International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
NAAS Rating: 4.61
VET 2025; 10(6): 237-247

www.veterinarypaper.com
Received: 12-04-2025
Accepted: 18-05-2025

Sonu Kumar Yadav
Department of LPM, College of Veterinary Science & AH, Rewa, Madhya Pradesh, India

Anjani Kumar Mishra
Department of LPM, College of Veterinary Science & AH, Rewa, Madhya Pradesh, India

Pramod Sharma
Department of ILFC, College of Veterinary Science & A.H., Jabalpur, Madhya Pradesh, India

Bhavna Aharwal
Department of LPM, College of Veterinary Science & A.H., Jabalpur, Madhya Pradesh, India

Nishtha Kushwah
Department of Veterinary Physiology and Biochemistry, College of Veterinary Science & A.H., Rewa, Madhya Pradesh, India

Sanket Pathak
Department of LPM, Nagpur Veterinary College, Nagpur, Madhya Pradesh, India

Corresponding Author:
Sonu Kumar Yadav
Department of LPM, College of Veterinary Science & AH, Rewa, Madhya Pradesh, India

Livestock production under change in environmental conditions

Sonu Kumar Yadav, Anjani Kumar Mishra, Pramod Sharma, Bhavna Aharwal, Nishtha Kushwah and Sanket Pathak

Abstract
Global demand for livestock products is expected to double by 2050, mainly due to improvement in the worldwide standard of living. Meanwhile, climate change is a threat to livestock production because of the impact on quality of feed crop and forage, water availability, animal and milk production, livestock diseases, animal reproduction, and biodiversity. Human population is expected to increase from 7.2 to 9.6 billion by 2050. This represents a population increase of 33%, but as the global standard of living increases, demand for agricultural products will increase by about 70% in the same period. Meanwhile, total global cultivated land area has not changed since 1991, reflecting increased productivity and intensification efforts. Livestock products are an important agricultural commodity for global food security because they provide 17% of global kilocalorie consumption and 33% of global protein consumption. Worldwide milk production is expected to increase from 664 million tonnes (in 2006) to 1077 million tonnes (by 2050), and meat production will double from 258 to 455 million tonnes. Consequently, the livestock sector will be a key player in the mitigation of greenhouse gas emissions and improving global food security. Therefore, in the transition to sustainable livestock production, there is a need for Assessments related to the use of adaptation and mitigation measures tailored to the location and livestock production system in use. Policies that support and facilitate the implementation of climate change adaptation and mitigation measures.

Keywords: Atmosphere, animal health, climate change, global warming, greenhouse gases, livestock, mitigation

1. Introduction
Human population is supposed to expand from 7.2 to 9.6 billion by 2050 UN (2013). It represents a 33% increase in human population, but as the global quality of living rises, the need for agricultural goods will go up by almost 70% during the same time. (FAO, 2009a). Meanwhile, the overall worldwide agricultural land area has remained unchanged since 1991. (O'Mara, 2012) [31], Showing improved production and intensified efforts. Livestock products serve as an essential agricultural product of world food security, providing 17% of world kilocalorie intake and 33% of all global protein intake (Rosegrant *et al*., 2024) [38]. The livestock industry provides livelihoods for one billion of the world's poorest people and employs almost 1.1 billion people (Hurst *et al*., 2005) [17]. The "livestock revolution" refers to the fast rise of livestock products in emerging nations (Thornton, 2010; Wright *et al*., 2012) [49, 53]. Global milk output is anticipated to rise from 664 million tonnes (in 2006) to 1077 million tonnes (by 2050), while the meat industry will triple from 258 to 455 million tonnes (Alexandratos and Bruinsma, 2012) [1]. Rising temperatures, competition for land and water, and food security at a critical moment are all expected to have a negative impact on livestock output (Thornton, 2010) [49]. Global change in climate is mainly brought about by the production of greenhouse gases (GHG) which induce overheating of the climate (IPCC, 2013) [18]. The livestock industry accounts for 14.5% of worldwide emission of greenhouse gases (Gerber *et al*., 2013) [15], and thus may increase land degradation, air and water pollution, and declines in biodiversity (Bellarby *et al*., 2013; Reynolds *et al*., 2010; Steinfeld *et al*., 2006; Thornton and Gerber, 2010) [49].

At the same time, global warming will influence livestock production through competition for natural resources, quantity and quality of feed, livestock illnesses, heat stress, and loss of biodiversity, while demand for livestock products is predicted to rise by 100% by the middle of the twenty-first century (Garnett, 2009) [14]. The problem is to strike the right equilibrium between production, family food security, and protecting the environment (Wright *et al*., 2012) [53]. Climate change is viewed as a serious danger to the survival of numerous species, ecosystems, and the long-term viability of cattle production systems across the world. (Moss *et al*., 2000) [25].

Climate change provides a serious obstacle to India's livestock industry growth. The anticipated rise in temperature of 2.3 to 4.8°C across the country, combined with increased precipitation as a result of climate change, is likely to exacerbate heat stress in dairy animals, reducing their productive and reproductive performance and thus reducing the total area where high yielding dairy cattle can be economically reared. Given India's susceptibility to sea level rise, the increasing severity of severe events will have a significant and disastrous impact on the livestock industry in low-income rural regions. As the ecosystems are sensitive to changes in climate, it is necessary to examine the likely impact of climate change on various sectors within the ecosystems to be able to comprehensively understand the effects of climate change.

2. Climate

Climate change is defined as a change in climate caused directly or indirectly by human activity that modifies the composition of the global atmosphere, in addition to natural climatic variability observed over similar time periods. The influence of climate change on livestock productivity has been classified as on Availability of feed grain, Pasture and forage crop production and quality, Health growth and reproduction and disease and their spread (Rotter and Van de Geijn, 1999) [39].

Climate change may reduce or raise the population of a livestock species in an area (Moss *et al*., 2000) [25]. Animals that are more resilient and acclimated to the reference climatic conditions may prosper, but others may relocate to a more appropriate place or suffer from a stressful environment. Livestock acclimated to hot environments will be preferred in the country's hot semi-arid/arid regions over high-producing sheep that are less thermally resistant. Thermal stress is known to have a more severe effect on non-adapted and high-producing sheep. The production performance and survivability of Bharat Merino sheep, i.e., Crossbred (75% exotic inheritance), were unsatisfactory at Avikanagar (semi-arid tropical area), but their shifting to Mannavanur (sub-temperate location) resulted in a marked increase in production and health performance. (Barbehenn *et al*., 2004) [3]. Climate change is typically connected with an increase in global temperatures.

3. Greenhouse Effect & Global Warming

The 'greenhouse effect' is the warming of the climate caused by the atmosphere trapping heat emitted from Earth into space. Certain gases in the atmosphere act like glass in a greenhouse, allowing sunlight to enter while preventing heat from leaving into space. Water vapour, carbon dioxide (CO_2), methane, nitrous oxides, and chlorofluorocarbons (CFCs) all contribute to the greenhouse effect. Global warming is the gradual increase in the average temperature of the planet's atmosphere because an increased quantity of energy (heat) impacting the earth from the sun is trapped in the atmosphere and not dissipated away into space Nikolov and Zeller (2024) [28]. Global warming has occurred on Earth several times throughout past times, and it seems to be happening again right now. The current warming is typically ascribed to a rise in the greenhouse effect, which is caused by elevated GHG levels, mostly as a result of human activity and livestock (Forster *et al*., 2007) [12].

3.1 Essentiality of GHG for ecosystem

GHGs account for less than 1% of all gases in the atmosphere. However, these gases perform a crucial function in keeping the atmosphere at a temperature suited for humans, plants, and other organisms. Without GHGs, plants and animals could not have survived and thrived on this planet (Shine, 2009) [43].

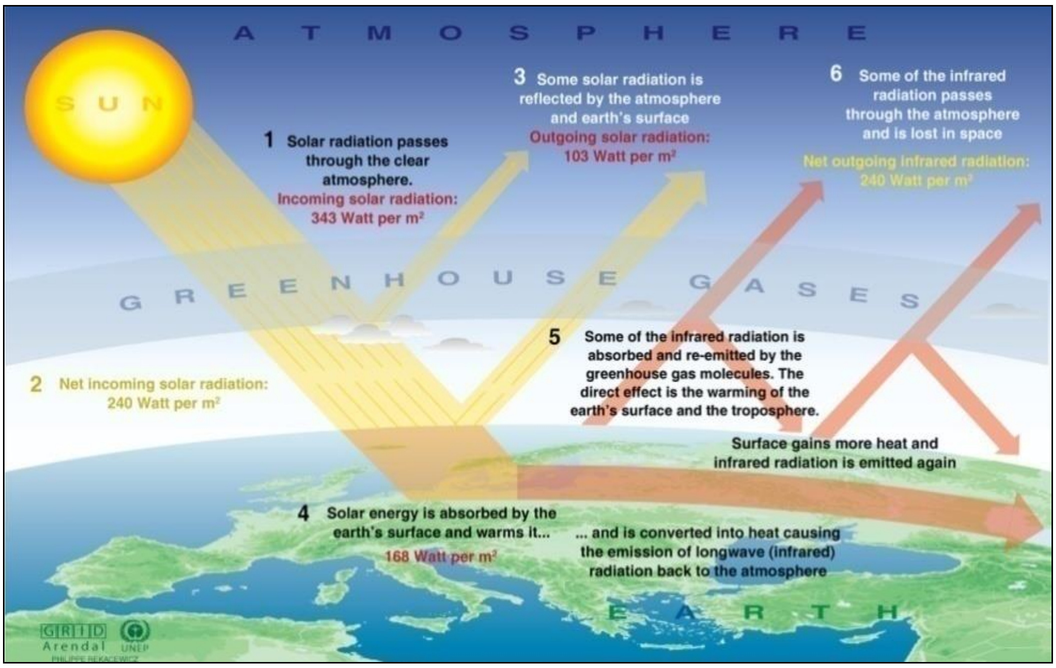

Fig 1: Global warming

3.2 Gases associated with global warming

Livestock emit greenhouse gases such CO_2, CH_4, and N_2O, they either directly or indirectly influence climate change (Bhatta *et al*., 2015) [33]. The industry accounts for 18% (7.1 billion tons CO_2 equivalent) of worldwide greenhouse gas emissions. Despite making up just 9% of the world's CO_2, it produces 35% of CH4 and 65% of human-related N2O, which have GWPs that are 23 and 310 times greater than CO_2, respectively.

CO_2, CH_4 and N_2O among the biggest greenhouse gas emissions from animals. CH4 is the leading contributor to anthropogenic GHG emissions (44%), which follows N 2O (29%), and CO_2 (27%).

3.3 Effects of global warming

Climate change affects the physical environment, ecosystems, and human civilization. They also include the economic and societal changes that result from living in a warmer climate. Human-caused climate change is one of the most serious risks to sustainability. Many physical effects of climate change are already observable, such as extreme weather events, glacier retreat, changes in the timing of seasonal events (for example, earlier blossoming of plants), sea level rise, and Arctic Sea ice loss. Since the 1980s, the ocean has absorbed 20-30% of human-induced atmospheric carbon dioxide, resulting in ocean acidification. The ocean has also been warming, absorbing more than 90% of the surplus heat in the climate system since 1970.

Global climate change has already had an impact on the ecosystem. Glaciers have receded, ice on rivers and lakes is breaking up earlier, plant and animal ranges have altered, and trees are blossoming earlier. Scientists are certain that global temperatures will continue to rise for decades, owing primarily to greenhouse gas emissions from human activity. According to the IPCC, the impact of climate change on specific areas will vary over time and depend on the ability of various societal and environmental systems to mitigate or adapt to change. The IPCC anticipates that global mean temperature increases of less than 1.8 to 5.4 degrees Fahrenheit (1 to 3 degrees Celsius) over 1990 levels will have a positive influence in certain places and a negative impact in others. Global temperatures will rise over time, increasing net yearly costs.

3.4 Trends of south-west monsoon (Mm) in 100 year

The 'Southwest Monsoon' season runs from June to September. The Southwest Monsoon period is the main rainy season for the Indian subcontinent. During this time, the country receives about 75% of its total rainfall. The Monsoon season begins with a dramatic increase in rainfall activity. It moves inwards in phases, eventually covering the whole country by mid-July. It begins recovering from the far northwest around the beginning of September and gradually moves southeast. Tamil Nadu is regarded a rain shadow region since it is located on the eastern (leaward) side of the Western Ghats. The state's southernmost region receives the greatest total yearly rainfall (http://www.imdchennai.gov.in/swweb.htm).

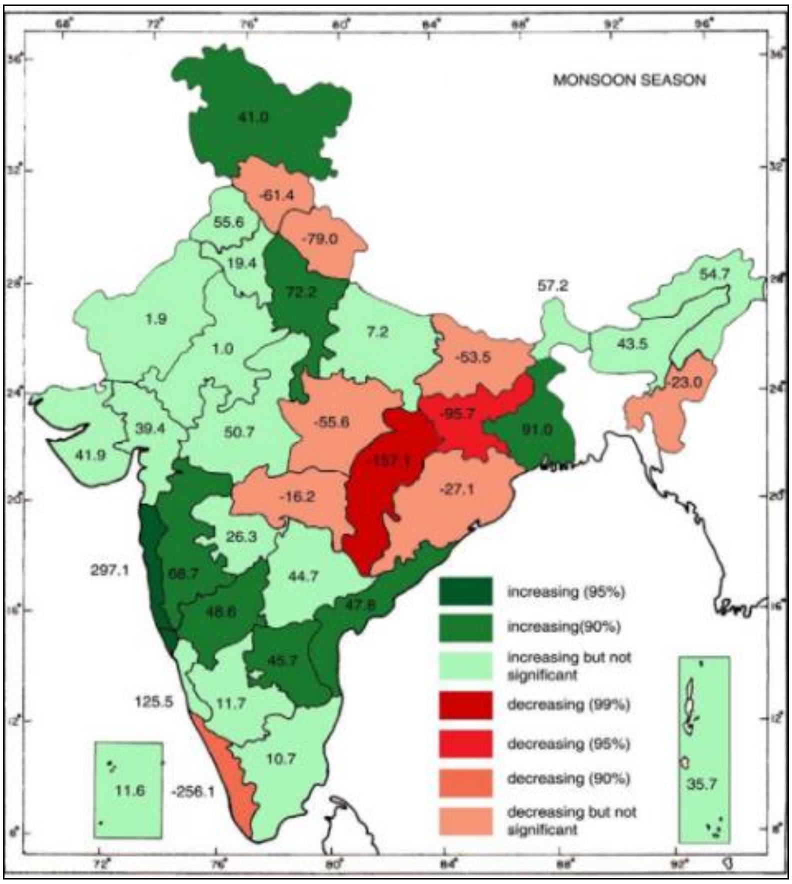

Fig 2: Effect of South-West Monsoon

Looking at the image above, we can see that there is a significant decrease in monsoon season rainfall in the eastern half of India, including Kerala, Himachal Pradesh, and Uttarakhand. A significant rise has been seen in various sections of the southern peninsula, western Uttar Pradesh, West Bengal, and Jammu and Kashmir (Attri & Tyagi, 2010)

[2]. The average yearly temperature in most regions of the nation is 25°C or above, which is within or above the thermal comfort zone of cattle and buffaloes, allowing for optimal milk output. In India, the top temperature restriction of the comfort zone for maximum milk production is 27 degrees Celsius. In India, the top temperature restriction of the comfort zone for maximum milk production is 27 degrees Celsius. However, the average yearly temperature exceeds this upper critical limit in some regions of the nation, notably the south-east region, which includes the states of Andhra Pradesh and Tamil Nadu. For India, climate change forecasts with a doubling of carbon dioxide concentration in the atmosphere imply that temperatures will climb between 2.3 and 4.8°C, combined with increasing precipitation (Lonergan, 1998) [21]. Furthermore, temperatures are projected to climb throughout the year. These conditions, particularly the more hot-humid climatic conditions and the rise in summer (April to June) temperature (which already ranges from 25 to 45°C maximum daily temperature in most parts of the country), could exacerbate thermal stress in animals and negatively impact their productive and reproductive performance.

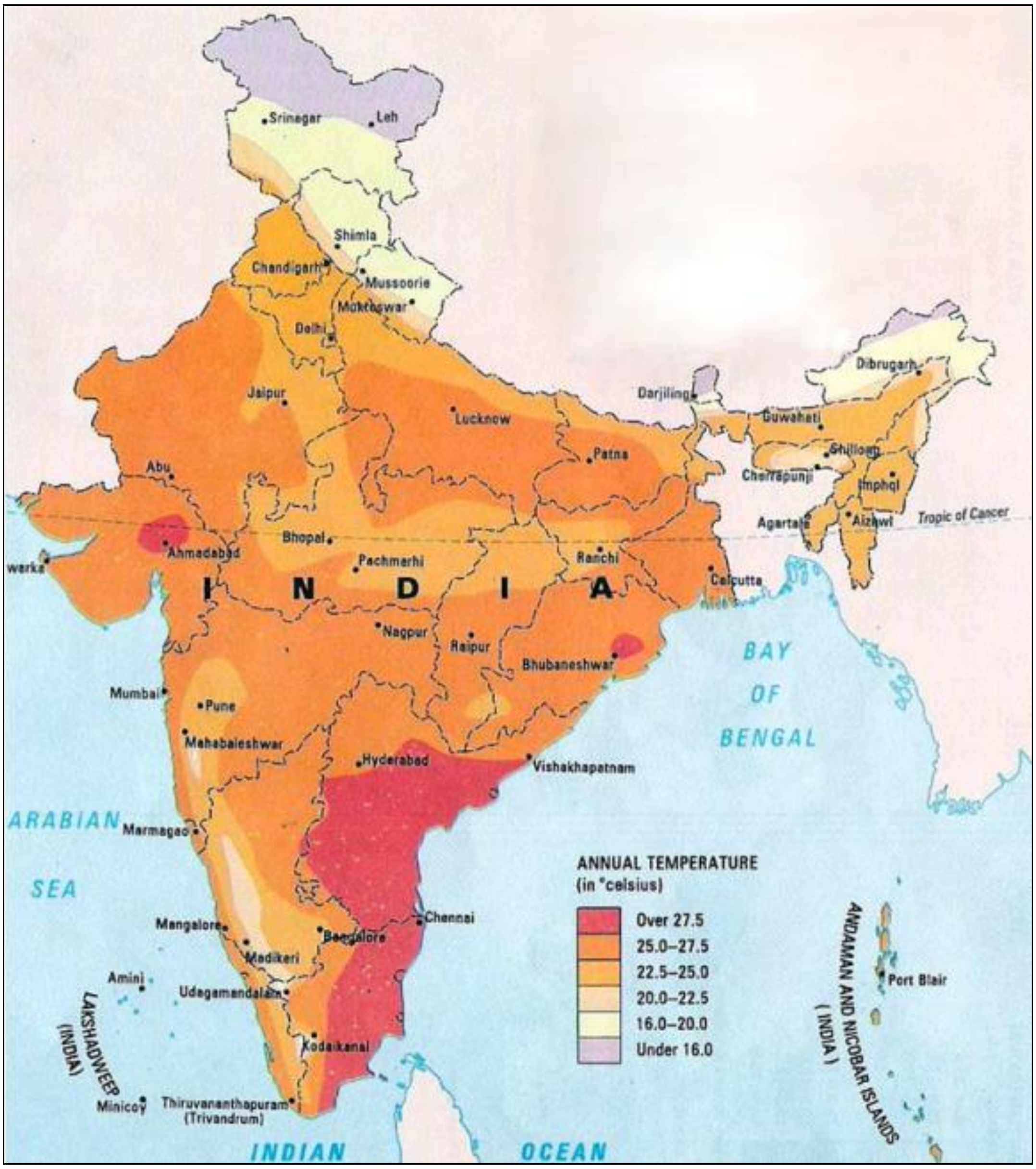

Fig 3: Average Annual Temperature of India

4. Methane production by cattle

Enteric fermentation is a natural element of the digestive process of ruminants in which bacteria, protozoa, and fungus in the animal's forestomach (rumen) ferment and degrade the plant material consumed. Plant biomass in the rumen is transformed into volatile fatty acids, which flow past the rumen wall and enter the liver via the circulatory system. This mechanism provides a significant portion of the animal's energy demands and allows for the high conversion efficiency of cellulose and semi-cellulose, which is typical of ruminants. Eructation removes the majority of the gaseous waste products of enteric fermentation from the rumen, including carbon dioxide and methane. Methane emission in the reticulo-rumen is an evolutionary trait that allows the rumen ecosystem to eliminate hydrogen, which would otherwise build and impede carbohydrate fermentation and fiber destruction. Enteric methane emission rates vary depending on meal intake and digestibility (Grossi *et al*., 2019) [16].

Cattle in the United States are classified into three types: dairy cows, meat cattle on feed, and cattle on range. Range cattle are uncommon in Europe and the Soviet Union, while dual-purpose cattle raised for dairy and meat production are commonplace. In other nations, such as Australia and Argentina, cattle are predominantly raised on the range, and dairy cows are comparatively scarce. Because cattle are fed at varying amounts of energy intake and food quality throughout the world, we will proceed to offer specific assessments for the United States, West Germany, and India. We will extend these statistics to other regions of the planet to get worldwide estimates of methane output. Methane yields of 5.5%, 6.5%, and 7.5% of gross energy intake for these categories, with an energy content of 55.65 MJ/kg CH, result in yearly methane output of 84 kg, 65 kg, and 54 kg, respectively. The cattle population in the United States consists of 10% dairy cows, 12.5% feed-lot beef cattle, and 77.5% range cattle. Cattle in the United States produce an average of 58 kg of methane each year Crutzen *et al*., (1986) [8].

Anthropogenic warming would have potentially rapid and permanent consequences. The partial loss of ice sheets on ice arctic land might result in metres of sea level rise. Major alterations in coasts and flooding of low-lying places Excellent results in river deltas and low-lying islands. Global warming's indirect impacts, such as soil infertility, water shortages, grain yield and quality, and disease dispersion, may have a greater impact on animal productivity in these systems than direct consequences. Indeed, under these settings, animals may better cope with the direct consequences of high temperatures, i.e. heat stress, through food, cooling measures, or farm management. Furthermore, industrialized systems create more manure than can be utilized as fertilizer on neighboring agriculture, causing phosphorus, nitrogen, and other contaminants to accumulate in the soil (Bengtsson *et al*., 2007) [5].

The globe is seeing fast change in how animal products are produced, processed, eaten, and marketed. The patterns seen in rich nations, such as growing production and concentration of large-scale enterprises with greater environmental difficulties, are increasingly seen in emerging countries. According to others, the reason for this is because small-scale manufacturers cannot compete with bigger enterprises that benefit from economies of scale (Delgado, 2003) [9].

Most developing nations rely significantly on agriculture, and the consequences of global warming on productive croplands are projected to jeopardize both human welfare and country economic progress. Tropical locations in the developing world are especially sensitive to possible environmental harm since their weak soils have already rendered most of the land unfit for cultivation. Although agronomic simulation models anticipate that increased temperatures will diminish grain yields as cold wheat-growing areas warm, they have not included the likelihood that farmers could adjust by making production decisions that benefit themselves. A recent set of models explores cross-sectional evidence from India and Brazil and indicates that although while the agricultural industry is susceptible to climate, individual farmers do take local climates into consideration, and their capacity to do so will help offset the consequences of global warming (Mendelsohn., 2003) [23]. Stress is defined as the amount of external forces that shift the body's systems from their resting or ground condition. In this light, heat stress for the dairy cow may be defined as any high temperature-related pressures that cause changes from the sub-cellular to the entire animal level to assist the cow avoid physiological dysfunction and better adapt to its environment. Homeotherms' efforts to maintain body temperature within relatively limited ranges are critical for controlling biochemical reactions and physiological processes involved with appropriate metabolism Kadzere *et al*., (2002) [20]. Dairy farmers and the dairy industry should utilize these findings to develop and prioritize adaptation strategies to deal with expected increases in heat stress frequency and intensity Nelson *et al*., (2010) [27].

5. Sensitivity of livestock production to climate change

Animal organ systems respond to physical, chemical, biological, and climatic stimuli in their environment and work together to execute important bodily functions. Climate has a significant direct and indirect impact on livestock performance (e.g., growth, milk and wool production, reproduction), health, and well-being (Colditz and Hine, 2016) [7].

5.1 Direct Effects

Livestock are homeotherms, which means that they must keep their body temperature within a small range in order to stay healthy and productive. Animals become stressed when the ambient temperature falls below or rises over the thermoneutral range. According to reports, the optimal thermal-comfort zone for adult cattle performance is between 5 and 15 degrees Celsius. However, major changes in feed intake or a variety of physiological processes will not occur between 5 and 25°C. Compared to other livestock species, dairy cattle have a lower upper critical temperature. Cows are stressed by hot and humid environments. Heat stress causes behavioural and metabolic changes, such as lower feed intake and metabolic activity, resulting in a decrease in output, which can have a significant financial impact on livestock producers (Fournel *et al*., 2017) [13].

5.1.2 Impact of climate change on animal health

Global warming and climate change are increasingly acknowledged as threats, and some concerning changes have already taken place. The Asian continent may be particularly impacted by the effects of climate change due to its size and variety, and it plays a crucial role in reducing the potential negative effects of climatic variability on animal health given its recent emergence as a "hub" for livestock production. Infectious diseases, particularly vector-borne diseases that are highly reliant on environmental and climatic conditions, heat-related illnesses and stress, extreme weather events, and the adaptation of animal production systems to new environments are the four ways that climate change may impact animal health Forman *et al*., (2008) [11].

Triglycerides, the body's fat reserves, are mostly composed of non-esterified ("free" or unsaturated) fatty acids (NEFAs), which are made up of three fatty acids joined by a glycerol backbone. NEFAs and glycerol are released when hormone-sensitive lipase hydrolyzes stored triglycerides (fat) in adipose tissue. Many tissues, including hepatocytes and skeletal muscle, may use NEFAs as an energy source. Hepatocytes can be utilized to produce energy, repackaged into triglycerides and exported as very low density lipoproteins (VLDL), stored in the liver, or converted to ketones, depending on their energy demands, hormone balance, and substrate availability (Odens *et al.*, 2007) [30].

More CO_2 is exhaled as a result of the elevated respiratory rate. Hyperventilation causes blood CO_2 levels to drop in a heated environment, and the kidneys release HCO3 to keep the ratio stable. (Schneider *et al*., 1988) [40]. As a result, there is less HCO_3 available to buffer and maintain a healthy rumen pH (via saliva). Additionally, the amount of saliva that would have typically been deposited in the rumen is decreased when ruminants pant and drool.

It has been documented that HS damages or alters follicle growth during folliculogenesis, which has a delayed detrimental effect on ovarian function. There have been reports of decreased LH pulse and frequency due to HS. The study discovered that the cows in the HS group had fewer tiny follicles. It has been shown that small antral follicles are extremely susceptible to HS. Gir cows, a native Indian cattle breed, have decreased oocyte competency as a result of HS's carryover effect on tiny follicular growth and development. Heat stress decreases the chosen follicle's degree of dominance, which is manifested by a decrease in blood estradiol levels and a diminished steroidogenic ability of its theca and granulosa cells. Depending on the animal's metabolic condition and whether the heat stress is acute or prolonged, plasma progesterone levels may rise or fall (DeRensis and Scaramuzzi, 2000) [34]. Heat stress has a wide range of effects on the reproductive axis. Some of these effects directly affect individual reproductive organs such as the hypothalamus, the anterior pituitary gland, the uterus, the follicle and its oocyte and the embryo itself, while the other effects of heat stress are indirect and probably mediated by changes in the metabolic axis in response to reduced dry matter intake. We suggest that there is not a single mechanism by which heat stress can reduce in dairy cows and that this problem is due to the accumulation of the effects of several factors.

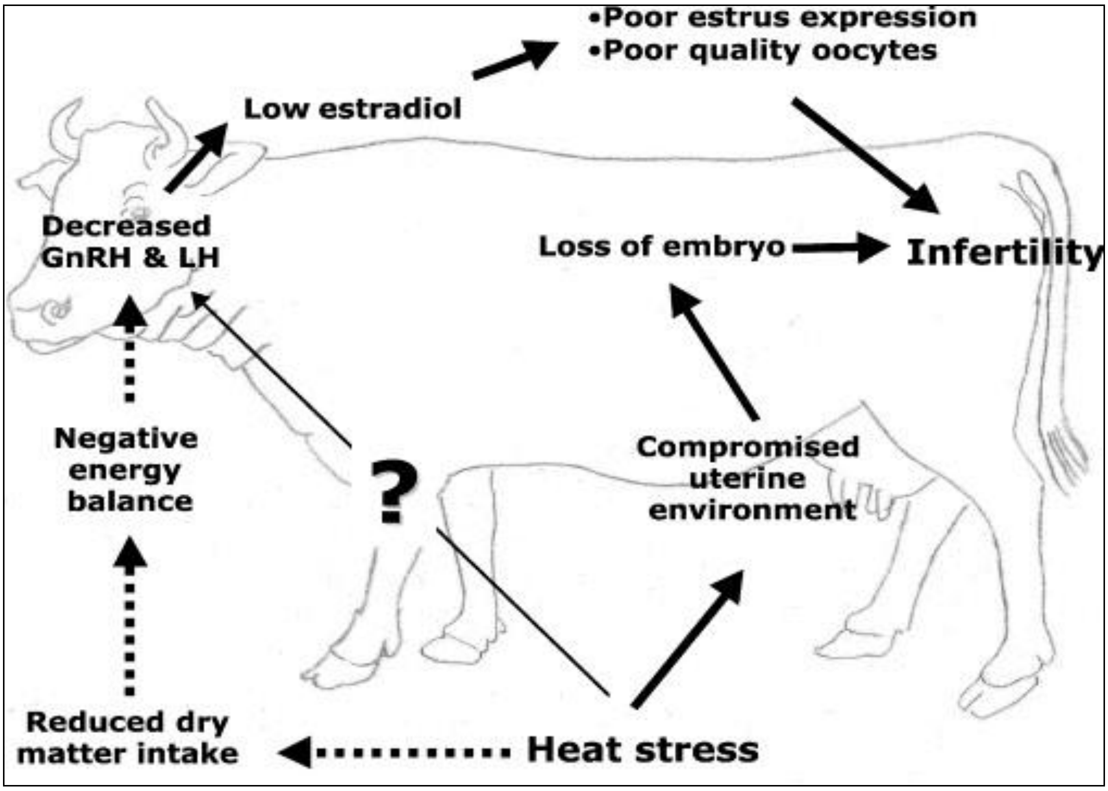

Fig 4: A schematic description of the possible mechanisms for the effect of heat stress on reproduction in the lactating dairy cow (DeRensis and Scaramuzzi, 2000) [34]

5.1.3 Impact of Thi (Temperature Humidity Index) on milk production

Thermal humidity index is a measurement that has been used since the early 1990s. It takes into consideration the combined impacts of ambient temperature and relative humidity, and it is a helpful and simple method for assessing the danger of heat stress in animals. When the THI hits 72, cows are more prone to experience heat stress, which affects calf rates. When the THI hits 78, cow milk output suffers significantly. When the THI exceeds 82, milk supply suffers significantly, cows exhibit acute stress, and they may eventually die. A THI of 72 may underestimate heat load in high-yielding Holstein-Friesian cows, as increased milk supply increases cow sensitivity to heat stress. All THI maps for baseline and 2030 show a temperature rise and change in THI in Uttar Pradesh, Madhya Pradesh, Gujarat, Rajasthan, and other Indian states using the regional climate model (Sreenivasaiah, 2016) [46]. It was shown that increases in humidity and air temperature eventually raise the temperature humidity index (THI), that influences heat dissipation, feed intake, and other physiological functions, finally causing stress on milk production (Sharma *et al*., 2021) [41].

Thorns formula for calculating THI is as follows

$THI = 0.72(T_{Db}+T_{WB}) + 40.6$

Where T_{DB} is dry bulb temperature (in C) and T_{WB} is wet bulb temperature NRC (1971) [29]

5.1.4 Predicted DMI & Milk Production

The impact of heat stress on dry matter intake and milk production in dairy cattle was assessed using the Cornell Net Carbohydrate and Protein System (CNCPS) model A dairy cow weighing 1,400 pounds and producing 80 pounds of milk was assessed for ration/ For this cow, an initial ration was balanced at 60 °F/ Next runs varied temperature, humidity, and night temperature/ It is possible to estimate the effect of night cooling by using night temperature. The following are the key outcomes of this exercise:- The maintenance energy required rose by 22% at 90 degrees Fahrenheit in comparison to the base run at 60 degrees. Between runs 1 and 4, the predicted dry matter intake dropped by 18%. The predicted ME milk dropped by 32% from run 1 to run 4. A 20% drop in predicted MP milk was observed between runs 1 and 4. In order to supply extra energy, 1 pound of a rumen bypass fat source was added to the feed during run 5. As a consequence, a forecasted gain of 8 pounds per day (14%), was achieved.

Table 1: CNCPS model for a 1,400 lb. dairy cow

Run	Temp., ºF	Humidity	Night Temp., ºF	Maintenance ME, Mcal	DMI, LBS.	Milk, LBS.
1	60	50	50	16.38	48.8	85.3
2	90	50	60	18.27	47.2	77.8
3	90	70	60	19.95	46.6	73.1
4	90	70	75	19.95	39.8	57.7
5	90	70	75	19.95	40.8	55.8

5.1.5 Potential impact of climate change

Examining the effects of climate change on India's animal production system from a macro viewpoint will require a thorough research study, however it is acceptable to draw attention to a few key concerns. Since the beginning of Indian planning in the early 1950s, the country's livestock development program has placed a strong focus on the crossbreeding of Indian cattle with foreign sires. Climbed milk production was the aim, and as a result, crossbreeding has climbed from a minuscule percentage of the nation's dairy cattle three decades ago to around 17.5% now. The noted seasonal variations in milk production and air temperature serve to highlight this even more. Although the amount of change in milk output across the three seasons varies by region and is not exclusively reliant on seasonal fluctuations in air temperature, the milk yield often decreases when summers arrive following winters and recovers with the start of the rainy season. The greatest temperature at which milk may be produced in India is 27°C, which is around two degrees warmer than the same temperature seen in temperate nations. This may be the result of some foreign breeds (such Brown Swiss, Jersey, and Friesian) crossing with local Indian breeds, which have somewhat adapted to the country's climate. Additionally, it is anticipated that temperatures would increase throughout the year. These factors, particularly the hotter, more humid climate and the rising summer temperatures (April to June), which in most regions of the country already range from 25 to 45°C on a maximum daily basis, would likely make animals more susceptible to heat stress and negatively impact their ability to reproduce and produce. One potential outcome would be a decrease in the overall area available for the economically viable rearing of high-yielding dairy cattle. Small and marginal farmers, who own the majority of India's livestock, frequently cannot afford the proactive management remedies during heat waves (such as installing sprinklers or altering the housing arrangement, etc.) or animal feeding techniques to lower excessive heat loads (Mandal *et al*., 2002) [22]. Consequently, 17.5% of Indian's dairy cattle are crossbred. This percentage was essentially insignificant almost forty years ago. Crossbred cows, on the other hand, are extremely susceptible to temperature increases. In regions that have greater mean annual temperatures, crossbred dairy cow efficiency is lower (Table 2), (Sirohi and Michaelowa 2007) [45].

Table 2: Average annual temperature and milk productivity of crossbred cows in selected districts of India (Sirohi and Michaelowa 2007) [45]

Districts	Annual mean temperature	Average daily milk yield of crossbred cows
Ongole	29.74	3.98
kurnool	29.05	3.02
Anantpur	28.61	3.21
Chennai	28.27	4.65
Ahmadabad	27.86	5.56
Cuttack	27.72	3.15
Rajkot	27.14	5.28
Tiruvanthapuram	27.10	5.65
Jodhpur	27.09	3.27
Kolkata	26.98	5.48
Balasore	26.88	3.57
Nagpur	26.85	3.29
Hyderabad	26.10	4.86
Patna	25.58	3.50
Jaipur	25.17	5.45
Aurangabad	25.04	3.78
Lucknow	25.01	4.00
Agartala	24.86	5.50
Bhopal	24.85	6.01
Pune	24.79	6.28
Ranchi	24.33	6.00
Guwahati	24.21	5.85
Banglore	23.80	6.34
Ludhiana	23.50	7.58
Ambala	23.45	6.44

The production of milk and meat is adversely affected by heat stress. A heated environment has a significant and detrimental impact on the quality of animal products in addition to their quantity. Heat stress has a more significant impact on high-grade milk products, such as cheeses with protected designations of origin from several European nations that are known for their exceptional quality. The detrimental effects of heat stress on the organic and inorganic components of milk

Summer *et al*., (2019) [48]. Global warming is expected to have a significant detrimental effect on India's climate. In addition to having the greatest livestock population in the world (520.6 million), India is also the country with the highest percentage of cattle (16.1%), buffaloes (57.9%), goats (16.7%), and sheep (5.7%). Livestock production is a crucial component of mixed agricultural systems that are used all throughout the nation. Cows for Dairy Products Although there is little information on how vulnerable animal production is to climate change in India, experimental research has been done on how the season and climate affect dairy animal performance, productivity, and other physiological factors. A heat wave is characterized by exceptionally hot and typically humid weather that lasts for at least one day, but typically lasts for many days to several weeks. Animal heat exchange is impacted by these heat waves. During days when there are multiple hours with THI well over the comfort limit and little time for recovery, they are unable to discharge the additional heat load that has accumulated. Thus, eating behavior and thermoregulation are impacted. When THI-hs at or above a base of exceed 15 per day for three or more consecutive days with limited or no nighttime recovery opportunity, some death losses can be expected if relief measures are not provided. An examination of the milk production reactions of grazing Holstein cattle in the central milk supply area of Santa Fe was conducted using the description and features of heat waves as suggested by. It was determined that under a grazing system, heat waves had an effect on the performance of high-producing dairy cows. During the testing, two heat waves were identified. When comparing milk production levels before and after the three-day heat wave, the animals showed a 10-14% drop. Even though the second heat wave, which was recorded a month later, was more intense than the first, they did not react to it and never recovered. Because of their reduced level of production, the scientists believe that animals were less vulnerable to heat stress during the second wave.

Table 3: Displays milk output prior to, during, and following heat waves

		Before	During	After	Prob.
First Heat Wave	C	24.4±0.32	22.9±0.73	20.9±1.24	0.007
	T	25.6±0.38	24.7±0.57	22.8±0.89	0.001
	Prob.	0.003	0.009	0.023	
Second Heat Wave	C	22.4±0.41	21.9±1.71	21.6±0.37	0.371
	T	23.1±0.31	22.7±0.53	22.2±0.33	0.727
	Prob.	0.043	0.077	0.051	

Rinaldo and Mourot (2001) [36] Determined that the growth rate was not significantly impacted by the tropical climate during the cool season. The backfat of 35-94 kg pigs raised in the tropical cool season was slimmer than that of the control group, and their voluntary feed consumption was 9% lower ($P < 0.01$). Meat quality may vary indirectly as a result of adjustments made to livestock and poultry management techniques in response to climate change-related risks. For instance, switching to Bos indicus cattle sire lines that can withstand high temperatures may result in meat that is harder, less juicy, and has less marbling. Additionally, pre-exposing broilers to heat stress in order to improve their chances of surviving during transportation may result in more varied pH levels in the breast meat. There will be regional differences in the potential effects of short-term climate change. The management of the repercussions must be grounded in experience while acknowledging the variety of possible strategies. The LT muscle's meat quality attributes were significantly impacted by the season. The final pH values (6.24) of muscles harvested during the hot season were substantially higher than those of cool season samples (26.01%) compared to hot season samples (19.75%). Beef from the hot season group had significantly. Strong negative effects of the hot season (average temperature of 34.3±1.67 °C and 48.8±7.57% relative humidity) on the quality characteristics of beef meat Kadim *et al*., (2004) [19].

Modern broiler chickens are preferred in regulated farms for their high feed efficiency and quick growth rate in a short life cycle. Because of their rapid metabolism, which increases metabolic heat output, these birds find it more difficult to sustain homeothermy while under heat stress These traits suggest that birds with high productivity may be more vulnerable to climate change Two major disadvantages will affect the poultry industry's response to climate change the monetary effects of productivity losses as a result of heat stress, as well as the cost of ameliorating heat stress by altering birds' environmental conditions.

5.1.6 Effect of heat stress on reproductive patterns in dairy cows

Both male and female animals' fertility and reproductive efficiency are very susceptible to changes in the climate, especially extreme heat. The most obvious effects of heat stress are reduced fertility in females and decreased sperm production in both quantity and quality in males. Both male and female animals' reproductive systems are negatively impacted by high temperatures. It causes the oocyte to age prematurely in females (Mirza *et al.*, 2021) [24].

Peripheral plasma inhibin concentrations rise sharply over the winter months, from the lowest value in the mid-luteal phase to the late luteal phase and finally to the periestrus phase. The early luteal phase then saw a sharp decline in inhibitory concentrations. During the summer, no particular pattern was seen, and there was no discernible variation in the levels of inhibin at different stages of the cycle (Palta *et al*., 1997) [32].

5.1.7 Evidence for climate change's effects on infectious disease

Increased wheat yields in Australia and lower rice yields in Asia have been attributed to recent climate change. Crop damage in the United States has been associated with an increase in the frequency of extreme weather events. Warmer winters have caused the European corn borer to move northward. Until the late 1990s, the biting midge *Culicoides imicola* was only found in the hottest regions of Europe, which included the Greek islands to the east and southern Spain and Portugal to the west. Along with a notable northward shift, the insect has recently expanded over most of southern Europe, including France and Italy. It has been followed by a disastrous outbreak of blue tongue, a ruminant viral illness spread by midges in southern Europe.

In India, the seasonality of Foot and Mouth (FMD) disease in cattle in the hyper-endemic division of Andhra state and the meso-endemic region of Maharashtra state can be explained by climatic factors such as temperature, humidity, and rainfall in 52 and 84% of cases, respectively. The mass migration of animals, which is influenced by meteorological conditions, was shown to be associated with the illness epidemic (Sharma *et al*., 1991) [42]. Singh *et al*., (1996) [44] found that, as a result of increased heat stress and a larger fly population linked to hot and humid weather, dairy cows had a higher prevalence of clinical mastitis. Furthermore, it was discovered that the hot, muggy weather made cattle tick infestations like Boophilus microplus, Haemaphysalis bispinosa, and Hyalomma anatolicum worse.

Significant effects on vector-borne illnesses include the spread of vector populations into more temperate regions (like bluetongue disease in northern Europe) or colder regions (higher altitude regions, like malaria and livestock tick-borne diseases). Variations in rainfall patterns may also have an impact on the growth of vectors in years with higher precipitation, which might result in significant disease outbreaks (East Africa's Rift Valley Fever virus).

A thorough examination of the existing state of climate change, GRFA conservation and GRFA use is a crucial step in incorporating GRFA into national adaptation planning and creating a GRFA adaptation strategy. Assessment should be a part of this. Current patterns of GRFA usage, as well as the state of several genetic resources sectors and related biodiversity for food and agriculture, Institutions and procedures that facilitate the preservation and utilization of GRFA, such as the functions of local and informal institutions like local markets and civil society groups.

5.2 Indirect Effects

Aside from the direct effects of climate change on animal and animal production, there are significant indirect effects, such as climatic influences on the quantity and quality of feed and fodder resources such as pastures, forages, grain and crop by products, as well as the severity and distribution of livestock diseases and parasites (Sirohi *et al.*, 2007) [45].

5.2.1 Effect on biodiversity loss

Diversity in Biodiversity Biodiversity is already being significantly impacted by contemporary change agents. Around 16% of the nearly 4000 breeds of ass, water buffalo, cattle, goat, horse, pig, and sheep that were documented in the 20th century were extinct by 2000, and 12% of what remained were rare. This loss of genetic and cultural diversity in agriculture is a result of the forces of globalization. According to the 2007 FAO study on animal genetic resources, about one species per month is going extinct, and 20% of documented breeds are currently categorized as at danger. Significant geographic variance exists. But. 20 to 28 percent of mammalian species in industrialized regions are considered to be at risk, and these areas have highly specialized livestock sectors where a few breeds dominate production. Although about 7-10% of mammalian species are at danger in developing countries, 60-70% of mammals are categorized as having an uncertain risk status (CGRFA, 2007) [6].

5.2.2 Effect of climate change on livestock production systems

A combination of dryness and heat is expected to reduce crop production in the tropics and subtropics by 10 to 20% by 2050. During droughts, 45% of pastoral households in Gujarat state's Banni grassland area move their animals. Approximately 90% of the world's milk, 70% of its ruminant meat, over 25% of its monogastric animal meat, and 40% of its eggs are produced in all mixed systems. An industrial system provides 55% of pork, 60% of eggs, and 70% of poultry meat (Nardone *et al.*, 2010) [26].

5.2.3 Impact on grazing, mixed agro-zootechnical or industrial livestock systems

Climate change will have an impact on pastoral systems, especially in Africa, Australia, Central America, and Southern Asia. According to some research, by 2100, the amount of biomass that is accessible in these places might drop by as much as 50%. Particularly in subtropical and Mediterranean regions, the animals are prone to endure heat stress for an extended length of time. The rise in vector-borne illnesses and external parasites is a frequent result. The nematode Cloverstem Fibrous forages and the thermoregulatory requirement for water (high TDS) might be another issue. (Wittmann *et al*., 2001) [52].

6. Mitigation

For dry cows, evaporative cooling outperformed shade in terms of peak milk production (90.9 vs. 87.2 lb), services per conception (3.1 vs. 3.7 services), and culling for reproductive failure (7.7 vs. 19%). using additional fats, feeding more grain, and using high-quality fodder. The rumen may benefit from sodium bicarbonate as a buffer to help it adjust to greater concentration levels. A 0.3-meter rise in sea level is expected to have an impact on 35 villages in the districts of Raigad and Ratnagiri. Kerala-9, Maharastra-5 Eleven districts of Tamil Nadu are particularly vulnerable to climate change. Punjab indicated Ludhiana (0.27) as the least risk district and Bathinda (0.66) as the most vulnerable. vulnerability analysis, crop modeling, and modeling of natural resources. Initiative to raise awareness of climate change among KVK employees, farmers, and agricultural extension agents.

7. Conclusions

Increase in temperatures cause severe damage to the physiology, metabolism, and productivity and to the healthiness of animals. In India, maximum area comes under high range of THI which severely affect the agriculture and livestock production. The positive trend both in the number of heads and in productivity that we observed in recent decades could slow down or even become negative, if an effort is not made to adapt. Implementing adapted herd management strategies as early as possible before the problems are visible at production level.

8. Recommendation

Integrated effort of all animal scientists with agronomists, physicists, meteorologists, engineers, economists etc. can improve the prevailing Climate change condition

Conflict of Interest

Not available

Financial Support

Not available

9. References

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How to Cite This Article
Yadav SK, Mishra AK, Sharma P, Aharwal B, Kushwah N, Pathak S. Livestock production under change in environmental conditions. International Journal of Veterinary Sciences and Animal Husbandry. 2025;10(6):237-247.