 to 2019

Districts	% Share in milk production (TE 2019)	CGR
Anantapur	5.89	9.51
Chittoor	11.39	8.66
East Godavari	8.45	5.53
Guntur	10.36	5.92
Krishna	11.05	8.36
Kurnool	8.87	8.26
Prakasam	10.19	8.03
SPS Nellore	5.51	8.24
Srikakulam	4.51	8.27
Visakhapatnam	5.28	5.56
Vizianagaram	4.69	8.66
West Godavari	8.81	7.82
YSR Kadapa	4.99	9.81
Overall		7.89

Source: Integrated Sample Survey reports, Animal Husbandry Department, Govt. of Andhra Pradesh

Table 3. Determinants of district-level variations in HER in Andhra Pradesh

Independent variables	Regression coefficients
Share of crossbred cattle in total bovine population (%)	0.2790***
	(0.0208)
Share of buffaloes in the total bovine population (%)	0.2050***
	(0.0274)
Groundwater irrigated area (% of Net sown area)	0.0071
	(0.0254)
Surface irrigated area (% of Net sown area)	-0.0224
	(0.0142)
Veterinary institutions (No. per one lakh of bovine population)	0.0714**
	(0.0361)
Tractor density (No. per 1000 ha of NSA)	0.0138***
	(0.0044)
Road density (km per km^2 of geographical area)	-2.0329
	(1.6241)
% area under barren land and pastures	-0.0211
	(0.0304)
Actual rainfall (mm)	0.0005*
	(0.0003)
Constant	14.31***
	(2.6567)
No. of Observations	117
R^2 value	0.61

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

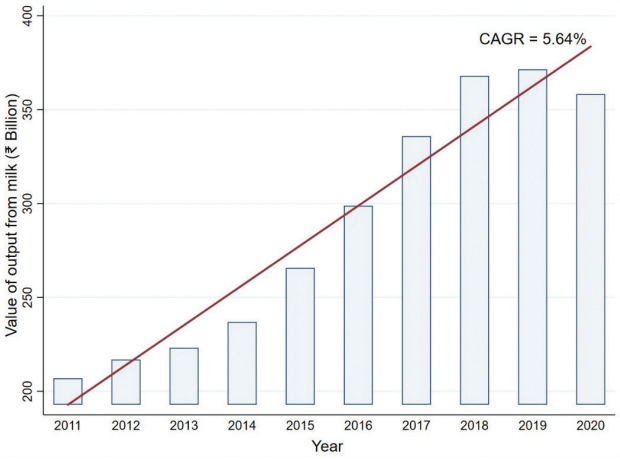

Fig. 2. Trends in value of output from milk in Andhra Pradesh from 2011 to 2020 (2011-12 constant prices)

then declined to ₹ 358.27 billion in 2020 due to the COVID-19 lockdown. Overall, the value of output from milk registered an annual growth of 5.94% during the period 2011- 2020.

The results showed significant inter-district variations in the level of dairy development as measured by bovine density, bovine composition, HER, and milk production levels. Chittoor, Prakasam, Krishna, and Anantapur districts were characterized by lower bovine density, higher HER and milk production. In contrast, Vizianagaram, Vishakhapatnam, and Srikakulam districts lagged with lower HER and less milk production despite having higher bovine density. Vizianagaram and Vishakhapatnam could be defined as aspirational districts with a higher share of tribal population and poverty level, where dairy development could make a notable difference. The panel data analysis showed that districts with higher density of veterinary institutions recorded significantly higher HER. Tractor density, share of crossbred cattle and buffalo population also had a positive influence on HER. The study suggested formation of a policy to enhance market and veterinary infrastructure to promote dairy development.

ACKNOWLEDGEMENT

The first author sincerely acknowledges ICAR-National Dairy Research Institute for providing financial assistance for pursuing Postgraduate research work on this topic.

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