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Invited Review Article

Impact of climate change on animal health and animal production

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Abstract

The article aims to provide insight into the impact of climate change on animal health and production. Climate change is the complex and multidisciplinary change in the global or regional climate patterns, which could pose a significant risk for natural systems including animal health and production systems. India is a leading producer of milk, fish, poultry, and livestock besides other agricultural crops. However, the animal husbandry sector continues to battle several intimidating challenges of depleting natural resource bases, aggravating climate change, and reducing farm income. We are now reimaging the animal husbandry system and prioritizing enhancing farmers' income, reducing water use, reducing greenhouse emissions, etc., Successful adaptations and the organization's priorities need to be more effectively served and adjusted as means of coping with the detrimental effects of climatic changes on animal health.

Key words: Animal health, Climatic changes, Influence of climate

Highlights

- Climate has an impact both directly and indirectly on livestock production.
- Long-term high temperatures can affect different physiological processes.
- Changing climate scenarios cause the emergence of many zoonotic and parasitic diseases.
- Heat stress may affect the effectiveness of both male and female reproduction.

INTRODUCTION

Climate change involves variability in the overall earth's climate or variation in the overall state of the atmosphere over long durations, ranging from decades to millions of years. The effects of climate change are shifts in weather patterns that cause the melting of glaciers at poles and the water level rising thresholds of oceans and seas that raise the possibility of a catastrophe flooding worldwide at an unprecedented magnitude. In all continents and the majority of oceans, significant physical and biological systems changes have already occurred in the expected direction of warmer temperatures (Rosenzweig *et al.*, 2008). It's evident that until we don't generate win-win solutions, climate change makes every other global challenge situation worser. In developing nations, like India, there is rapid population expansion, economic reform, environmental degradation, rapid urbanization, and food insecurity and if these are anticipated to continue, in the ensuing decades, there will be a significant increase in the requirement for animal products globally (Delgado *et al.*, 1999) and these will be among the 21st century's most critical consequence of climate change.

The Global demand for foods of animal origin is growing and it is apparent that the livestock sector needs to expand accordingly. Animals are adversely affected by the detrimental effects of extreme weather. Climate extremes and seasonal fluctuations in herbage quantity and quality will affect the well-being of livestock and hence lead to a decline in production and reproduction. One of the factors that cause climatic change and are a result of the population explosion of humans and livestock are greenhouse gases (GHGs). According to the IPCC (Inter-Governmental Panel on Climate Change), the three major contributors to the rise in GHGs seen during the previous 250 years, are agriculture, land use, and

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fossil fuels. Livestock /Agriculture/Farming leads to an increase in the production of greenhouse gases (GHGs) in the form of methane and nitrous oxide (N_2O) from excess usage of nitrogenous fertilizers. Fossil fuels and energy usage leads to the production of carbon dioxide (CO_2), while land usage and animal manures are the contributors to methane (CH_4) and nitrous oxide (N_2O). Due to the increase in GHGs in the atmosphere, climate change has become a serious worry. The livestock industry is the most susceptible because it is both badly impacted and also a major source of greenhouse gases. According to FAO, livestock contributes to 18% of total global GHG emissions which is more than the share contributed by transport.

Agriculture and animal output, hydrologic balances, input sources, and other elements of the agricultural system are all impacted by climate change and variability. In India, more than half of the population relies directly on climate-sensitive industries like agriculture, forestry, and fisheries. Since climate change significantly affects the nation's water, land and biodiversity resources, it indirectly affects physiological processes like the reproduction and production of the nation. Climate plays a significant role in the system of animal production and has an impact both directly and indirectly. Using the knowledge and research on the influence of climate change and heat stress consequences on animals and birds' growth performance, production and reproduction, this review paper provides a better understanding of how climate change affects animal health and what problems are being faced directly or indirectly by livestock farmers, taking into account what future mitigation plan could be made further for sustainable animal welfare.

Influence of climate change on animal feed fodder and water availability

Depending on the area and duration of the growing season, effects can be seen on fodder quantity and quality (Thornton *et al.*, 2009; Polley *et al.*, 2013). A 2°C increase will be detrimental to pasture and cattle productivity in arid and semiarid environments. This continuous rise in biospheric temperature has altered the quantity and distribution of the average annual precipitation and the primary climate change drivers including carbon dioxide (CO_2) to increase. The ecological climate drivers generate increased heat waves and droughts which vary significantly among different ecological regions and cause a detrimental change in the vegetation of those zones. However, as temperatures rise atmospheric CO_2 is directly stimulated, which in turn encourages plant growth and enhances the water use efficiency by plants and thus lessens the consequences of drying in a warmer climate. Also, humid conditions likely enhance the processes of water use efficiency by plants and soil-water availability and thus it could be beneficial in warmer and humid temperate zones. Climate change affects the length and timing of the forage's availability, the duration of the growing season is also a crucial element in determining the quality and amount of forage. The quality of forage depends on the non-digestible fibers (NDF) and as the forage quality declines these NDF are increased and alters the ruminal microbes' efficiency (Benchaar *et al.*, 2001) and thus methane emissions are increased. On the basis of the modelling approaches and studies on the evaluation of dietary strategies to reduce ruminal methane emission when starchy concentrates are fed, there is a 22% decrease in methane emission (Benchaar *et al.*, 2001). Therefore, it may be necessary to reduce forage consumption and replace it with grain to minimize increased methane emissions by animals (Polley *et al.*, 2013). The livestock industry is affected by water availability as it depends on water for animal drinking, feed crops, and product processes (Thornton *et al.*, 2009). A temperature rise may result in a factor of two to three times increased animal water consumption, which accounts for around 8% of all human water consumption worldwide (Nardone *et al.*, 2010). To solve this problem, it is obligatory to grow crops and rear cattle in livestock systems that use less water in areas where water is scarce (Nardone *et al.*, 2010).

Research on the effects of decreased water availability for land-based livestock systems owing to climate change is lacking (Thornton *et al.*, 2009). In the framework of sustainable livestock production, it is crucial to consider water availability as an appropriate mitigating measure.

Influence of climate change on livestock health and diseases

Health: According to Nardone *et al.* (2010), several climate change-related livestock health issues exist. The variations in climatic temperature, humidity, and radiation cause potential hazards in the health and production of nearly all animals. The long-term influence of environmental modifications on animal health status can be physiologically assessed by different physiological processes including rectal temperature, pulse and respiration rate, metabolic rate, endocrine status, oxidative status (Bernabucci *et al.*, 2002), metabolism of glucose, protein and lipid, liver functionality (reduced cholesterol and albumin), non-esterified fatty acids (NEFA). These variables take into account the degree to which dairy cows adapt to fluctuating environmental conditions. This indicates the disturbance in the homoeothermic status of the animals. The high rectal temperature and respiration rate were observed for the heat-stressed animals. During heat stress-free, radicals are formed and as a result, the scavengers of these free radicals i.e. thiols are increased and since plasma albumins are high extracellular sources of these thiols, there is an increase of plasma albumin concentrations in heat-stressed cattle and buffaloes (Rasooli *et al.*, 2004). Additionally, high lactation after parturition causes the formation of non-esterified fatty acids (NEFA) and creates bigger energy deficits which ultimately affect cow longevity and fitness (King *et al.*, 2006). Factors like imbalances in nutrition and their deficiencies exaggerated effects of heat stress. These factors influence impairment in reproduction and production performance and affect individuals' growth. Thermal stress due to climatic changes causes a reduction in feed intakes. It also reduces the feed conversion ratio (FCR) and utilization of feeds. Thus, there is an overall disturbance in the metabolism of carbohydrates and proteins, mineral and hormone balances, and secretions of blood metabolites. Peripheral thermal receptors transmit nerve impulses to suppress the appetite center in the hypothalamus. Livestock mortality may be impacted by heat stress. According to Nardone *et al.* (2010), temperature increases between 1-5°C may cause substantial mortality in grazing cattle. Thus, suggesting use of sprinklers, shade or other management techniques to cool the animals as a mitigating intervention.

Diseases: The geographical region, kind of land use, disease and animal factors and animal exposure all affect how animal diseases are affected by climate change (Thornton *et al.*, 2009). Under a changing climate scenario, there may be an increased probability of the emergence of many zoonotic and parasitic diseases, including cryptosporidiosis, leishmaniasis, trypanosomiasis, schistosomiasis, onchocerciasis, filariasis, etc. (Patz *et al.*, 2000). In particular, rising temperatures can have a large effect on animal health, either directly or indirectly (Nardone *et al.*, 2010). The temperature rise has immediate consequences by raising the risk of morbidity and mortality. The consequences of climate change on microbial load (pathogens or parasites), the expansion of vector-borne and food-borne illnesses, host resistance, and the scarcity of feed and water are other indirect effects (Tubiello *et al.*, 2008; Thornton *et al.*, 2009; Nardone *et al.*, 2010). According to Karl *et al.* (2009) the growth of viruses and parasites that spend part of their life outside their host could be accelerated by temperature changes which would be detrimental to livestock. Climate change could change how diseases travel, outbreaks of serious illnesses or even the introduction of new diseases that could affect livestock that isn't typically exposed to these kinds of illnesses (Thornton *et al.*, 2009). In some regions, climatic changes may also impact the magnitude and frequency of outbreaks of livestock diseases such as hemorrhagic septicemia and Foot and Mouth disease (FMD) virus. According to studies from India, variations in the seasonality of the Foot and Mouth disease (FMD) in cattle can vary by 52 and 94% depending on the hyper-endemic division of the Andhra and meso-endemic regions of Maharashtra states, respectively. Livestock must be evaluated for disease dynamics and response to preserve their resiliency. Variations in precipitation and global warming affect the amount and spread of pests carried by vectors like flies, ticks and mosquitoes (Thornton *et al.*, 2009).

Additionally, warmer temperatures increase the likelihood of disease transmission between hosts (Thornton *et al.*, 2009). There is a strong likelihood that the advent of new diseases will serve as a mixing bowl for humans and livestock, blending new genetic material and facilitating its transmissibility. Because diseases depend on animal exposure and other circumstances, it is challenging to evaluate the real disease risk (Randolph, 2008).

Climate change affects vectors: Arthropod vectors are affected by climatic variables such as precipitation, temperature, humidity and other environmental conditions that might influence their survival, reproduction, development, behaviour and population dynamics. Since vectors like cattle ticks (*Boophilus microplus*, *Haemaphysalis bispinosa*, and *Hyalomma anatolicum*) are cold-blooded. Climatic parameters consequently affect availability of their habitats, abundance, distribution, and the severity and seasonal pattern of vector activity. Most vectors are significantly increased in numbers during the hot, humid weather condition and animals are worst affected by them during these climatic conditions (Sridhar *et al.* 2020).

Climate change affects pathogens: The number of infectious cycles that may occur for diseases related to the warm or cold seasons within a year may grow or decrease depending on how long the warm season is maintained. Extreme weather conditions such as flooding cause pollution to runoff from the agricultural land to animal farms and this runoff mixed with the water supply in farms can be the source of entero-haemorrhagic *Escherichia coli* and C*ryptosporidium* parasites. This threatens other livestock and because it contaminates water systems, it also puts people in danger of acquiring zoonotic diseases. Along with diseases that limit production, future challenges in controlling parasitic zoonoses such as those connected to climate change require further attention (Polley and Thompson, 2009).

Climate change affects hosts: As a result of increased exposure to ultraviolet B (UVB) radiation, an expected outcome of stratospheric ozone depletion, vertebrate cellular immunity may be reduced. Heat stress changes the body's immune response by degrading cell membranes through oxidative changes, causing degeneration of lymphoid organs (thymus, bursa and spleen) and reducing the volume of lymphoid follicles and thymus lobules. It also alters the Toll-like receptors (TLR) and proin flammatory cytokines in birds (Ahmad *et al.*, 2022). As a result, T helper 1 lymphocytes which are involved in the immunological response to intracellular infections are particularly down in number. Thus, pathogens for animal sickness including viruses (influenza), cowdria and anaplasma, and some bacteria, like Brucella could easily target the immune system of animals and birds and causes mortality in them (Baylis and Githeko, 2006).

Animal production

Animal husbandry is an integrated key asset for resource-poor farmers, accounting for 40% of the world's agricultural GDP. Moreover, 1.3 billion people depend upon livestock husbandry for their livelihood (FAO, 2006). Presently, the dairy sector's output alone accounts for almost 25.6% of the output from the entire agriculture, fishing and forestry sector.

However, productivity from livestock is greatly influenced by environmental factors.

The negative impacts on livestock productivity, health and animal performance are influenced and affected by many essential factors increasing environmental temperatures followed by humidity, wind velocity and radiation. Heat stress is one of the main reasons for lower productivity in the dairy and cattle industries (Nardone *et al*., 2010) and there have been estimated significant monetary losses of nearly 2% of the total milk production in India. In tropical countries, the animals experience a significant amount of heat stress because of humidity and rising average temperature.

Stress may be considered a phenomenon in which an animal cannot cope with its environment and fails to achieve genetic potential (Dobson and Smith, 2000). It is a self-regulatory system. Among various stressors, heat stress significantly limits animal productivity in tropical belts and arid areas.

Dairy cows with high milk production produce more metabolic heat than those with low milk production. Dairy cows with high production levels thus show a high risk of heat stress. Consequently, milk production decreases when metabolic heat output rises together with heat stress (Berman, 2005). The production of buffalo, goat and sheep milk is similarly impacted by heat stress (Finocchiaro *et al*., 2005). Ewes are typically more sensitive to the combined effects of temperature and relative humidity (the temperature humidity index) than individual effects. However, different breed types have different index values that cause heat stress in sheep (Finocchiaro *et al*., 2005). Goat milk composition and production are also impacted by heat stress. When there are water shortages during hot summer seasons, a water loss reduction system is noticed in lactating goats. This system lowers urinary water loss to support milk production (Olsson and Dahlborn, 1989).

High temperatures also lead buffalo to produce less milk since they have an impact on their physiological processes like heart rate, respiration rate, and rectal temperature (Seerapu *et al*., 2015). However, these animals have received less attention due to their capacity to adapt to hotter environments and low productivity (Nardone *et al*., 2010). According to the National Innovation On Climate Resilient Agriculture (NICRA) project, experiments showed that an increase of 4^{O}C temperatures above during summer had an adverse effect on lactation and milk production in crossbred buffaloes and cattle. The reduction in lactation is maximum in crossbred with 0.63%, followed by buffaloes with 0.5%. Furthermore, the experimental evidence shows that a decline in the milk yield varies from 10-30% in 1st lactation and 5-20% in the 2nd and 3rd lactation.

When it comes to the production of meat, beef cattle with heavy weights, thick coats, and darker colours are at high risk of heat stress (Nardone *et al*., 2010). Ruminant body size, carcass weight, and fat thickness may decrease due to global warming (Pitesky *et al*., 2001). In pig production, the same is true, with larger pigs experiencing higher reductions in growth, carcass weight, and feed intake (Nardone *et al*., 2010). The likelihood of piglets surviving may be decreased if sows consume less feed when nursing at temperatures above 25^{O}C, which also lowers the sow's milk production.

Low productivity at temperatures above 30^{O}C could also pose a threat to the poultry business. Heat stress on birds reduces body weight gain, FCR, carcass weight, and the amount of protein and calories in the muscles. Due to lower feed intake and ovulation disruption, heat stress may decrease reproduction efficiency and egg output. Under hotter conditions, egg quality, including egg weight and shell weight and thickness, may also be badly impacted.

Reproduction

Heat stress may affect the effectiveness of both male and female reproduction. It impairs embryo development, pregnancy rate (Nardone *et al*., 2010) and oocyte quality and growth in pigs and cows (Barati *et al*., 2008). In addition, heat stress and increasing energy shortages may impair cow reproduction (King *et al.*, 2006). Heat stress has also been linked to reduced sperm concentration and quality in bulls, pigs, and poultry.

In females, follicular dynamics and estrus expression are modulated and disturbed due to rising environmental temperatures and humidity. This may lead to a high risk of incidence of silent estrus. During hotter summer, there are signs of being sexually inactive and the conception rate reduce, and embryonic mortality cases increases. In cases of cattle, there is a 20-30% reduction in conception rates during summer. Also, there is a reduction in In-Vitro Fertilisation (IVF) procedures' success during the summer season. Heat stress causes hypothalamic dysfunction which causes a reduction in the secretion of gonadotropin-releasing hormone (GnRH) and Luteinizing hormone (LH), as a result the ovulation rates in laying and breeder birds are decreased (Ebeid *et al.*, 2012)

Semen quality and libido get affected by heat stress. The primary target cells for heat stress are Sertoli cells (Ahmad *et al.*, 2022). Existing climatic conditions and the rise of temperatures affects the testes and impose detrimental effects on the seminal parameters (semen volume, sperm concentration and sperm motility, live/ dead sperms). Heat stress prompts an increase in lipid peroxidation due to reactive oxygen free radical formation, as a result it damages testes. As a result, unfavourable circumstances impair spermatogenesis, increase the number of defective sperms and thus lead to the overall reduction of semen quality and sperm morphology of males, ultimately resulting in sub-fertility and infertility (Fouad *et al.*, 2016). From the studies and literature, during heat stress, the acrosome and sperm plasma membrane was found to be damaged during ejaculation.

Future perspective

In order to combat the "impact of climate change on animal health and animal production" it may be necessary to make management, technological, and infrastructure changes. The most effective adaption approach will depend on the environment itself and reducing greenhouse gas emissions (GHGs) in the landscape through the processes of conservation, restoration, and improved land management, are the most promising ways ahead.

It is crucial to adopt good farming practices with strong farm biosecurity and herd health management in the future at the field level which can be achieved by the development and use of advanced techniques to link climatic data to an animal disease surveillance system, the manufacture of modern feeding management techniques along with fodder management techniques that can withstand salt and drought, development of disease-resistant animals by natural selection and breeding, as well as conservation and maintenance of the genetic diversity of local animals and lastly by the development of medicines and vaccines to combat endemic and emerging diseases brought on by climate change.

Conclusion

The nature and extent of climate change/ heat stress impact on feed nutrient absorption, utilization, animal production, reproduction, and health require further research. With more understanding of cattle's metabolic and nutritional processes, management approaches could be modified to improve animal performance. Hence, there is a need to work on the early warning of weather and its changing consequences for livestock owners, which will adapt and save the productive livestock against severe weather conditions.

Conflict of interest: The authors declare that there is no conflict of interest.

Author's contribution: AP: Compile influence of climate change on animal feed, fodder and water availability; GVK, VB: Compile influence in animal production meat, dairy and poultry industry; AK, PD: Compile influence of climate on reproduction; GS: Performed interpretation and conclusion.

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