

# Impact of Population Dynamics on Milk Production Trends in India: A Statistical Analysis

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Received 20<sup>th</sup> April 2025; Accepted 21<sup>st</sup> May 2025; Published online 25<sup>th</sup> June 2025

## Abstract

Dairy farming is a cornerstone of India's agricultural economy, sustaining millions of rural livelihoods and contributing to national food security. This research paper explores the sector's transformation from traditional methods to modern, technology-driven practices, catalyzed by the White Revolution and Operation Flood. India now leads global milk production, driven by population growth, supportive policies, and cooperative models. Using secondary data from 2017–2022, the study reveals a strong positive correlation (0.994) between population increase and milk output, underscoring demographic demand as a key growth factor. Despite progress, small-scale farmers face persistent challenges—limited cold chain infrastructure, inconsistent quality, and restricted access to advanced technologies. The paper emphasizes the strategic importance of dynamic supply chain management in addressing climate variability, disease outbreaks, and market fluctuations. It recommends strengthening infrastructure, promoting climate-resilient practices, enhancing market access, and investing in capacity-building initiatives. These measures are vital for sustainable development, improved farmer welfare, and the continued economic and nutritional contribution of India's dairy sector.

## Keywords

Dairy Farming, Milk Production, Small-Scale Farmers, Supply Chain Management, Technology Adoption

## Introduction

Agriculture and its allied activities continue (Joshi, Singh, & Singh, 2021) to be the cornerstone of India's economy, contributing not only to income and employment but also to food and nutritional security. Within this framework, the dairy sector occupies a central role (Pingale & Singh, 2022) due to its capacity to support rural livelihoods, enhance household income, and provide a steady supply of nutritious food. India has established itself as the world's leading milk producer (NDDDB, 2020; FAO, 2019), accounting for a significant share of global output. This growth, however, cannot be understood in isolation from the country's demographic changes (Kumar, Birthal, & Meena, 2017). Variations in population size, distribution, and socio-economic characteristics directly influence the demand for milk and dairy products, thereby shaping production trends over time.

The concept of *population dynamics* encompasses changes in the size, growth rate, structure, and geographical distribution of people, influenced by fertility, mortality, and migration patterns. In a country of over 1.4 billion people, such demographic factors exert substantial pressure on the food system. Milk, a staple in Indian households across diverse regions and cultures, is particularly sensitive to these shifts. Population growth intensifies demand, while urbanization, rising incomes, and lifestyle transitions alter consumption preferences and patterns. This growing and diversifying demand compels both producers and policymakers to continuously adapt production systems, supply chains, and distribution networks.

Historically, India was a milk-deficient country, with production largely confined to small-scale, subsistence-oriented systems. The launch of the White Revolution through Operation Flood (Delgado et al., 2001; Chand, Chauhan, & Kumar, 2019) in the 1970s transformed this scenario by promoting dairy cooperatives, improving veterinary infrastructure, and encouraging technological adoption. This initiative enabled India to transition from a milk-importing nation to the largest global producer. Nonetheless, the drivers of this growth were not merely technological or institutional; they were also rooted in the country's demographic expansion, which created a consistent demand (Rao, Sharma, Jain, & Others, 2020) for milk. Presently, India produces more than 220 million tonnes of milk annually, yet the pressing question remains whether this rate of production can sustain the demands of a rapidly growing and increasingly urbanized population.

The relationship between population dynamics and milk production raises several critical issues. Does the growth of milk production correspond proportionately to population expansion, or are there phases of imbalance resulting in shortages or surpluses? How do rural and urban population changes affect consumption differently? While rural populations are both consumers and primary producers of milk, urban populations are largely dependent consumers, relying on organized dairy supply chains. Furthermore, socio-economic variables such as income growth, literacy, and employment also play a decisive role in shaping consumption behaviour. These factors collectively highlight the importance of examining the interplay between demographic trends and milk production in India.

Milk is not only an economic commodity (Guzmán-Luna et al., 2022) but also an essential source of nutrition. It provides vital proteins, calcium, and micronutrients, particularly important for children, women, and vulnerable groups. An imbalance between demographic growth and milk availability can contribute to nutritional deficiencies (Kumar, Birthal & Meena, 2017), especially among low-income households. Conversely, adequate and affordable availability of milk can significantly improve nutritional outcomes and support human development (Birthal, Negi, Jha, & Singh, 2014). Thus, studying the linkage between demographic change and milk production has direct implications for public health, rural development, and food policy.

When compared internationally, India presents a distinctive case. Several developing nations are simultaneously grappling with rapid population growth and the need to modernize their food production systems. India has managed to expand milk production at an impressive scale, yet sustaining this growth in the future requires a deeper understanding of demographic pressures. In developed nations, where population growth is slower, the focus has shifted toward improving quality, efficiency, and diversification into value-added dairy products.

India, by contrast, faces the dual challenge of meeting the quantitative requirements of a growing population while also responding to quality-conscious and urbanized markets.

A statistical analysis of the relationship between population dynamics and milk production offers a rigorous framework to assess these issues. Employing techniques such as correlation, regression analysis, and time-series modelling can provide empirical evidence on how demographic changes influence production trends. Such insights can guide policymakers, dairy cooperatives, and private stakeholders in designing strategies that balance supply with demand. It can also help identify regional disparities, forecast future requirements, and ensure nutritional security for a growing population.

In essence, the dairy sector in India is not only an economic enterprise but also a mirror reflecting the demographic shifts of the country. As India continues to experience population growth, urban transformation, and rising income levels, it becomes imperative for the dairy industry to align its growth trajectory with these demographic realities. The present study, by statistically analysing the interaction between population dynamics and milk production trends, seeks to provide a comprehensive understanding of this relationship. The findings will offer valuable insights for sustainable dairy development, policy formulation, and nutritional security in the decades to come.

This introduction lays the foundation for further exploration of India's demographic profile, its dairy sector evolution, relevant literature, methodological framework, and the empirical results that demonstrate the nature and magnitude of this vital relationship.

## **Review of Literature**

In 2021, Jothi carried out an investigation involving 120 participants from primary milk marketing co-operative societies, chosen from the Vazhakulam Block Panchayath in the Ernakulam District of Kerala. A meticulously designed questionnaire combined with an interview schedule is employed for the purpose of data collection. The primary challenges encountered by farmers can be categorised into three key areas: Economic Constraints, Marketing Constraints, and Veterinary Constraints. The results indicate that 66.7% of farmers spend over Rs. 8,000 on animal maintenance, while 55.83% receive a procurement price below Rs. 35 per litre. The study indicates that the ongoing increase in feed prices is the primary concern, followed closely by significant daily expenses and diminished profits. The primary marketing issue encountered by farmers is the low procurement price of milk, accompanied by insufficient cold storage facilities within the societies. The absence of a nearby veterinary facility during emergencies constitutes a significant challenge for farmers. It is recommended that societies enhance subsidies for cattle feed to farmers, establish adequate veterinary services, and raise the procurement price of milk in accordance with the increased production costs. The establishment of adequate cold storage facilities will prevent the spoilage of milk produced by members.

Tamila and Edwinraj (2022) highlight that the relentless contribution of millions of rural dairy farmers has enabled India to emerge as the largest milk producer globally. The country now contributes nearly 15% of the total world milk production. Within this context, Dharmapuri district plays a significant role in the projected growth of milk output. For the present research, data were mainly collected from five Milk Producers' Cooperative Societies functioning in the Dharmapuri region. We rely on Milk Producers Co-operative Union and Milk Producers Co-

operative Societies to compile secondary data. In addition to official information from different divisions and audited annual reports, a great deal of library resources, journals, books, periodicals, papers, economic surveys, and websites were consulted. The percentage analysis was completed by using descriptive statistics such as mean standard deviation and coefficient of variation, inferential statistics such as t-test and factor analysis, and chi-square test. Dairy cooperatives utilise the Social Science Statistical Package, Version 20, for their computer applications.

Pingale and Singh (2022) noted that dairying has been vital in ensuring livelihood opportunities for farmers across India. Approximately 80 million rural households engage in milk production, predominantly including landless, marginal, or small-scale producers. The purpose of the research was to examine the difficulties encountered by the dairy sector in creating employment and broadening its operations. Data were obtained from two decades of annual industrial surveys and a case study based on detailed interviews with a cooperative society in the dairy field. The study employed an autoregressive distributed lag model for analysis. Results indicated that the dairy sector holds considerable potential for generating employment. The case study showed that companies in the dairy business make value-added products to make more money, but this remains limited owing to inadequate investment. Moreover, the absence of sufficient advertising for these products restricts their sales and curtails the earnings of farmers.

Asmara, Purnamadewi & Lubis (2017) emphasized that the central objective of Milk Producers' Cooperatives (MPCs) is to deliver essential services to members while enhancing the overall efficiency of their dairy enterprises. The study pursued three key goals: (1) to assess the performance of member dairy farms, (2) to evaluate the effectiveness of MPC service delivery, and (3) to examine the association between service performance and farm performance. Primary data served as the foundation of the analysis, employing descriptive statistics, profit analysis with R/C ratio, and Chi-Square testing. Results indicated that large-scale farms demonstrated superior productivity and profitability compared to smaller units. Conversely, small-scale farms exhibited relatively lower outcomes in both dimensions. Nevertheless, most members perceived MPC services as satisfactory. A significant positive correlation emerged between cooperative services (milk marketing, financial assistance, technical support, and training/education) and farm performance. The findings suggest that MPCs should prioritize intensive coaching and service expansion, particularly for members managing small-scale dairy enterprises.

Azarruddin and Mulani (2021) examined the dairy supply chain, which, similar to other agribusinesses, is highly complex. The production of raw milk is the starting point of the value chain, which ends when the products are used by processors, institutions, and consumers. Since consumer preferences and decisions are dynamic, the supply chain must adapt continuously to address changing needs. This shifting demand directly influences stakeholders within the chain, requiring them to adjust or modify practices accordingly. The supply chain functions as an integrated production process, wherein raw materials are transformed into finished products and subsequently delivered to consumers. At a broader level, the supply chain essentially consists of two fundamental integrated processes.

Tharani and Mishra (2018) presented a comparative analysis of a 100-cow dairy farm in India using biogas and off-grid solar photovoltaic (SPV) systems, offering both technical and economic evaluations. These renewable technologies are capable of adequately supplying energy to dairy farms that remain disconnected from the electricity grid owing to financial limitations or geographical constraints. The two different green energy systems are compared based on how efficient, reliable, space-consuming, gas-emitting, and profitable they are. After looking into the two systems' economic costs, efficiency, and other factors, it is suggested that the biogas system be used because it is more stable and less expensive than the other option for powering an independent 100-cow dairy farm in India.

In 2018, Idrus, Ahmar, and Abdussakir looked into how organisational learning affects market orientation, how job satisfaction affects market orientation, how organisational learning affects business performance, how job satisfaction affects business performance, and how market orientation affects business performance. A quantitative research design was used for the study. Partial Least Squares Structural Equation Modelling (PLS-SEM) was used to look at the causes and effects between the variables. An initial group of 46 dairy cattle milk cooperatives in East Java were used for the study. A poll was used to collect data, and items were made using Smart PLS. The results showed that better organisational learning and job satisfaction lead to a stronger focus on the market. Organisational learning has a positive effect on business performance, job satisfaction has an effect on business performance but is not statistically significant, and market orientation may have a negative effect on the business performance of East Javan dairy cattle milk cooperatives.

Kumar, Birthal, and colleagues (2014, 2017) indicate that demographic changes strongly influence milk production dynamics, particularly in developing countries like India, where population growth, urbanization, and rising incomes have altered consumption patterns. Their studies consistently highlight that increasing population density and higher income elasticity of demand have driven a steady rise in per capita milk consumption, placing greater pressure on the dairy sector to improve productivity.

Delgado, Chand, Chauhan, and colleagues (2001, 2019) emphasize that India, being among the world's largest milk producers and consumers, faces the dual challenge of fulfilling nutritional requirements while maintaining supply under resource limitations (NDDDB, 2020; FAO, 2019). Several researchers also highlight that demographic shifts, including rapid urbanization and evolving household structures, have driven dietary transitions from cereal-based meals toward protein- and dairy-rich diets.

Joshi and colleagues (2021) note that population growth simultaneously intensifies demand-side pressures, creating a need for enhanced farm-level productivity, improved feed efficiency, and more effective distribution systems.

Guzmán-Luna, Gerber, and colleagues (2022, 2013) report that studies employing Life Cycle Assessment (LCA) approaches in various contexts show that milk production is resource-intensive, with notable effects on the environment in terms of greenhouse gas emissions, water use, and land use. This indicates that population-driven increases in milk demand could exacerbate ecological pressures if not managed sustainably.

Rao, Sharma, Jain, and colleagues (2015, 2020) highlight that although technological innovations, cooperative initiatives, and policy measures have helped India attain self-

sufficiency in milk production, population trends continue to play a pivotal role in shaping future developments.

### Research Objectives

- To examine the trends in human population growth and milk production in India over the past decades.
- To analyze the correlation between population growth and milk production in India.

### Research Methodology

The data for the study have been collected through various secondary sources. The data has been accessed through various journals and reports published by the Government of India and other government organizations. The time period of five years has been taken for the study, starting from 2017 to 2022.

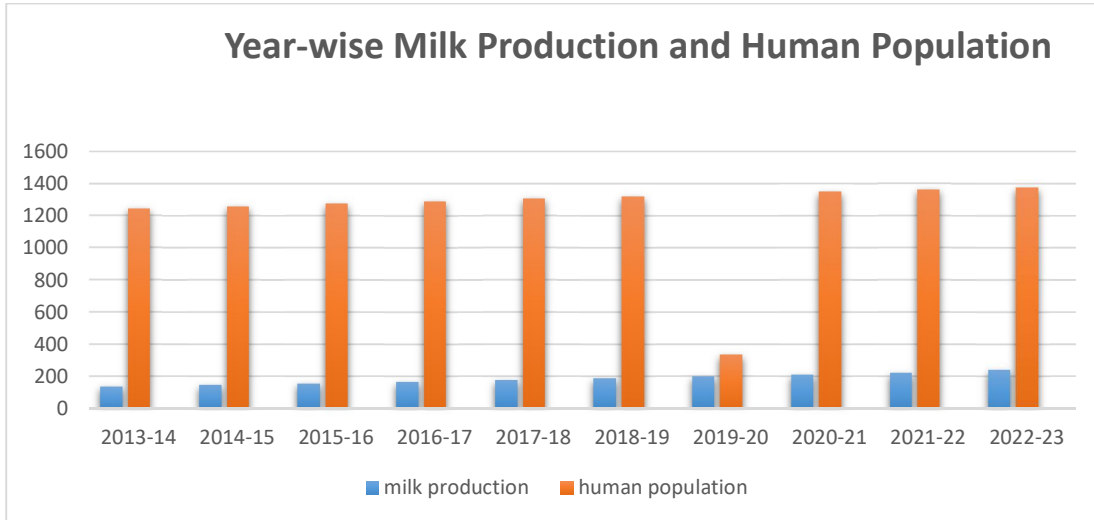
### Data Analysis and Interpretations

The present study is based on quantitative research focusing on secondary data collected from government sources such as the Ministry of Fisheries, Animal Husbandry and Dairying, the Census of India, and the Department of Animal Husbandry. The study analyses the relationship between population growth and milk production trends in India from 2013 to 2023. Descriptive techniques like trend analysis and CAGR are used to observe patterns over time, while inferential methods, such as correlation analysis, are used to quantify the impact of demographic factors.

### Year-wise Milk Production and Human Population

Year	Milk Production	Human Population
2013-14	137.7	1243
2014-15	146.3	1258
2015-16	155.5	1275
2016-17	165.4	1291
2017-18	176.3	1306
2018-19	187.7	1320
2019-20	198.4	1334
2020-21	210.0	1349
2021-22	222.1	1363
2022-23	239.3	1376

*Source: Basic Animal Husbandry Statistics, MoFAHD, DAHD, GoI, and Author's*



Source: Author's Creation

The data indicate a positive trend in India's dairy sector, where milk production growth is outpacing population growth, reflecting advances in dairy farming practices, better livestock management, and focused government policies. This trend is important for food security and economic development in rural areas.

### Correlation Analysis

	<i>Milk Production</i>	<i>Human Population</i>
Milk Production	1	
Human Population	0.99402	1

Source: Author's Creation

### Interpretation

The correlation matrix demonstrates a remarkably strong positive relationship between milk production and human population in India, with a correlation coefficient of 0.994. This suggests that milk production has closely followed the upward trend in population over the analysed period. As the population grows, the demand for essential nutrition sources such as milk also rises, driving production increases. The near-perfect correlation indicates that population growth is a major contributing factor to the expansion of the dairy sector, supported by improvements in dairy farming techniques, government initiatives, and increased awareness of milk's nutritional benefits. This relationship reflects not only the response of the dairy industry to meet the rising consumption needs of a growing population but also the structural development of dairy infrastructure, including enhanced livestock management, better breeding practices, and greater access to technology in rural areas. Overall, the strong correlation emphasizes the interdependence between demographic changes and agricultural production, particularly in the context of ensuring food security and economic growth in India.

### Findings

The analysis of data from 2013 to 2023 indicates a consistent and significant increase in both milk production and the human population in India. Milk production rose from 137.7 million tonnes in 2013-14 to 239.3 million tonnes in 2022-23, while the population increased from

1243 million to 1376 million during the same period. The correlation analysis revealed an exceptionally strong positive relationship (correlation coefficient of 0.994) between population size and milk production, implying that population growth has been a major driver of increased dairy production. This growth is supported by improved dairy practices, government programs like the National Dairy Plan, technological adoption, and cooperative models such as Amul. However, challenges such as a lack of infrastructure, cold chain facilities, and fluctuating seasonal production still affect the sector.

## **Suggestions**

### **1. Ensure Policy Effectiveness**

Establish robust monitoring and evaluation of dairy schemes (e.g., National Dairy Plan) to close implementation gaps, ensure timely support, and maximize benefits for rural producers.

### **2. Invest in Capacity Building**

Organize continuous training in animal health, feed management, disease prevention, and technology use. Building farmers' skills is essential for sustainable productivity.

### **3. Expand Market Access and Value Addition**

Strengthen direct producer–retailer linkages to ensure fair pricing. Encourage farmers to diversify into value-added products such as yogurt, cheese, and fortified milk, which improve profitability and resilience.

### **4. Accelerate Technology Adoption**

Introduce affordable automated milking systems, IoT-based livestock health monitoring, and data-driven farm management tools to improve efficiency and reduce costs.

### **5. Support Smallholder Farmers**

Provide targeted subsidies for quality feed, expand low-cost veterinary services, and improve access to credit and modern equipment. This is critical since smallholders form the backbone of India's dairy sector.

### **6. Promote Climate-Resilient Practices**

Encourage climate-adapted livestock breeding, efficient feed storage (silage, fodder banks), and water-smart practices to reduce vulnerability to heat stress and erratic rainfall.

### **7. Strengthen Infrastructure**

Invest in rural cold chain facilities, refrigerated transport, and modern processing units to reduce spoilage, stabilize supply, and improve farmers' market access.

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