Chapter 11
Climate Change Impacts on Animal Production

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Abstract Change in climate presents a serious peril to the animal species. Long-term deviations in the global or regional climate patterns have evident repercussions on the environment. Variance in the climatic pattern has a direct and indirect impact on animal production, so for this reason, it is requisite to perceive the appropriate way out not only to maintain the economy but also to reduce the hazardous environmental pollutants that will mitigate the negative impacts of climate change. The science of climate change signifies an increase in temperature of the sea surface, plummeting of air quality, and disruption of the natural systems due to elevation in the emission of greenhouse gases. Climatic variations are the utmost stressors of animal production as it exerts great influence on the forage quality, water accessibility, breeding, milk production, and the overall cattle farming sector. Salination of freshwater river systems due to the upsurge in sea level lessens the hygienic status of the production. Any transition in the temperature threatens the fish resources equally. Besides warming, climatic variability generates acidic conditions in the water bodies, which in turn curtail the global fish supply. Rising temperature hastens the growth of parasites that intensifies the potential for morbidity and death. Augmentation in heat stress reduces the yield in the dairy, beef, and poultry industry and thus induces heavy economic loss. The animal industry in the USA witnessed a loss of between 1.69 and 2.36 billion dollars annually due to heat stress. Animal products are the principal agricultural products of food security across the globe. These products provide 17% of worldwide consumption of energy in kilocalories and 33% of protein consumption globally. Climate change has adverse implications on animal production and productivity which accordingly influence food security.

Keywords Animal industry · Climatic pattern · Food security · Heat stress · Morbidity

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11.1 Introduction

11.1.1 Global and Country Scenario of Climate Change

Climate change has a great influence on animal and plant lives, in every continent of the world. Variation in the degree of warming by every small fraction makes a difference, and any climate change is a serious threat to biological diversity in the succeeding years. Global warming is considered the serious cause of the extinction of species. Loss of species due to climatic changes may range from 0% to 54% (Urban 2015). There is a reduction in the viability of species due to climate changes. According to the Intergovernmental Panel on Climate Change, 2013 rise in global temperature due to an increase in the concentration of greenhouse gases will lead to a decrease in the snow and glaciers, and eventually sea level will also rise. There has been a decline in Arctic sea ice extent by 7.4% per decade, and in both the Southern and Northern Hemisphere, snow cover and glaciers have lessened (Yatoo et al. 2012). According to the United Nations Intergovernmental Panel on Climate Change, there will be an increase of 1.8 to 4.0 °C in temperature, and sea level is expected to rise between 18 and 59 cm in the next 90 years. Rising levels of greenhouse gases, i.e., CO_2, CH_4, and N_2O, in the atmosphere because of the activities of humans is the key factor of climate change. The last 6 years, i.e., from 2014 to 2020, are recorded as the 6 warmest years. There is a surge in the sea level, which further increases by the melting of glaciers. With the increasing carbon dioxide concentration in the atmosphere, the concentration of carbon dioxide also increases in the ocean which decreases the pH level of the water body, and the phenomenon is called ocean acidification. All these climatic changes have an impact on the biotic components present on the Earth's surface. According to IPCC, an average rise of 1.5 °C increases the risk of extinction of about 20–30% species. Various plant and animal species will not be able to adapt themselves to climate change. Climate change has pernicious repercussions on animal life, which can prove disastrous in the upcoming times (Fig. 11.1). According to Food and Agriculture Organization (2020), there is a dire need to intumesce the livestock sector globally owing to the escalating demand for animal-origin foods. Change in climatic conditions poses a serious threat to animal production.

11.1.2 Animal Production Under Climate Variability

Livestock production plays a significant role in the maintenance of the food supply. Change in climate conditions vitiates the production and quality of meat, milk, and eggs as it influences the reproductive behavior, metabolism, health conditions, and immunity of an animal. Conversion of forest land into barren lands due to drought and deforestation decreases the food availability for grazing animals. In developing countries, the livestock sector is growing expeditiously because of the elevated

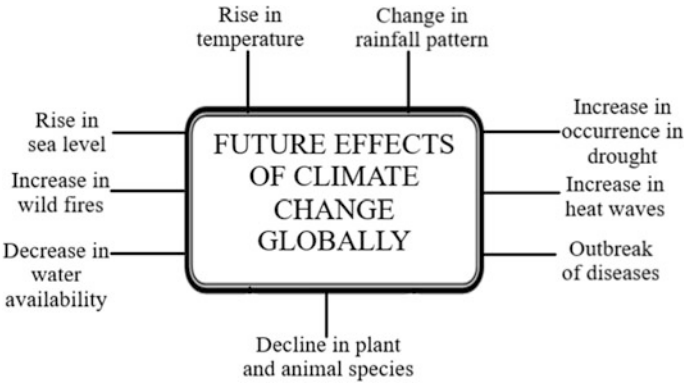

Fig. 11.1 Effect of alterations in climatic conditions

demand for animal products. However, in developed countries, this sector is endeavoring to become more efficient. It is predicted that in the near future, animal production will get adversely affected in view of competition for land, water, food, feed, and other changes looming in the environment. In developing countries, the livestock sector is one of the rapidly thriving agricultural subsectors. Demand for animal products in such countries is soaring at a rate of knots due to an increase in the population growth, movement of people from the rural to urban areas, and increase in per capita income (Delgado 2005). Animal production is the engine of development in various countries across the globe. The majority of the people, especially those dwelling in the developing countries, depend on animal production to boost up the several attributes of their livelihoods (Thornton et al. 2006; Thornton and Gerber 2010). Approximately, 30% of the Earth's ice-free land surface area is occupied by the livestock system (Steinfeld et al. 2006). The livestock sector proffers employment to 1.3 billion people across the globe, and in the developing countries, this sector directly augments the sustenance of 600 million poor farmers (Thornton et al. 2006). Globally, animal products accord 17% to kcal consumption and 33% to the consumption of proteins, although striking differences exist between the poor and rich countries (Rosegrant et al. 2009). Fisheries form the primary source of food for the increasing population across the world. They contribute to 17% of the world's total animal protein. They are important in developing tropical countries that depend on the fish for 70% of their nutrition. Loss of fish as a source of protein will put up an increased pressure on forests and other croplands.

11.1.3 Demand for Animal Products

There is an increased demand for animal productivity due to various reasons as follows.

11.1.3.1 Population Growth

According to the UNDP Annual Report (2008), it has been estimated that in the year 2050, the human population would be in the range of 7.96 to 10.46 billion, and much increase in population will be espied in developing countries. This alacritous surge in the population enunciates an increase in the food supply, which can be accomplished by improving the production of animal products. Animal products will provide nutrition security to the surging population. According to a report generated by Alexandratos and Bruinsma (2002), over the next 40 years, it is expected that the world population will increase by 2.25%, and so the global food production needs to be increased by 70% with doubling the production from developing countries.

11.1.3.2 Growth in per Capita Income

In a country, an increase in per capita income by 1% effectuates growth in the output of animal production by 0.21% (Chand and Raju 2008). Food preferences have been changed owing to the rise in per capita income in developing nations. World GDP revealed an annual increase of 3.85% between 1950 and 2002, which according to Maddison 2003 resulted in an increase in the per capita income growth rate by 2.1%. Across the globe, over the period of 40 years, global real per capita is expected to augment by over 10,000 US dollars per capita.

11.1.3.3 Urbanization

Across the globe, more than four billion people reside in urban areas, and it has been estimated that by the year 2050, approximately seven billion people will live in urban areas. With the rise in income, people begin to migrate from rural to urban areas. According to Yitbarek (2019), migration of people from rural space to urban centers will continue at a rapid pace, and it is expected that 70% of the world's total population will be living in urban areas in the near future. In developing nations it is prophesied that urbanization will continue at a swift rate, which in turn will influence the consumption habits of the people, and evidence support that an increase in the rate of urbanization may lead to an increase in consumption of animal products (Rae 1998; Delgado 2003). According to the studies done by Delgado (2005), urbanization often whets improvements in technologies like cold chains, to allow the trade of perishable animal products more widely and easily. In developing nations, due to rapid urbanization, animal production plays an indispensable role in accomplishing food security (Godber and Wall 2014).

Worldwide, more than 60 billion land animals are utilized for the production of meat, egg, and dairy products. According to Yitbarek (2019), animal production will

depict a significant increase by the year 2050, viz., pig meat by 290%, egg meat by 90%, poultry meat by 700%, milk by 180%, sheep and goat meat by 200%, and buffalo and beef meat by 180%. Approximately, one-third of the global human protein consumption is met by the food obtained from animals and other animal products (Popp et al. 2010). The livestock sector acts as the source of livelihood across the world for around one billion of the poorest people (Hurst et al. 2005). According to the International Fund for Agricultural Development (2007) and Kabubo-Mariara (2009), whenever there is a failure in crop production, at that time animal products come to the rescue of the people by acting as an important food source. Yawson et al. (2017) reported that the average per capita consumption of meat is prognosticated to upsurge from about 34 kg in 2015 to 49 kg in 2050. Demand for animal products is predicted to rise considerably in the near future. According to the data provided by the Agricultural and Processed Food Products Export Development Authority (2018), India accounts for approximately 5.65% of egg production and 3% of the meat production over the world. India has the largest population of milk-producing animals in the world. Various animal species are important as they form the important food source having high nutritive value; some species are important for industrial purposes as they supply hides, skin, and fiber. Even some valuable by-products such as dung for fuel and manure and the horns are also obtained for the production of fancy items. Animal production can be a small-scale cottage industry or large-scale manufacturing industry and so helps in providing part-time or full-time employment to the people. The livestock sector is the source of regular income because of the quotidian production of dairy and poultry products. Fluctuations in climatic conditions have a tremendous effect on the fisheries sector. In the next few years, the air temperature and water temperature will continue to rise, due to which the level of the sea will surge up as the glacial mass will begin to melt. This will lead to acidification of water bodies owing to increased absorption of carbon dioxide emissions (Bindoff et al. 2007). Climate change even affects the distribution of fish in water bodies.

11.1.4 Institutes Working on Animal Production Under Changing Climate

The Indian Council of Agricultural Research (ICAR)-National Institute of Animal Nutrition and Physiology (NIANO), set up on November 24, 1995, at Bangalore, plays a pivotal role in conducting elementary analysis with respect to resource management of animal forage using various physiological-nutritional perspectives to ameliorate the animal productivity. Animal Production Research Institute (APRI) was established in the year 1908. Since then it is working to increase per capita animal productivity and profitability of farmers involved in livestock production.

This institute also aims to optimize the utilization of natural resources such as land and water to safeguard and preserve the environment. The National Research Institute of Animal Production was set up in Poland in 1950 and is authorized to carry out development and research work related to genetics and breeding of animals and all the issues related to animal production. Animal Production Research Institute-Giza situated in Egypt facilitates innovative and effective research on agri-food issues to achieve sustainable development outcomes. The Institute of Animal Sciences and Pastures (IZ) at Sau Paulo State, Brazil, works with an aim to research increasing animal productivity by using new technologies. This institute is committed to face any kind of challenges in the near future. Post Graduate Institute of Animal Sciences, Kattupakkam, situated in Chennai city, Tamil Nadu, was founded in the year 1957. The institute aims to improve livestock productivity by using various scientific techniques in the management of livestock. National Dairy Research Institute-National Innovations on Climate Resilient Agriculture (NDRI-NICRA), in Karnal, Haryana, effectuates pioneering research for animal welfare while sustaining the animal productivity in changing climate conditions. The institute is striving hard for increasing livestock production by fighting against both biotic and abiotic stress conditions. International Livestock Research Institute (ILRI), a global research center based in Kenya, was established in the year 1994. This institute is a member of the Consultative Group on International Agricultural Research (CGIAR). The research work focuses on various livestock challenges such as the vaccine for animal diseases, animal genetics, changing climatic conditions adaptation and mitigation, rapidly emerging infectious diseases, and markets for animal products. The Institute of Animal Husbandry was founded in 1948, in Belgrade (Zemun), and it carries out research activities in the areas of animal breeding, feeding, genetics, and physiology to enhance the productivity of animal products. The National Animal Production Research Institute was set up in Zaria (Nigeria) to develop new appropriate technologies for increasing animal production to assure food security to the growing population.

11.1.4.1 Livestock Census

The 20th livestock census was set in motion during October 2018 in both the rural and urban cities. This census was performed in approximately 6.6 lakh villages and 89,000 urban places across India and included more than 27 crore households and non-households:

- Total livestock population = 535.78 million.
- Total bovine population = 302.79 million.
- Total cattle population = 192.49 million.
- Total cow population = 145.12 million.

11.2 Quantification of Climate Change

11.2.1 Overview of Responses to Temperature, Drought, and Carbon Dioxide

11.2.1.1 Temperature

According to the report generated, the US livestock industry suffered a loss of 1.69 to 2.36 US billion dollars due to warm conditions of the environment. Increased temperature reduces the sperm quality and concentration in bulls, poultry, and pigs (Karaca et al. 2002; Kunavongkrita et al. 2005). Temperature increases between 1 and 5 °C can whip up the mortality rate in grazing cattle (Howden et al. 2008). An increase in the temperature of water alters the physiology and male-female ratio of the fish species. Increasing temperature accelerates the rate of transmission of communicable diseases. According to Tubiello et al. (2008), forage supply gets affected by high temperature as it shifts C3 grasses to C4 grasses. Howden et al. (2008) reported that the temperature rise has shifted *Kobresia* communities, the highly productive alpine, to the *Stipa* communities that are less productive. In the swine industry, Mayorga et al. (2019) reported huge loss linked with heat stress as this decreases feed efficiency, carcass quality, and reproductive performance and increases infection and death rate. Above a certain maximum limit of temperature, intake of feed, production of poultry, milk, reproduction, hormonal activity, and the immunity of an animal get suppressed (Das et al. 2016). Temperature changes decrease the production of dairy and beef products that incur a striking loss in the economy (Nardone et al. 2010).

11.2.1.2 Drought

Besides being affected by an increase in temperature due to changing climate, livestock is susceptible to extreme events such as drought (Kanwal et al. 2020). Drought poses a serious risk to the environment that influences the production of livestock negatively. This prolonged period of scanty rainfall is considered a momentous natural menace and is generally acknowledged as one of the dominant causes of damage to the environment, farming, and ecosystem (Vicente-Serrano et al. 2010). Dzavo et al. (2019) recorded water shortage as the most common cause for the loss of cattle in semiarid and subhumid areas. Starvation was found to trigger cattle loss due to lack of food. Fodder supply becomes sparse due to lack of rainfall as a result of which the price of fodder also rises. In India, approximately 68% of the sown area is at the risk due to drought, and every year it affects about 50 million people. The deficiency of nutrition in the diet of livestock is balanced by the fat resources in the body. Drought leads to fluctuations in the populations of livestock by increasing death rate and decreasing birth rate (Ellis and Swift 1988; Oba and Kotile 2001). According to the United Nations Environment Programme (1989),

India is vulnerable to utmost events due to changing climate. The effect of a dry spell is noticeable even in lactating animals (Kanwal et al. 2020). The scarcity of rainfall has a strong influence on the sheep. Research studies have shown that drought leads to depletion in offspring production and lessens milk production, and infertility issues even cause serious diseases and death of an animal in certain cases. Studies conducted by Salmoral et al. (2020) revealed that the drought that occurred in the UK in the year 2018 imposed a remarkable impact on the growth of grass that affects the availability of feed, prices, the income of farmers, and thus animal welfare. Nanson et al. (2002) reported that more than 50% of the world's surface area is drained by the dryland rivers. The abundance of fish in these dryland rivers is affected by the drought conditions as the water flow stops and most of the river channels dry up (Knighton and Nanson, 2000). The drought conditions threaten the resistance of the fish population which eventually leads to mass mortality in fish (Hopper et al. 2020; Vertessy et al. 2019).

A decrease in abundance and biomass of trout in streams was observed in water systems near Western Cascade Mountains during the drought year (Kaylor et al. 2019). Hakala and Hartman (2004) reported that in response to drought-like conditions, the abundance of adult brook trout decreased by 60%. On similar lines, James et al. (2010) observed a decline in population biomass of adult brown trout following drought. Drought also presents an acute risk to the livestock sector as such condition lowers the production of hay and fodder (Schaub and Finger 2020). Smit et al. (2008) and Webber et al. (2018) had observed considerable diminution in the production of grassland and feed crops. Changing climatic conditions have an indirect effect on the production of poultry as it greatly affects the maize yield production. Availability and the price of poultry feed get affected due to climate change as reported by Liverpool-Tasie et al. (2019).

11.2.1.3 Carbon Dioxide

The livestock population is facing a serious challenge due to changing atmospheric conditions. Over the last previous 200 years, levels of carbon dioxide in the atmosphere have been increased by approximately 30%. Semple (1970) reported that natural ecosystems act as the source of the majority of food supply to ruminants and 95% of the livestock food is supplied by the rangelands (Holochek et al. 1989). Plants produce their food by the process of photosynthesis and so act as the primary producers. During this process, carbon dioxide is transformed into sugars such as glucose; thus CO_2 is vital for the growth of plants. But the increased levels of CO_2 drop the level of nitrogen in the leaves, which is considered as a most crucial nutrient for animals that depend on plant-based food (Ehleringer et al. 2005). Under elevated concentrations of carbon dioxide in the atmosphere, it has been reported that the plants elevate the release of secondary metabolites due to which animals feeding on such plants show a decrease in growth rate and increase in death rate (Percy et al.

2002). Roughly, one-third of the CO_2 that is produced due to human activities dissolves in the oceans which causes ocean acidification. Elevated levels of CO_2 lead to difficulty in breathing in marine fishes, and as a result, it inhibits their food-capturing ability and they become prone to predators. The most drastic effects of the elevated CO_2 concentration are prophesied in oxygen minimum zones in the oceans, where oxygen is found at very low concentrations (Brewer and Peltzer, 2009).

The quality of forages has been reduced due to morphological changes linked with elevated CO_2 (Owensby et al. 1996). Due to the increased concentration of carbon dioxide, more waxes get deposited in the plant leaves, which further lessen the forage quality for livestock (Thomas and Harvey, 1983). In the future, the production of livestock will most likely get distressed by increasing temperature and increasing CO_2 levels as they modify the growing conditions of plants that are used by animals for feeding purposes (Loholter et al. 2012). Preliminary analysis has revealed that in 2020, the average concentration of carbon dioxide in the atmosphere all over the globe was 412.5 ppm, which indicates a surge of 2.6 ppm over the levels of CO_2 recorded in the year 2019. Levels of CO_2 have depicted an increase of 12% since the year 2000.

11.2.2 Overview of Responses to Biotic Stress Such as Parasites

Livestock animals such as sheep and goats act as the vital component of the dairy farming section. Various helminths act as parasites in these animals and thus affect the farming systems across the world. These parasites lessen the productivity of these animals as they feed on the body or the blood of the host. Greer (2008) reported that *Haemonchus contortus* absorbs nutrients from the gastrointestinal tract of the host species, and this way the parasite damages the lining of their GI tract. As a result, the host shows various symptoms such as a decrease in weight, hyperoxia, and death in certain cases. Climate affects the copiousness and survival rate of infective stages of parasites, thus increasing the infection rate of animals (O'Connor et al. 2006). Stress triggered by the direct and indirect effects of bacteria, viruses, insects, and nematodes is referred to as biotic stress. This stress leads to loss due to pathogenicity and death in animals (Jaya et al. 2016). Changing climatic conditions have a great influence on the infectious diseases in animals as they alter their spatial distribution, disturb the seasonal and annual cycles, modify the vulnerability of animals to diseases, and also change the prevalence and severity of diseases in them (Patterson and Guerin, 2013; Bagath et al. 2019 and Filipe et al. 2020). Various transmissible disease-causing organisms responsible for causing various diseases in animals are sensitive to climate change especially rainfall, temperature, and moisture. Pathogens transmitted through food, water, and soil are most probably affected by the change in climatic conditions (McIntyre et al. 2017).

11.3 Impact of Climate Change on Livestock Production Systems

Long-term change in the climate of the Earth due to an increase in the average temperature of the atmosphere is called climate change. Animal production is an indispensable resource for the people living in poorly developed communities. Any change in the environment of an animal affects the efficaciousness of the animal production system as these changes markedly influence the growth, development, and reproduction of all animals (Fig. 11.2).

11.3.1 Quality of Feed

Change in the climatic conditions such as fluctuating temperature, intense heat waves, wind, precipitation, etc. in a certain region presents a great threat to the animals. Animal production gets affected because of the decreased quality of the forage available for feeding. Decrease in the production of herbs and increase in lignification of plant tissues vitiate the forage digestibility by animals. Furthermore, the area under the shrub cover is increasing with the change in climate that tends to diminish both the quality and quantity of feed available to the animals (Hidosa and Guyo 2017). The research findings have suggested that with the increase in temperature and carbon dioxide levels, the primary productivity of greensward and grazing lands decreases. Climate change decreases the productivity and grazing capacity of pasture lands. Moreover, it changes the pasture composition and also increases the offset of biomass yield (Attia-Ismail 2020). Plants growing on pasturelands entirely rely upon rainfall, so any change in the pattern of rainfall will affect the plants. Climatic changes such as reduced rainfall and the increase in drought-like conditions will decrease the primary productivity of rangelands/pastures, which will lead to overgrazing which may result in conflict over the scarce food resources. There is a growing probability of an increase in weather events, and that will have a great impact on the grazing systems in arid and semiarid areas especially at altitudes (Hoffman and Vogel 2008). Similar kinds of effects can be expected in the

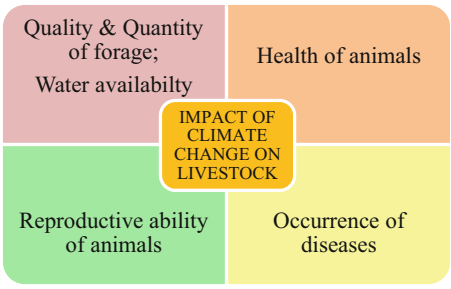

Fig. 11.2 Effect of climate change on animals

non-grazing systems where the animals are confined to climate-controlled buildings. Decreased agricultural production and the increase in the competition for food resources will surge the prices of oilcake and grains, which are considered major feed sources in non-grazing systems. In various regions of the world, wide fluctuations in the pattern of rainfall will have a great impact on forage production (Sejian et al. 2016). Studies done by Giridhar and Samireddypalle (2015) suggested that any climatic change has an adverse impact on productivity, quality of species, production of forage, and also the ecological roles of grasslands.

A dry spell over a long period also poses a great threat to pasture and feed supplies, as this leads to a decrease in the availability of quality forage to the grazing animals. Decreased precipitation and high temperature in the summer season in certain areas cause intense droughts, which may affect crop production and thus pose a significant problem for the animals that rely on grains for their food. So, it is evident that climate change has a negative impact on the animal production system.

11.3.2 Health of Animals

Change in climate may have a direct or indirect influence on animal health. Studies conducted by the National Research Council revealed that at a temperature above 30 °C, feed intake of cattle, sheep, goats, pigs, and chickens lessens by 3–5% with a single-degree rise in temperature. The secretion of stress hormones is also provoked by the temperature change. Reduced intake of feed due to prolonged exposure to high air temperature dwindles the production of catecholamines, growth hormones, and glucocorticoids. Studies done by Itoh et al. (1998a, b), Moore et al. (2005), and Sano et al. (1983, 1985) depicted the change in the metabolism of glucose, lipids, and proteins in animals that were under heat-stressed conditions. A decrease in the intake of feed and availability of forage leads to acute rumen acidosis, which increases the risk of laminitis and milk fat depression in animals. Heat stress impairs the protective value of the colostrum in cows and pigs. Animals require different types of nutrients such as minerals, vitamins, protein, and energy which vary with the region and the type of animal (Thornton et al. 2009). Any disruption in the availability of these nutrients due to heat stress affects both the process of digestion and metabolism in animals (Mader 2003). The deficiency of sodium and potassium in dairy cattle engenders metabolic alkalosis and increases the rate of respiration (Chase 2012). The reproductive capability of hens decreases because of heat stress, which has a significant effect on the production of eggs due to interference in the process of ovulation. Change in climatic conditions in the different regions of the world presents a great threat to the sustainability of animal production systems. Under cold stress conditions, animals overfeed on the protein-rich feed to increase the production of heat; howbeit it causes complications in the gastrointestinal tract. Increased temperature reduces the activity of chymotrypsin, trypsin, and amylase which decreases the nutrient digestibility in poultry (Amundson et al. 2006). An increase in the temperature of water jeopardizes the existence of various fish species.

Le Quesne and Pinnegar (2012) reported that ocean acidification decreases the development of otolith and calcified structures in fishes.

11.3.3 Reproduction in Animals

Unpredictable changes in the rainfall pattern and temperature influence the maturity and gonadal development of fishes during the breeding season. An increase in temperature influences the spawning and maturation of fishes. So the overall productivity of marine and freshwater ecosystems gets decreased due to any change in climatic conditions. The transfer of energy between the animal and its surrounding gets altered due to extreme changes in the climate which has an adverse effect on the reproduction in animals. The time period of the estrous cycle varies due to seasonal fluctuations in the environment of any animal. Heat and cold stress conditions bring down the rate of conception. Moreover, the functioning of the endocrine system also gets disrupted. Singh et al. (2013) reported that heat stress induces an increase in the secretion of adrenocorticotrophin hormone and cortisol that results in obstruction of sexual behavior induced by estradiol. According to Roth et al. (2000), ovarian follicles get damaged and are not able to survive when the temperature of the body surpasses 40 °C. Bilby et al. (2008) reported that high-temperature conditions lead to infertility due to an increase in the production of uterine PGF (2 alpha). In the cold season, the rate of conception was recorded to be 40–60%, whereas it decreases to 10–20% in hotter months (Cavestany et al. 1985). Balic et al. (2012) reported that an increase in temperature alters hormonal balance, sexual behavior, and quality of semen that has a significant impact on the overall reproductive performance of bulls. Seasonal infertility has also been reported in pigs because of the changes in photoperiod and temperature conditions (Auvigne et al. 2010), due to which the swine industry suffers a lot. Change in climate affects the process of reproduction in most of the fishes (Pankhurst and Munday 2011). According to Pankhurst and King (2010), in autumn-spawning fish species, increased temperature impedes the inception of ovulation, thus swaying the process of reproduction.

11.3.4 Diseases in Animals

The risk for the outbreak of diseases increases due to changes in the temperature of water systems; thus this may incur huge economic losses in the aquaculture sector. Prathap et al. (2017) reported that the temperature of the udder in dairy cows increases due to heat stress which is recognized as the fons et origo of mastitis disease. Animal productivity across the globe gets decreased by 25% due to various livestock diseases (Grace et al. 2015). Heat stress can lead to acidic conditions in the rumen of animals that cause lameness in dairy and beef cows (Cook and Nordlund 2009). A biting midge species, *Culicoides imicola*, serves as a vector for

Schmallenberg virus and bluetongue virus in ruminants, and the studies done by Wittmann et al. (2001) revealed that 2 °C rise in air temperature spreads this species tremendously. These animal viruses are proliferating at a faster rate due to change in climatic conditions. According to Caminade et al. (2019), with ascend in humidity to about 85%, reproduction in ticks increases; thus climate change accelerates tick infestation in animals. Clearing away of forests and decreasing the area under vegetation lead to an imbalance in the ecosystem due to an increase in humidity and temperature that augment the spread of vector-borne diseases. Fox et al. (2012) reported that the larvae of *Haemonchus contortus*, a nematode, show an increase in the development with the increase in temperature, thus causing severe anemic conditions in sheep as this worm is responsible for the bloodsucking from the stomach of the sheep. Animal diseases caused by the helminths are known to increase with climate change. According to data generated by WHO (2008), alterations in the climatic condition such as an increase in rainfall, temperature, and humidity can augment the spread of spores of *Bacillus anthracis* that cause anthrax disease in animals. Salinity affects the water that animals use for drinking purpose, thus causing diarrhea in animals. Alam et al. (2017) revealed that changes in the salinity of water bodies cause malfunctioning of the immune system and various diseases related to the skin in animals, thus having a negative impact on the health of animals. White et al. (2003) performed studies on Australian livestock and concluded that outbreak of ticks leads to an 18% decrease in the bodyweight of animals. In sheep, cutaneous myiasis increases with elevation in humid conditions and rainfall during the summer season (Sutherst 1990). Due to a surge in humidity and temperature, the developmental rate of parasites and the disease-causing organisms increases as reported by Mashaly et al. (2004). Thus, it can be concluded that the economy of the nation gets disturbed due to decreases in animal production owing to various diseases with climatic changes. The aquaculture sector gets equally affected by the change in the climate. Altered weather conditions have a negative influence on both the wild and cultured fish population due to an increase in susceptibility to sundry diseases. Elevated water temperature increases the risk of furunculosis and white spot disease in fishes (Lopez et al. 2010). Alteration in climatic conditions has a proclivity for various diseases in animals.

11.4 Impact of Climate Change on Animal Productivity

11.4.1 Milk Production

Heat stress has a great impact on animal productivity. Temperature-humidity index lesser than 68 is apt for the performance of cattle in a temperate climate (Gauly et al. 2013). The temperature-humidity index of approximately 72 is desirable for high milk-producing cows in the subtropical and tropical climate. Panting, sweating, and standing for long periods indicate heat stress in dairy cows (Koirala and Bhandari 2019) due to which the cows eat less forage. Both composition and the quality of

milk decrease due to climatic changes. Various constituents of milk such as percentage of fat, amino acids, lactose, and casein content change due to an increase in the temperature of the body that influences the synthesis of fat in the mammary gland. Prathap et al. (2017) reported the production of milk is affected by the increase in temperature as it causes an imbalance of various hormones such as lactotropin, estrogen, birth hormone, growth hormone, and progesterone hormone. There is a decrease in milk production in the animals when the temperature increases above 35 °C (Wheelock et al. 2010). Valtorta et al. (2002) recorded a 10–14% reduction in the production of milk in dairy cows in response to heatwave conditions. Heat stress has a negative effect on the production of milk and meat. According to Bernabucci (2019), the hot environment negatively affects the quality of animal products besides its quantity. Summer et al. (2018) pointed out that both the organic and inorganic constituents of milk get affected by heat stress.

11.4.2 Wool Production

Unevenness in the rainfall pattern and concentration of carbon dioxide in the atmosphere affects the quantity and quality of forage available to the animals. The amount of water resources are declining, and so it is envisaged that the health of animals will be badly affected by increasing temperature. Alterations in the forage quality will lessen the productivity of clean wool. Reduction in the availability of pasturelands will affect the diameter and strength of wool fiber (Howden et al. 2004).

11.4.3 Poultry Production

Climate change has a similar impact on the poultry industry. Tankson et al. (2001) reported that an increase in temperature will decrease the body and carcass weight of poultry which has a significant impact on the energy and the protein content of the birds. Moreover, the rate of reproduction also declines due to climate changes. Obtrusion of ovulation and decrease in the feed intake affect egg production (Nardone et al. 2010). An increase in temperature also reduces the quality of eggs.

11.4.4 Meat Production

The findings of Nardone et al. (2010) have revealed that beef cattle with thick and dark color coats are at more risk of increased temperature. In ruminants, global warming can lessen down the size of the body, the thickness of fat, and the weight of the carcass. Lucas et al. (2000) observed that the survival rate of the young ones of

pigs decreases when the temperature rises above 25 °C. Moreover, there will be a reduction in feed intake and carcass weight due to changes in climatic conditions.

11.5 Climate Change and Mortality

When the body temperature of an animal increases by 3 to 4 °C above normal, then it may lead to heatstroke, heat cramps, and organ dysfunction in animals. Extreme weather conditions increase the death rate among animals (Vitali et al. 2015). In the year 2003, during the summer season in Europe, thousands of poultry, pigs, and rabbits died due to severe heat waves. According to Howden et al. (2008), a rise in temperature between 1 °C and 5 °C above-average levels leads to high mortality in grazing animals. An increase in the death rate in Mecheri sheep was observed by Purusothaman et al. (2008) in India during the summer months due to thermal stress or heat stress conditions. Various events are on the record that depicts that extreme weather conditions increase the mortality rate in animals. In Ethiopia, a drought occurred in the years 1973–1974, which leads to mortality of 30% goats, 50% sheep, and 90% cattle due to a decrease in the availability of water and feed (Kidus, 2010). Elevated carbon dioxide concentration in water bodies has a detrimental impact on the growth and viability of early life stages of fishes that inhabit the bottom of water bodies as they do not possess a regulatory system for the maintenance of pH (Frommel et al. 2014).

11.6 Modeling and Simulation

Changing climate leads to precariousness in livestock production. Climate models apprise humans about the rising unevenness in the climate patterns. Climate change adaptation has gained huge attention, and it is managed by making high-tech innovations and new policies (Crane et al. 2011). Based on different climate scenarios, various models such as regional circulation models (RCMs), general circulation models (GCMs), economic models, etc. are used to depict the impact of changing climate in the near future (Hein et al. 2009; Olson et al. 2008). General circulation models figure out the potential causes of climate variability and project climatic variations in the coming decades. GCMs are also called global climate models. Sutherst et al. (1999) and Sutherst (2000) described CLIMEX, a bioclimatic modeling software that validates the evolution of models which outline the abundance and distribution of any species based on climate. Regional climate modeling (RCM) is another alternative for global modeling, which simulates smaller portions instead of the entire globe. According to Maure et al. (2018), CORDEX regional climate models predicted that the western part of South Africa will receive less rainfall and heat waves will increase that have a negative impact on various productivity sectors like utilization of wildlife, apiculture, the fisheries sector, and

livestock as the effective temperature for living species may surpass. Harrison et al. (2016) utilized farm systems and economic modeling for predicting the effects of climate change on the production and economy of dairy products. They used historical climate data and regional climate change projections for the years 2040 and 2080 to determine the upcoming climate conditions. Biophysical modeling has been used to predict the impact of climate change on consumption of pasturelands, additional feeding, and milk productivity and also determines the risks to the corporate sectors that are related to varying prices of milk and other input costs (Harrison et al. 2017). Global Livestock Environment Assessment Model (GLEAM) has been developed by the Food and Agriculture Organization (2020) that quantifies the productivity and utilization of natural resources in the animal production sector. This model identifies the impact of environmental changes on the animals, thus contributing toward the evaluation of alteration and reduction scenarios to develop a more sustainable animal sector. This modeling framework can be used both at the regional and global levels.

11.7 Adaptation Options

Changing climate conditions undoubtedly have a negative impact on the health of animals. Under the conditions of heat stress, modifications in the diet composition in such a way that it either increases the feed intake by animals or compensates for the less consumption of feed can help in improving animal productivity. Alteration in the frequency and time of feeding can help in eluding excessive load of heat and thus increases the chances of survival, particularly in poultry (Renaudeau et al. 2012). Efficient cooking systems can be applied to decrease heat stress in animals. A combination of cooling with other treatments can be used to ameliorate the fertility rate in heat-stressed livestock (Bernabucci 2019). Climate change induces heat stress, increases the incidence of disease, and brings a reduction in the availability of the pasturelands, and the livestock tolerates these environmental constraints through morphological, behavioral, hormonal, biochemical, and cellular adaptation (Sejian et al. 2017). Adaptation strategies include modification both in the production and management systems, breeding practices, amendment in policies, advancement in technologies, and modifying the perception of farmers (Rowlinson et al. 2008; USDA 2013). According to IFAD (2010), integrating livestock animals with crop production and forestry and altering the time and site of farm operations acts as an adaptative measure for livestock production. Diverseness of livestock and variety of crops can surge the tolerance for heatwaves and dry spell which intensifies the production of livestock even when the animals are vulnerable to stresses of temperature and rainfall. Besides this, crop and livestock animal diversity are effectual in combating the diseases related to climate change (Batima et al. 2005; Kurukulasuriya and Rosenthal 2003). According to the studies conducted by Renaudeau et al. (2012), Thornton and Herrero (2010), and Havlík et al. (2013), changes in feeding practices such as alteration of diet composition, modification of

feeding time, and inclusion of agro-sylviculture species in the diet of animals can help them to adapt in the changing climate conditions. All these practices lessen the risk of changing climate by reducing feed insecurity during drought conditions, decreasing extreme heat load, and reducing malnutrition and death rate in animals. Transition in breeding practices can surge the tolerance for heat stress and diseases in animals by ameliorating their breeding and growth (Henry et al. 2012). The development of genebanks can enhance the breeding programs which will act as an insurance policy for livestock animals (Thornton et al. 2008).

11.8 Conclusion

Certain steps are required to be taken by the government by focusing on the advancement to lessen the effect of climate change on the livestock and aquaculture sector. Climate change is viewed as a substantial threat to the continuance of life on the earth, and it is one of the serious challenges of this century. The cognizance of change in climate conditions and their impact on animal health is very limited across the world. Climatic events have a serious impact on the biotic components of the ecosystem. It is necessary to understand the alterations in climate, and certain policies should be developed in response to these climatic variations. Varieties of fodder that are resistant to drought-like conditions need to be developed so that good-quality feed remains available to the animals. Shelter for animals should be designed in such a way, keeping in mind the heat stress, comfort, and behavior of animals (Ali et al. 2020). Climate alterations jeopardize the existence of the livestock system. Adaptation to climate changes and framing various policies at the regional, national, and international levels are ultra-critical to defend animal production. One of the most propitious adaptations is to use various crop varieties as feed for the livestock (Downing et al. 2017). Diversification of feed increases the tolerance toward the alterations in climate changes. Advanced technologies can be utilized to link data on climate change with the outbreak of various diseases.

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