Climate Resilient Dairy Farming: Prospect

Abstract: Climate change raises major problems for dairy farming around the world, especially in areas where dairy animals are a major source of livelihood. Reproduction, production, and animal health are ~~all~~ directly impacted by the rising frequency of extreme weather events like heat waves and shifting precipitation patterns. These changes in the climate cause physiological stress in animals, which decreases their intake of feed, metabolic efficiency, and milk production. They also make vector-borne diseases more likely to spread. The effects of climate change on dairy farming are reviewed in this paper, with particular attention given to heat stress, shifts in feed availability, and the increase of parasites and illnesses. It talks about how these stressors have an adverse impact on milk production, cattle health, and reproduction, especially in tropical and subtropical areas. The study also looks at the potential of climate-resilient dairy production methods, which emphasize reducing environmental effect and managing to changing weather. These methods include developing cooling systems to reduce heat stress, integrating renewable energy sources, improving feed management, and genetically breeding for heat tolerance. The dairy business may advance toward lower emissions and greater resilience with sustainable practices and policy changes, ensuring both economic and environmental sustainability. The future of climate-resilient dairy production will be shaped by innovation, the use of renewable energy, and ~~customer~~ demand for sustainable dairy products, based to the paper.

Keywords: Climate change, dairy farming, heat stress, milk production, livestock health, reproduction, climate resilience, adaptation strategies.

Introduction:

Climate change is one of the biggest problems facing worldwide today. It is defined by changes in long-term temperature and precipitation patterns as well as an increase in seasonal variation (Chakra et al. 2018). Climate change is real, and its effects are felt differently around the world, according to the fifth Assessment Report of the Inter governmental Panel on Climate Change (IPCC, 2014). In addition to the natural climate variability seen over similar time periods, "climate change" refers to changes in the climate that is directly or indirectly caused by human activity that

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Commented [3]: One tab space is required affects the composition of the global atmosphere. According to the (2022 IPCC AR6) assessment, if global temperatures rise by more than 2°C, it will be difficult to achieve climate resilient development. Climate change has a significant effect on livestock which is important because dairy farming is the only source of income for millions of farmers (Herrero et al., 2009), livestock have challenges due to weather extremes, such as extreme heat waves. Animal performance, including health, productivity, and reproduction, is directly impacted by climate change. High temperatures and changes in rainfall patterns are two direct effects of climate change that may lead to a rise in the prevalence of already-existing vector-borne illnesses and macro parasites as well as the rise and spread of new diseases. Animals under heat stress decrease feed intake and perform poorly due of growth (Rowlinson, 2008) Reduced feed intake is one of the animals' thermoregulatory physiological attempts to lower metabolic rate (Baumgard and Rhoads, 2013), which in turn reduces the metabolic heat produced by metabolism (Gonzalez-Rivas et al., 2020; Sammad et al., 2020). According to Sheahan (2014), lowering dry matter intake (DMI) indirectly contributes to maintaining core body temperature by reducing heat production during ruminal fermentation and nutrient metabolism. Cows kept in no-shed conditions throughout the day consume 56 percent less feed during hot weather than cows kept in sheds (Reynaldo et al., 2016). Cattle kept in no-shed conditions consumed 13 percent less feed overall and 19 percent more feed at night than cattle kept in sheds, ~~according to numerous studies~~ (Berry, 2023).

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The production of livestock is negatively impacted by the adverse affects of extreme weather. The combined effects of summer heat stress and global warming on cattle and buffaloes are expected to result in a yearly shortage of milk production of approximately 3.4 million tons in 2020, which would cost more than 5000 crores at the current price rate (Singh et al., 2015; Kumar et al., 2022). Heat stress on livestock is expected to affect about 15 million tonnes of milk production in India by 2050 (Upadhyay et al. 2009; Das et al., 2016; Balhara et al., 2017; Aatralarasi et al., 2021; Singh and Ukey, 2024) According to Seo and Mendelsohn (2006), climate change also indirectly affects the amount and quality of feedstuffs such as pasture, forage, and grain, as well as the severity and spread of parasites and livestock diseases. Animal welfare will be impacted by severe weather and seasonal variations in the amount and quality of herbage, which will also result in decreased productivity and reproduction efficiency (Muzzo et al., 2024).

Dynamics of Milk Production in India:

In India, from 1950 to 51, milk production was only 17 million tons (MT). Milk output was only 21.2 MT in 1968–69 when Operation Flood began. By 1979–80, it had risen to 30.4 MT, and by 1989–90, it had reached 51.4 MT. As of 2020–21, it has risen to 210 million tons. In the world today, milk production is increasing at a growth of 2%, whereas in India, it is growing at a rate of over 6%. According to (Hopper, 1999) India's milk production increased due to a number of factors, but the start of the Operation Flood program was vital in bringing about this change (Coppock, 1962).

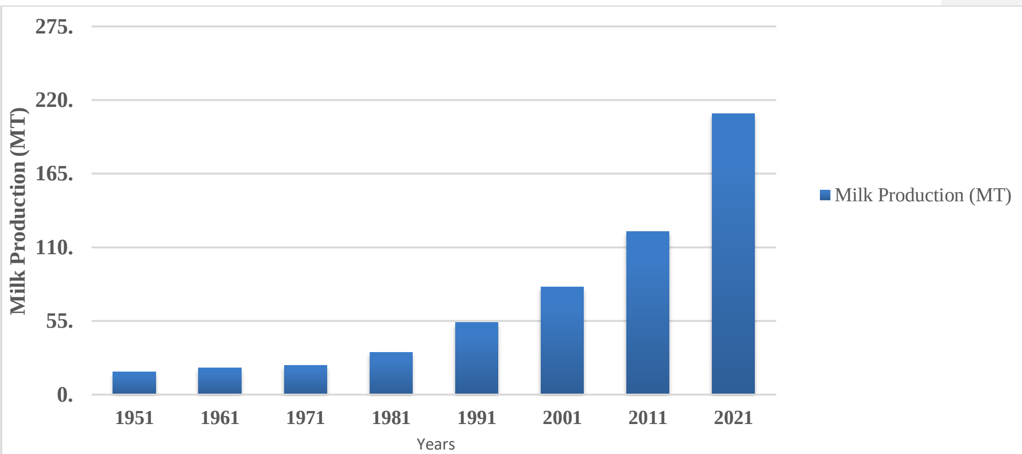

Figure: 1- Growth of Milk Production in India

Source: Ministry of Fisheries, Animal Husbandry & Dairying, Govt. of India. (2022).

The first phase of the "Operation Flood" program, which lasted from July 1, 1970, to March 31, 1981, involved an investment of Rs. 116.50 crores and covered 39 milk sheds, 13,270 dairy cooperative societies (DCSs), 17.5 lakh members, 2.56 million kg of milk on average per day, and 27.8 lakh litres of liquid milk per day. The goal of Operation Flood II, which started in 1981, was to provide the infrastructure needed to support an economical dairy enterprises and to connect 136 rural milk sheds across 22 states and UTs with the nation's major demand centers. At an investment of Rs. 137.95 crores, the "Operation Flood-III" program covered 170 milk-sheds, 72,744 DCSs, 93.0 lakh members, 11.0 million kg of milk procurement on average per day, and 110.0 lakh litres of liquid milk marketing per day. It started on April 1, 1987, and ended on April 30, 1996 (Shah, 2012a).

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The replication of the Anand pattern cooperative across the nation is considered as the Operation Flood program's most important contribution (Dastagiri, 2003).There are three tiers of well-organized organization in a typical Anand Pattern dairy co-operative structure, with a milk producer consulting the smallest business unit of the total operation. The three levels are as follows: the state level federation made up of all district level unions; the district level co-operative milk producers' union federating the village societies; and the village level dairy co-operative society federating producer members. Because it owns the physical infrastructure needed for milk procurement, processing, and product manufacturing as well as for producing inputs needed to boost milk output, the district cooperative union is the most active of these three tiers (Shah, 2012b) India's dairy industry has changed significantly over the years as a result of medium- and large-scale farmers using scientific production techniques and the increased focus on building dairy cooperative infrastructure, which has helped to significantly increase milk production since the early 1970s. India has gone from being a minor player to a key one in the global dairy scene thanks to the investment, hard work, creativity, and dedication of our farmers and industry. As of right now, India is the world's largest producer of milk, and the value of its output surpasses that of any other agricultural product ~~(Bedi, 1987).~~

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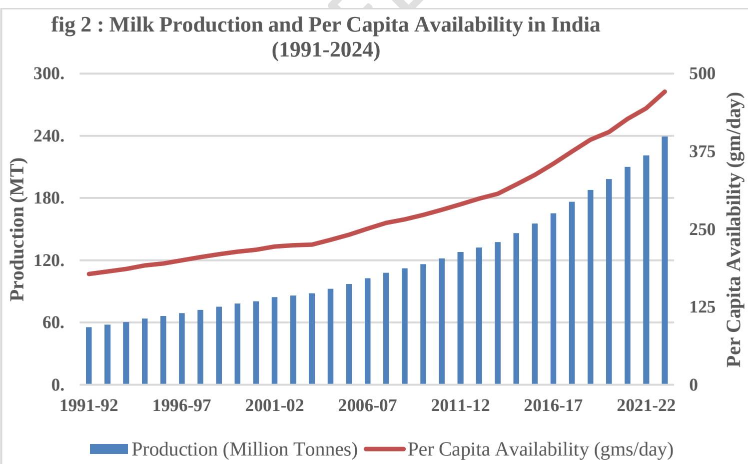

fig 2 : Milk Production and Per Capita Availability in India (1991-2024)

Source: Basic Animal Husbandry Statistics, MoFAHD, DAHD, GoI

~~The total milk production and per capita milk availability trends over the last five years show steady development. Milk output climbed from 55.6 million tonnes (MT) to 66.2 MT, a 19.1% increase, while per capita milk availability increased from 178 g/day to 195 g/day, a 9.6% increase, between 1991-92 and 1995-96. Over the next five years (1996-97 to 2000-01), milk output increased by 16.6%, from 69.1 MT to 80.6 MT, while milk availability increased by 8.5%, from 200 g/day to 217 g/day. Production increased by 15.1% from 84.4 MT to 97.1 MT between 2001-02 and 2005-06, while availability increased by 8.6% from 222 g/day to 241 g/day.~~

~~Growth started to pick up speed from 2006–07. Per capita milk availability rose 11.9% from 251 g/day to 281 g/day between 2006–07 and 2010–11, while output climbed significantly by 18.7% from 102.6 MT to 121.8 MT. Production increased by 21.6%, from 127.9 MT to 155.5 MT, for the next five years (2011–12 to 2015–16), whereas availability increased significantly by 16.2%, from 290 g/day to 337 g/day. From 2016–17 to 2020–21, milk production climbed by 26.9%, from 165.4 MT to 210 MT, while milk availability increased by 20.3%, from 355 g/day to 427 g/day.~~

Per capita milk availability increased by 19.5% from 2018–19 to 2023–24, from 394 g/day to 471 g/day, while total milk output increased by 27.5%, from 187.7 MT to 239.3 MT. These patterns show a definite acceleration in development in output and per capita availability, especially in the past 20 years, due to improvements in dairy farming methods, higher productivity, and growing consumer demand.

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However, it doesn't directly tie into the concept of climate-resilient dairy farming, which typically focuses on adapting dairy farming practices to climate change impacts, such as heat stress, changing precipitation patterns, water scarcity, and other environmental factors.

Factors Influencing Dairy Health and Milk Production:

Many factors affect dairy cows' health and milk production. Heat stress caused directly by extreme temperatures can have an impact on cow health and reproduction in addition to decreasing milk production. Rural poverty people are particularly susceptible to the negative impacts of climate change, making livestock—especially dairy cattle—one of the most environmentally conscious sectors in developing nations (Kimaro and Chibinga, 2013). The implications of climate change on animal health, especially infectious illnesses, have frequently been neglected, even though the effects on productivity have drawn a lot of attention (Yatoo et al., 2012b). Furthermore, by affecting the distribution of pathogens and disease vectors, climate change impacts livestock health by influencing the transmission of infectious illnesses (ESAP). Dairy farming is also impacted by illnesses and infections; mastitis, for example, decreases the quantity and quality of milk produced.

According to Lacasse et al., (2018), metabolic disorders can significantly decrease the quantities and quality of milk produced. Maintaining cow health and consistent production levels requires illness prevention through proper sanitation, immunizations, and veterinarian care. Another important aspect is reproductive health. Stressors that affect fertility, such as lack of nutrition or extreme heat, can cause gaps in milk production. A consistent milk production can be maintained by keeping a watch on and promoting reproductive health.

There are many factors that affect milk production, including Species, Breed, Feed, Age, Milking Frequency, Weather, climate and geography situations, etc. Breed selection, together with enhancements in cow management and nutrition, all contribute to a higher milk yield. Increases in milk yield and compositional alterations can be achieved very fast through nutritional adjustments to the quantities and composition of particular components. Mastitis-related poor udder health is one of the major issues affecting milk supply (Dalanezi et al., 2020).

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Species: The milk produced by buffalo is higher than that of pure native dairy cows, however, this varies from species to species.

Breeds: Naturally, the quantity of milk produced by various cow breeds varies. The breed of cow has an impact on both milk yield and composition (Walstra et al. 2015). The quality of milk produced by some cattle breeds, however, can be improved by adapting to India's climate (NDRI, 2016).

Feed: The quantity and quality of milk produced are directly correlated with the quantity and quality of feed, which is influenced by weather and climate. What farmers may use can be significantly impacted by feed availability and prices. Reduced feed intake from higher temperatures results in poorer productivity overall (Pragna et al., 2017). Particularly in low-income developing nations, where small-scale dairy farmers may face months of poor milk production as a result of climate change, climate change can raise the price of cattle feed, lower milk productivity, and affect farmers' income (Tricarico et al., 2020). Energy and protein from a well-balanced diet are needed. A dose of energy lack causes a decrease in production that remains for a while after the deficiency is removed (Wilkanowska, 2017). Dietary problems may decrease milk production and affect cow health. Milk production may be significantly impacted by an unbalanced ration that is not modified to the present season and physiological state (Tumanowicz, 2018).

Age: In general, younger cows yield more milk than older ones, and the milk output varies depending on the cows' age (Mabrook ~~M F~~ et al., 2006).

Milking Frequency: Farmers are particular about the number of times they milk their cows. The cost of manpower and equipment is increased by the volume of milking done each day. However, if milking is delayed for too long, both quantity and quality will decrease. Numerous studies (Knight and Gosling 1995; Castillo et al., 2005, 2008, 2009; Prieto et al., 2013, Torres et al. 2013; Bortacki et al. 2017) have examined the impact of milking frequency on milk yield and composition in dairy cows.

Weather, climate and geography – Cows are less stressed by milder seasons and temperate regions than by more harsh weather. Climate and weather have a strong relationship with geography. India's climate influences the adaptability of some high-yielding cattle breeds, and variations in the climate can also affect the quality of milk production because of related diseases (Landes et al., 2017). The quality of milk production, milk procurement, and milk marketing for dairy producers are all greatly impacted by unpredictable fluctuations in the seasons (Singh and Srivastava, 2019). The quality of milk production and the health of cattle are closely connected to climate, environment, and cleanliness, according to a thorough study by Cardoso et al. (2016). Geographical, climatic, and other factors affect the quality of milk production in dairy farming in industrialized nations, even though India has the largest dairy herd in the world (Feroze et al., 2019). Dairy cows experience heat stress, which lowers milk production and quality, both directly and indirectly. Heat stress is brought on by rising temperatures and humidity. Lower milk yields are the result of heat stress's negative impact on the mammary glands growth and proliferation, particularly during dry periods (Tao et al., 2013).

Global surface temperatures have already risen by 0.2 to 0.6°C since 2000 and are expected to rise by an additional 1.5 to 5.8°C by the end of the century (IPCC, 2007). This temperature increase is likely to have a significant impact on regional precipitation patterns (Sanderson et al., 2009) and have a major effect on human populations (Battisti and Naylor, 2009). According to the Ethiopian Society of Animal Production (ESAP), global warming and climate change are now acknowledged facts that have impacted all ecosystems and will continue to do so if left uncontrolled (Yatoo et al., 2012a.)

Impact of climate on Production and Reproduction

Dairy animals' milk production and reproduction are negatively impacted by climate change, particularly those with high genetic merit (Upadhyay et al., 2009; Wheelock et al., 2010).

Compared to meat breeds, dairy breeds are more vulnerable to heat stress, and animals that produce more milk have higher metabolic heat output, which makes them more vulnerable to heat stress (Das et al., 2016). The efficiency of feed utilization and voluntary feed intake are directly impacted negatively by rising ambient temperatures (Baile and Forbes, 1974).The feed intake of lactating cows starts to decrease at room temperatures of 25–26°C and decreases more quickly above 30°C in temperate climates. At 40°C, it may decrease by 40 percent in cattle, 8–10% in buffalo heifers, and 22–35% in hooda et al. (2010) Animal physiology is disrupted and dry matter intake (DMI) and milk yield are reduced when air temperature and THI value rise above crucial thresholds (West et al., 2003). Every 1°C increase over the thermo neutral zone causes a 0.85 kg drop in DMI per cow and a 36% decrease in milk production because of changes in post-absorptive metabolism and nutritional partitioning (West, 2003; Rhoads et al., 2009). A THI value raises from 68 to 78 reduces DMI by 9.6% and milk production by 21%, indicating a negative correlation between THI and milk yield (Spiers et al., 2004; Bouraoui et al., 2002). When the temperature was raised to 0.6°F above the rectal temperature of 102.4°, the amount of milk produced per cow decreased by 0.7 kg per day (Igono et al. 1985). Cattle and buffalo reproduction is significantly impacted by climate change (Dash et al., 2015). Cattle and buffaloes' reproductive qualities were negatively impacted by heat stress, and this effect could be measured by creating a temperature humidity index (THI). Numerous studies have found that higher THI lowers the conception rates of dairy animals by more than 72–73 in cattle (Morton et al., 2007; Schuller et al., 2014) and 75 in buffalo (Dash, 2013). One of the main causes of lactating dairy cows' decreased fertility is heat stress (Sere et al. 2008; De Rensis and Scaramuzzi, 2003; Dash et al., 2016). Numerous studies found that in warmer climates, the rates of conception and pregnancy decreased by 20 to 30% (Schuller et al., 2014). However, in a tropical climate, heat stress is caused by air temperatures exceeding 25–37°C, which exceed heat gain and loss from the body (Vale, 2007; Kumar et al., 2011).

According to an inter-governmental panel on climate change (IPCC, 2007) states that in hot climates, feed intake, production, and reproductive efficiency decline while body surface temperature, rectal temperature (RT), respiration rate (RR), and pulse rate (PR) increase. With a 0.2°C increase in earth's temperature per ten years, the average global surface temperature would reach 1.45.8°C by 2100. The primary environmental variables that impact cattle production systems are wind speed (WS), precipitation, sun radiation, temperature, and relative humidity (RH) (Hahn et al., 2003). Numerous environmental conditions have an impact on animals' production

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performance, either directly or indirectly. Approximately 58.3% and 63.3% of animal production and reproduction are directly impacted by changes in the climate (Singh et al., 2012). Elevated ambient temperatures cause alterations in the physiology of the animal, including elevated body temperature (>102.5 ºF), raised respiration rates (>70-80/minute), and changed blood flow (Pereira et al., 2008).

Impact of climate on Animal Health

Climate is one of several factors that can change disease states and is predicted to have significant negative effects on both human and animal health (Rabinowitz and Conti, 2013). Direct and indirect effects of climate change on animal health are both possible; temperature-related disease and mortality are examples of direct effects. The spreading of vector-borne illnesses, food and water shortages, food borne illnesses, and the impact of climate change on microbial density and distribution are examples of indirect consequences that follow more complex pathways (Lacetera et al., 2013). Heat stress affects an animal's physiology, metabolism, hormones, and immune system, among other aspects of its health performance. .Lameness in dairy cows can be increased by heat stress (Shearer, 1999).Ruminal acidosis or increased bicarbonate production may be the cause of heat stress's contribution to lameness (Cook and Nordlund, 2009). Cattle facing heat stress are likely to eat primarily in the cooler hours of the day. One important cause of laminitis is acidosis, which can be brought on by reducing feed intake during the hotter portion of the day and increasing feeding when temperatures decrease (Shearer, 1999). Heat-stressed animals lose body weight and/or mobilize adipose tissue, which may be explained by an unstable energy balance brought on by a decrease in feed intake and an increase in energy expenditure for maintenance. Specifically, in the summer, early lactation dairy cows are more likely to develop liver lipidosis (Basiricò et al., 2009) and subclinical or clinical ketosis (Lacetera et al., 1996).

The immune system has developed as a group of protective mechanisms to keep harmful organisms from entering the host. The healthy operation of the immune system can be impacted by several circumstances (Lacetera, 2012). Dairy cows under extreme heat stress is lower levels of colostral immunoglobulin's (IgG and IgA), which hurt the immunization and survival of the newborn calves (Nardone et al., 1997). Because neutrophils play an important role in protecting the mammary gland from infections, the high temperatures seriously impact their ability to operate. The immune system's reaction to bacterial invasion of the teat canal or chemical, mechanical, or

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thermal damage to the cow's udder are the usual causes of mastitis, a significant endemic disease in dairy cattle (Lecchi et al., 2016).

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Heat stroke, heat exhaustion, heat syncope, heat cramps, and eventually organ failure can all be caused by high temperatures. When the body temperature rises 3 to 4 degrees Celsius over usual, certain heat-related problems arise. A higher death rate during extreme weather events (Hahn et al., 2002; Vitali et al., 2015) and a higher risk of mortality during the hottest months (Dechow and Goodling, 2008; Vitali et al., 2009).

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Prospect of Climate Resilient Dairy Farming

The prospects of dairy farming will be focusing on improving climate resilience, requiring farms to reduce their environmental effect and improve changing weather conditions. Animal health, reproduction, and production are among some of the ways that climate change is already having an impact on dairy farming. For example, excessive heat can reduce milk production, impact cow fertility, and increase their susceptibility to illnesses. Therefore, it will be vital to make sure cows are better prepared for heat and other climate challenges. Scientists are working with genetic methods to increase the feed efficiency of cows and lower produce methane emissions to breeding cows that are more tolerant to these changes**.**

- Renewable energy sources including solar, wind, and biomass are also being used by the dairy industry. This change will help farms become more energy-independent, decrease emissions, and reduce energy expenses (Solanki and Pal, 2021). It's an important step to reduce the impact of climate change on production and make dairy farming more sustainable (Malliaroudaki et al., 2022).

- The future also includes improved methods of feeding cows. These adjustments could reduce emissions, enhance cow health, and increase the eco- friendly of dairy farming. The dairy industry, like the majority of society, needs to think about and implement practice ways to decrease greenhouse gas emissions so as to help manage climate change. We may reduce the environmental impact of our farms and minimize these gas emissions by using alternative approaches to managing livestock and the manure they produce (Hristov et al., 2013; Montes et al., 2013; Del Prado et al., 2013; Chianese et al., 2009a, 2009b).

- Heat stress can affect immunological function, cause dehydration, and make animals more susceptible to illness (Aggarwal et al., 2013) Farms may need to make investments in improved cooling systems and animal welfare procedures to solve the problem and ensure that cows remain productive and healthy in hotter regions (Fournel et al. (2017).
- Dairy farming will have to adapt as environmental regulations change. To encourage the industry to be more responsible, new regulations may penalize farms that do not use sustainable techniques and makeup people who do (Arvindsson et al., 2020). As more people look for dairy products that are produced ethically and environmentally, consumers will also contribute to the advancement of sustainability (Nam et al., 2020). Better practices will be adopted by farms as an outcome.

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Conclusion

Climate change presents significant challenges to dairy farming, impacting animal health, production, and reproduction. Dairy farms must adjust by implementing climate-resilient techniques, such as heat-tolerant cattle breeding, feed efficiency, and the integration of renewable energy sources, to ensure the survival of the dairy sector. Productivity must be maintained by managing heat stress with better cooling systems and better animal management. Furthermore, changing environmental regulations and consumer demands for eco-friendly businesses will encourage the sector to become more resilient. The environmental impact of dairy production can be reduced while it keeps growing successfully by adopting these improvements.

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