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Prediction of Future Milk Production Trend in India and Central Punjab

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ABSTRACT

Livestock is an important source of livelihood for small and marginal farmers of India. Indian cattle require an ideal combination of environmental conditions with temperature less than 23°C and humidity of 68 per cent for the best milk production. However, due to climatic variations, 'thermo-regulatory' system of livestock has disturbed, which leads to decrease in milk production. Keeping this in view, the data of milk production and yield of Ludhiana district (1993-2013) and for different states of India (2001-2018) was analyzed. The regression analysis indicated that during 2018-19 milk production and yield of Indian states was highly dependent on the population strength of cattle and buffalo. The analysis also indicated an increase in India's total milk production in future mainly due to increase in cattle and buffalo population. But in the rising population scenario, this increase in livestock population does not seem to be sustainable due to land degradation and climate change induced weather unsuitability. Hence, intensification of production is a vital step to sustain milk supply for increasing population. The milk productivity for Ludhiana has been projected to be the lowest in 2040-41 and the highest in 2080-81 due to warming in future and then reduction in temperature at the end of the century (2094-95), the milk yield will be low as compared to the present time scenario. So, to increase the national milk yield, mitigation and adaptation strategies viz. construction of climate-resilient sheds, diversified farming, installing sprinklers etc. should be adopted to combat the effects of climate change.

HIGHLIGHTS

- Prediction of milk production trends in future.
- Regression models were developed for estimating milk production in future years using the average monthly temperature.
- In this climate change scenario, different mitigation techniques can elevate the milk yield.

Keywords: Climate change, Milk productivity, Mitigation, Adaptation strategies, Representative, Concentration Pathway

Milk represents one of the most complete single foods. India is the largest producer of milk contributing to 13 per cent of the world's total milk production. The dairy industry is contributing around 26 per cent to total agriculture GDP. The value of milk is 6.5 lakh crore, which is more than the combined value of wheat and rice in agriculture and food sector (Sodhi, 2018). The UN reported that the global population is expected to reach 9 billion by 2050. This emerging population growth with higher income levels is expected to elevate the demand for all the agricultural products, especially for animal protein. It was observed that in India due to rising population milk demand in 2050 would be around 401.4 Million Metric Tonnes (MMT), which would require a rise of 145 per cent in milk production to meet up the demand (Chand, 2012). This would be a challenge for higher milk production, as the UN reported that increasing production of resources should majorly (90%) come from intensification rather than expansion. FAO has also emphasized that the world must boost the output of food on existing agricultural land (FAO, 2003). So, an increase in milk production, under

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this realistic scenario, should depend on enhanced yield gains rather than increasing the units under production (Searchinger *et al*., 2018).

The productivity of dairy cattle is determined by the type of breed, environmental conditions, and interactions of both. Cattle belong to the warm-blooded group of animals as they have 'thermoregulatory' physiological system**.** European cattle have a comfort zone between -1 to 15°C while the range for Indian cattle lies between 10 to 27°C (Sparke *et al*., 2001). The effect of climate change elevates the level of body temperature above the normal range, indicating the intensity of heat stress in dairy cattle. Interactions of temperature and humidity levels regulate the comfort zone of dairy cattle. The severity of heat stress is demonstrated with Temperature Humidity Index (THI) as mild (THI = 72-78), moderate (THI = 79-88), severe (THI = 89-98) and very severe (THI = > 98) (Atrian and Shahryar, 2012).

The anticipated rise in temperature over the entire country resulting from climate change is likely to worsen the heat stress in dairy animals, reducing the total production from the high yielding dairy cattle. Indirect effects of climate change include aggravation of feed and fodder shortage as high temperature is associated with decline in rainfall or increase in evapotranspiration (Sirohi and Michaelowa, 2011). Lee *et al.* (2017) mentioned sustainability of increased livestock population is strongly dependent on forage availability. They also found the nutritional quality of forage to be lower at higher temperature ranges, which might lead to impairment of livestock regulatory functions. A hot environment also has negative effects on the milk quality (Bernabucci *et al*., 2014; Calamari, 2016). Milk composition traits are found rich in the hot humid season but deficient in other seasons (Arora and Bhojak, 2015; Sarkar *et al*., 2015).

Future population, with higher income level, would demand higher per capita milk requirement. So, there is a need to increase milk productivity. But in the face of climate change, cattle and buffaloes face severe 'thermoregulation imbalance', which reduces the milk yield. Knowledge of the trend in milk productivity is lacking for the study location, which is crucial to implement suitable adaptation and mitigation techniques. Keeping all this in view, the current study was planned to estimate the relationship between weather parameters (temperature and rainfall) and milk production and productivity for central Punjab and India.

MATERIALS AND METHODS

The study involved the analysis of milk production trends for central Punjab (Ludhiana) and different states of India at the national level. For national-level analysis, the data on state-wise milk production, productivity, and the number of animals (in milking) for the year 2018-19 and annual milk production data from 2001 to 2018 were downloaded from the National Dairy Development Board website (*https://www.nddb.coop/information/stats/milkprodstate*). Likewise, milk production data of Ludhiana were collected from the Statistical Abstracts of Punjab for the years 1993-94, 1997-98, 2003-04, 2007-08, 2008-09, 2010-11, 2011-12 and 2012-13 respectively. For projecting milk production with respect to future climatic conditions, meteorological data viz. temperature and rainfall were used for Ludhiana as well as India. Average monthly temperature data (January-February, March-May, June-September, October-December) and total annual rainfall of India were collected from *Indiastat.org* website for the period 2001-2018. The maximum and minimum temperatures for the Ludhiana district were collected from the Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana. Similarly, the milk productivity of Ludhiana district was also estimated for future RCP 4.5 scenario using annual maximum and minimum temperatures model. Regression models were developed for estimating milk production in future years with meteorological parameters using EXCEL. The model with the highest coefficient of determination (R^2) was used for projecting milk production for future. Temperature and rainfall data of RCP 4.5 were downloaded from Marksim Weather Data Generator for the year 2040, 2060, 2080, and 2095. These weather data were incorporated in regression models and the trends were analyzed.

RESULTS AND DISCUSSION

State-wise trends in milk production

Milk production is vital for the nation's nutrition and economic security. Studying its present trend helps to understand the key factors likely to influence its future variability. India produced 187.7 Million Metric Tonnes (MMT) of milk in the year 2018-19 from 272.6 million cows and buffaloes (Anonymous, 2019). Among the states, milk production was highest in Uttar Pradesh (30.5 MMT), followed by Rajasthan (23.6 MMT) and Madhya Pradesh (15.9 MMT). A similar trend was also observed for the total number of cattle and buffalo producing milk. The state of Uttar Pradesh had the highest indigenous cows and buffalo milk production, whereas crossbred milk production was dominated by Tamil Nadu (Islam *et al*., 2016).

During 2018-19, milk yield was highest in Lakshadweep (4.00 tonnes/animal), followed by Haryana (3.52 tonnes/animal) and Punjab (3.32 tonnes/animal) (Fig. 1). Further, the states having higher milk production *i.e.* Uttar Pradesh (1.22 tonnes/animal), Rajasthan (1.71 tonnes/animal), and Madhya Pradesh (1.26 tonnes/animal) had relatively lower productivity. Similarly, milk production data from 2013-14 to 2017-18 indicated that it was higher in Uttar Pradesh, followed by Madhya Pradesh and Rajasthan. In 2001, India had three times as many 'dairy animals' as the USA and productivity was about one-tenth as achieved in the USA and one-fifth as in New Zealand (Garcia *et al*., 2003).

In India, milk production is primarily dominated by cattle and buffaloes. The prevalence of crossbred varieties makes weather a crucial factor determining milk production. It denotes that cattle and buffalo population is one of the crucial factors contributing to milk production in different states. Nearly 84 per cent variation in milk production is caused by the population strength of cattle and buffaloes (Fig. 2). A case study indicated that increased heat stress

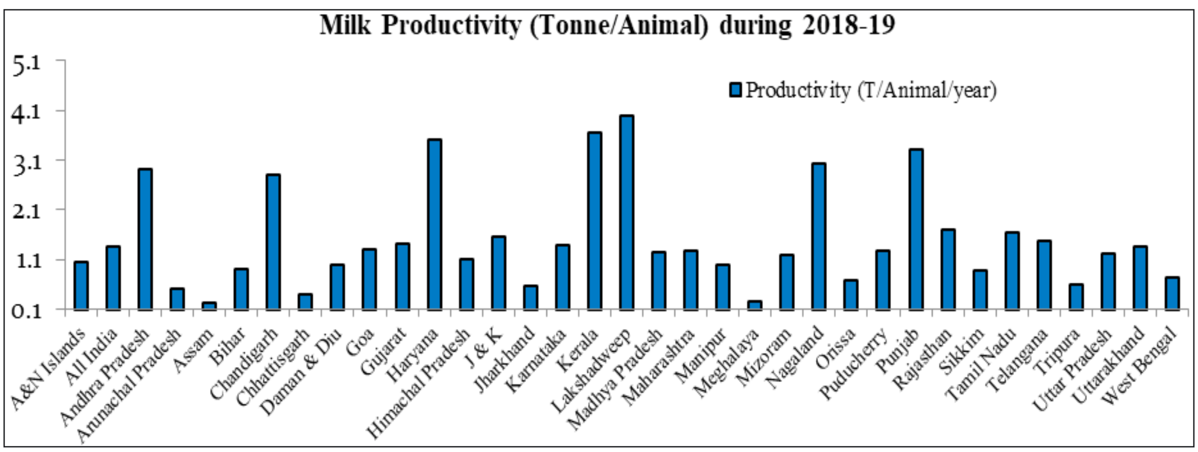

Fig. 1: Milk productivity of Indian states during 2018-19

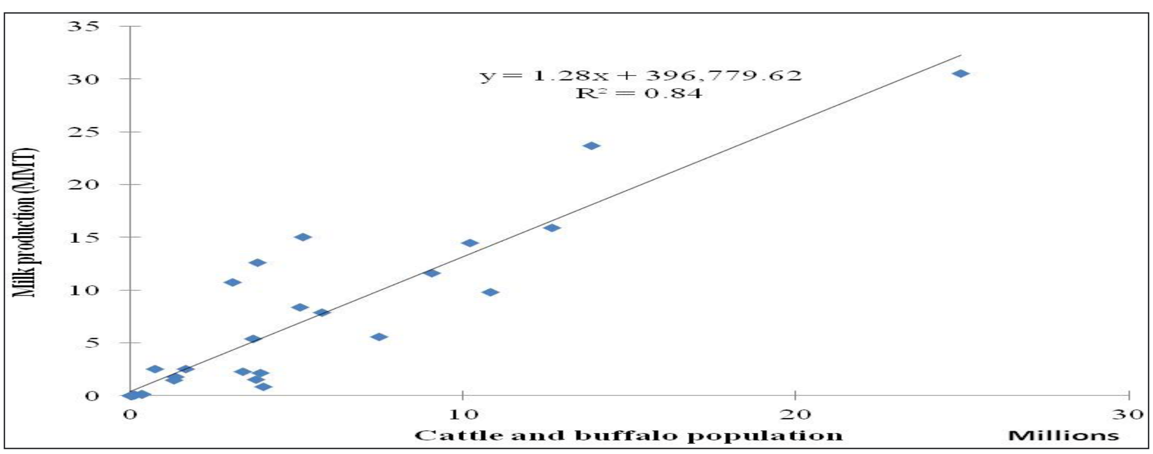

Fig. 2: Milk production (MMT) and the total number of cows and buffaloes of Indian states during 2018-19

associated with global climate change, causes distress to dairy animals, and possibly affect the milk production (Dash *et al*., 2016). It has been estimated that about 85% places in India experience moderate to high heat stress during April to June. Slight increase in core body temperature have profound effects on tissue metabolism, electrolyte balance, neuro-endocrine functions etc, which in turn reduce fertility, growth, lactation and ability to work (Singh and Naskar, 2019). It has also been estimated that India loses 1.8 million tonnes of milk production annually, amounting to over 650 million USD due to heat stress in different parts of the country. So, global warming is likely to have a negative influence on milk production more than 15 million tonnes by 2050.

Estimation of future milk production in India under RCP 4.5 scenario

Consequences of climate change in Indian livestock may be observed by studying the trend of milk production in the future climatic scenario. In this analysis, the future weather parameters of Representative Concentration Pathways (RCP 4.5) were used for estimating the corresponding milk production. Regression models were developed for estimating milk production in future years using the average monthly temperature of January-February, March-May, June-September, October-December, and annual rainfall from 2001-18 as shown in Table 1. Among all the models, the combined temperature and rainfall model had a higher coefficient of determination ($R^2 = 0.589$) and hence used for estimating future milk production in India.

Table 1: Regression equations between milk production, annual temperature and rainfall from 2001-18 (India)

Regression Equations	R^2-value
Y = 4493.1 + (2.2×T1) + (12.1×T2) + (100.5×T3) + (57.0×T4) + 1.56 × R	0.589
Y = 28.0 × T1 - 462.7	0.141
Y = 24.8 × T2 - 568.3	0.082
Y = 78.4 × T3 - 2083.6	0.263
Y = 53.6 × T4 - 1138.4	0.178
Y = -0.0334 × R + 127.5	0.01

Where, Y – Milk Production (MMT); T1 – January to February temperature (°C); T2 – March to May temperature (°C); T3- June to September temperature (°C); T4 – October to December temperature (°C); R – Annual rainfall (cm).

The projected increase in milk production also requires a rise in cattle and buffalo population as shown in Fig. 2. The required increase would be 1.27 thousand in cattle and buffalo population for every 1 MMT milk productions. The milk production projection for 2024-25 for five states of India was predicted using the Auto-Regressive Integrated Moving Average Model (ARIMA) (Mishra, 2020). It was forecasted that Uttar Pradesh would be leading milk-producing states with 37.68 MMT and also found that India's total milk production would reach 252.94 MMT during 2024-25. Even though India's milk production is projected to elevate by horizontal expansion of resources, intensification by increasing the milk yield will be a more sustainable option.

Milk production scenario in Punjab

Punjab has been one of the front runners in the white revolution in the country. Amongst all the Indian states and Union Territories, Punjab ranks sixth in milk production (12.5 MMT), fourth in productivity (3.32 tonnes/ animal/ year), and thirteen in total cow and buffalo population (3.8 million) during the year 2018-19 (Anonymous, 2020). The total milk production in the state has increased from 4.03 MMT in 1985-86 to 12.5 MMT in 2018-19. The increasing pattern of milk production in the state reflects the positive contribution of technological change in breeding and feeding. In Punjab, agriculture including forestry and fishery, contributes about 28.6 per cent to the state's GDP and livestock, including the dairy sector, contributing about 10.01 per cent (Anonymous, 2019).

Milk yield is a direct indicator of climate change impact on the animal's performance. Milk yield was observed to be highest during 2010-11 and lowest during 1993-94 (Fig. 3a). From the temperature trends, the highest maximum temperature was observed during 2003-04 and 2009-10, while the lowest was during 1997-98. The highest minimum temperature was observed in 2012-13 and lowest in 1997-98 as shown in Fig. 3b. The trend of milk production in three agro-climatic zones of Punjab viz. Sub-mountainous zone, Central zone, and Southern-western zone was analyzed. Milk production was found to be higher in the Central zone and it increased with herd size (Kaur and Singh, 2018).

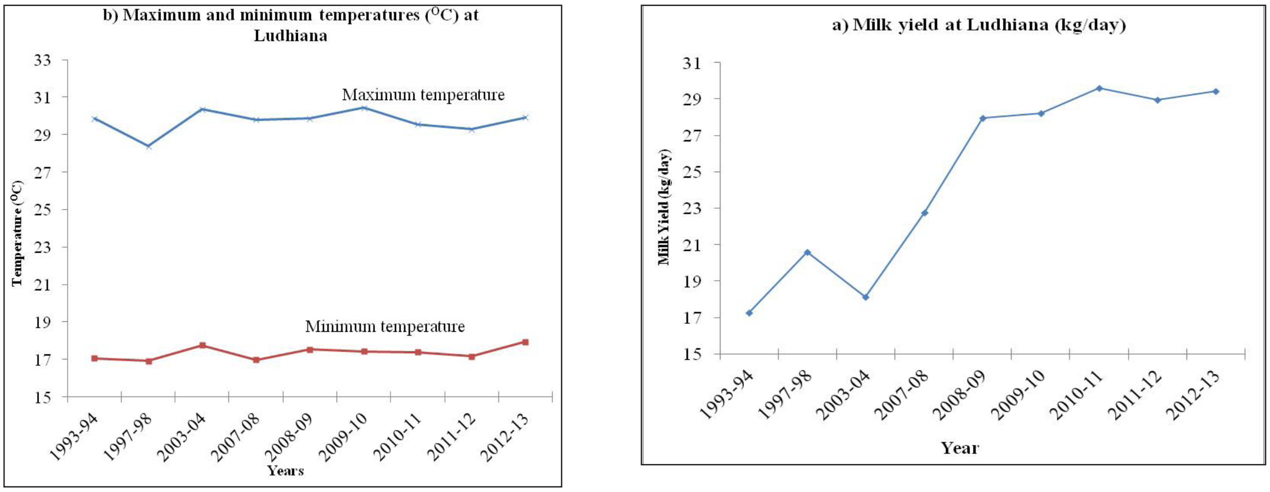

Fig. 3: Trends in milk yield **(a)** and maximum and minimum temperatures **(b)** at Ludhiana from 1993 to 2013

Table 2: Regression equations between milk yield (kg/day), annual maximum and minimum temperature (Ludhiana)

Regression equations	R^2-value	Parameters
$Y = T_{max} \times (-1.94) + T_{min} \times 6.84 - 36.28$	0.149	Y = Milk Yield (kg/day)
$Y = 0.426 \times T_{max} + 12.11$	0.003	T_{max} = Maximum Temperature (°C)
$Y = 4.83 \times T_{min} - 59.1$	0.113	T_{min} = Minimum Temperature (°C)

Effect of temperature on future milk productivity at Ludhiana

Diurnal temperature variation has a significant effect on the livestock's thermoregulatory system. The regression models for estimating milk productivity from maximum and minimum temperatures were developed as shown in Table 2.

The combined equation involving both the maximum and minimum temperatures has a higher R^2 value and hence it is used for estimating milk yield in the RCP 4.5 scenario. The graph of future milk yield (Fig. 4) depicts that the milk yield is projected to have a steep decrease to 26.6 kg/day in 2040-41 due to a steep increase in maximum temperature (33.5°C) and minimum temperature (18.7°C) conditions. Further, milk yield increases in the years 2059-60 (T_{max} = 34.0°C, T_{min} = 19.1°C), 2080-81 (T_{max} = 34.1°C, T_{min} = 19.2°C) and 2094-95 (T_{max} = 33.9°C, T_{min} = 19.1°C) as the temperature conditions during these years have relatively less elevation than 2040-41. The overall trend of milk yield is decreasing since it is not exceeding the present yield (Fig. 4). This might be due to the changing climatic conditions with increased frequency of heat stress. The State Action Plans on Climate Change revealed that the mean daily temperature, rainfall, and frequency of extreme climatic events are projected to increase in current century (Anonymous, 2013). These weather anomalies are likely to be more dominant in North Indian states like Uttar Pradesh, Punjab, and Haryana which will hit the livestock population (Balhara *et al*., 2017). Similar observations of reduction in livestock productivity due to droughts, heat waves, floods, pests, and diseases and humidity were reported in Punjab, Pakistan (Abbas *et al*., 2019). Therefore, better breeding programs with supportive environmental management is needed to meet the demand. This can be projected in different Representative Concentration Pathways (RCP). It is referred to as the prediction of future greenhouse gas concentration influencing the radiative forcing levels before 2100. The IPCC Fifth Assessment Report (AR5) mentioned four scenarios as RCP 2.6, RCP 4.5, RCP 6, and RCP 8 referring to 2.6W/m^2, 4.5W/m^2, 6W/m^2, and 8W/m^2 radiative forcing level before 2100. Each RCP describes different climatic conditions with variation in temperature and precipitation patterns.

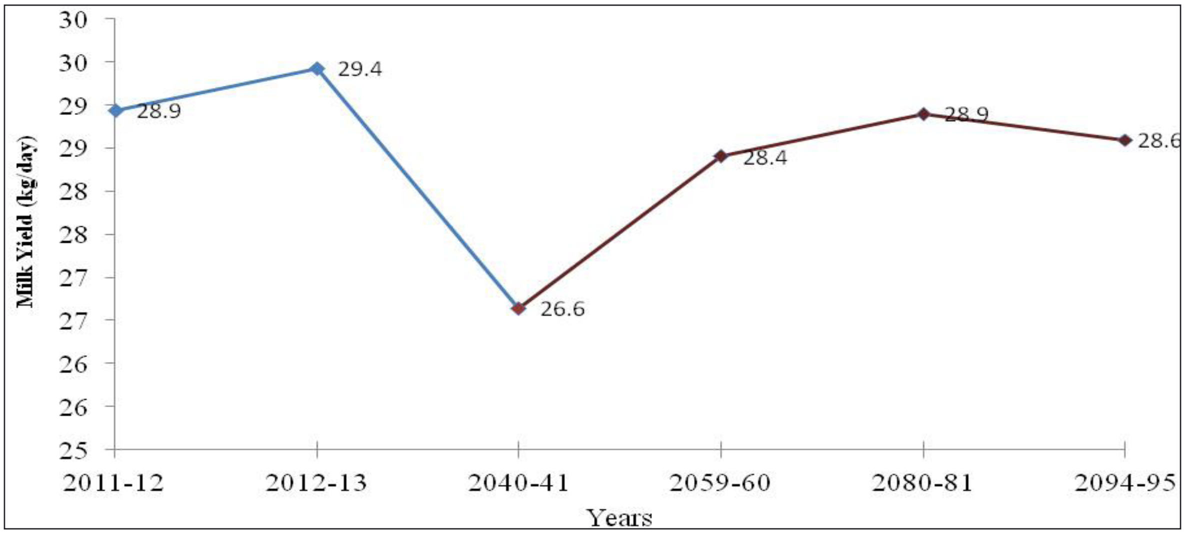

Fig. 4: Trends of future milk yield from the present time scenario (2011-12) under RCP 4.5

Livestock Adaptation to Climate Change

The development of the livestock sector in India is strictly affected by the phenomenon of climate change. Hybrid cattle are highly prone to experience aggravated heat stress due to an increase in temperature from 2.3 to 4.5°C along with erratic precipitation patterns. Therefore, it restricts the area under high yielding dairy cattle rearing (Nautiyal *et al*., 2016). All the considered climatic variables accounted for 28 and 21 per cent direct effect on milk yield and lactation length. Therefore, adaptation and mitigation strategies need to be followed at the national level for sustaining milk production as given below.

Proper management through diversification of livestock and crop varieties can increase drought and heat wave tolerance, and will increase livestock yield even under external temperature and precipitation stresses (Batima *et al*., 2006). It is an efficient way of preventing climate change-related pests and diseases (Kurukulasuriya *et al*., 2003).

Economic losses caused by heat stress-related effects in productivity may be decreased in management practices such as the installation of sprinklers in the shed, evaporative cooling of barns, feeding and nutritional strategies, and selection of more heat-tolerant animals (Das *et al*., 2016).

Mitigation strategies like mixed farming, providing more drinking water, muddy roof, livestock diversification, tree shade (Shahbaz *et al*., 2020).

Land management practices like Agroforestry can aid as an environmental protection measure by improving the quality of air, water, and soil (Smith *et al*., 2012)

Adaptation strategies like Climate-resilient sheds provide microclimate alteration by the provision of foggers and air circulators in the buffalo shed. This will increase milk yield, fat, SNF yield due to decreased heat stress (Seerapu *et al*., 2015).

So, mitigation measures, as per perceived thermal challenges, assessing the potential consequences and acting accordingly will reduce the impact of climate change.

CONCLUSION

Cattle and buffalo population is one of the crucial factors contributing to milk production in India. As compared to present time, milk yield of Ludhiana is likely to decrease upto 26.6 kg/day by 2040-41 due to warming but by end century, it will increase upto 28.6 kg/day due to decrease in temperature. The projected increase in India's milk production also requires a rise in cattle and buffalo population. As the UN several times emphasized intensification rather than expansion for increasing production, enhancing the yield is a sustainable solution to meet the milk demand for future population. In this climate change scenario, mitigation techniques like environmental modification through climate resilient sheds to alter the microclimate; land management through agroforestry, diversification of livestock and crop varieties etc can elevate the milk yield. Hence, implementation of climate change coping up strategies is highly needed to meet the milk requirement for growing demand.

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