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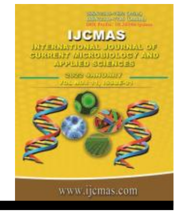

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Effect of Global Climate Change on Livestock Production and Mitigation Strategies to Decelerate Climate Change: A Review

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Livestock production and health are significantly affected by climate change which has direct and indirect impacts on the productivity of the animals. Disturbances in ecosystem occur due to global climate change and that affects animal production system and also allows the prevalence of many animal diseases since they are interrelated to each other. Livestock production has widely contributed to increasing global emission of greenhouse gases through rumen fermentation which makes livestock activity the main promoter of climate change. Global climate change has deleterious effects on animal health, reproduction, mortality, and production. Such impact can be reduced by modifying livestock diets through alterations in forage-concentrate ratios, supplementation of feed additives, shelter management, and prevention of disease outbreaks. This review focuses on the mitigation strategies necessary to be implemented in the animal agriculture sector addressing animal welfare overall.

Introduction

Climate change is a serious threat to the global community and arisen as a consequence of the escalating average surface temperatures and average sea levels. This poses a serious threat to the living community on the earth and concerns have been raised about the negative environmental impacts of increased greenhouse gas emissions and its effect on productivity of animals (Easterling *et al.*, 2007). Livestock is an integral component of economy and livelihood of millions of people worldwide. To meet the growing population demand for animal products, all animals must be maintained under thermal comfort zone that have the least effect on adaptation mechanisms (FAO, 1986). Control over microenvironment is a challenge under conventional livestock farming, but intensive livestock production systems have more control over environmental parameters and less influenced by climate change (Rotter and van de Geijn, 1999). Hancock *et al.*, (2007) defined that the "*Stress is the body's response to exterior stimuli which shifts its state from the resting phase*". Among the environmental factors which affect the animal health, production and reproduction is the temperature. Thermal stress is considered as one of the major stress in livestock and manifested by single stressor such as temperature or a combination of stressors such as temperature, humidity and feed availability. It impairs feed intake, nutrient utilization, animal production, reproduction, health and mortality. Though the livestock reared in temperate climatic countries are more affected by the increase of temperatures than the livestock reared under tropical countries because of its better adaptability to extreme hot climatic adverse conditions (Thornton *et al.,* 2009), the impacts on tropical climatic countries cannot be undermined because of higher demand of animal products in the growing population. The sustainability of livestock production systems and animal welfare are matters of concern due to the impeding impact on the environment comprising of water, soil, air quality, biodiversity, and greenhouse gas emissions. Though many articles address the impact of climate change on animal production but very few have focussed on the mitigation strategies exclusively. Thus, this review is written with the objective of addressing the various mitigation strategies that will help the stakeholders to look into the possibility of adapting those in their livestock production systems.

Impact of global climate change on livestock's

Health

Animals' health status can be identified by an alteration in physiological, behavioural, hormonal, hemato-biochemical and genetic expressions. Nardone *et al.,* (2010) reported grievous impression of climate change on animal health. Prolonged exposure to high temperature increases the frequency of drinking water, increases the lying time and decreases the standing time, defecation and urination causing various hemato-biochemical changes (Nardone *et al.,* 2010). The changes in hemato-biochemical parameters are enlisted in Table1.

Reproduction

Climate change has deleterious effects on reproduction efficiency of livestock (Figure 1). The principal regulators of reproductive behaviour found in the hypothalamus and pituitary gland synthesize releasing hormones such as gonadotrophin releasing hormone (GnRH) and corticotropin releasing factor (CRF) (Aggarwal & Upadhyay, 2012). Environmental stressors such as extreme climate, trigger the hypothalamic-pituitary-adrenal (HPG) axis, which results in activation of the stress response (Aggarwal & Upadhyay, 2012). Release of glucocorticoids mediates the reproductive hormones that affect reproductive traits (Aggarwal & Upadhyay, 2012). The impact of climate change on animal reproduction is enlisted in Table 2.

Mortality

Hot and humid conditions result in heat stress can have detrimental effect on livestock mortality (Figure 1). Howden *et al.,* (2008) reported that increase in temperature between 1°C and 5°C induces high mortality in grazing cattle.

As mitigation measure, sprinklers, shade and different management practices are recommend to cool the animals. Sirohi and Michaelowa (2007) linked livestock mortality to several heat waves between 1994 and 2006 in the United States and northern Europe. The animal's microenvironment temperature humidity index (THI) must be maintained within the limit of 72-76 for tropical dairy cattle. The THI above 78 is lethal for dairy cattle (Habeeb *et al.*, 2018).

Production

Milk production

India is the largest producer of milk in the world with a total production of 187.7 MMT in 2018-19 as per Basic Animal Husbandry Statistics, DAHD&F, the Govt. of India. It is predicted that by 2030, the world requires more to satisfy the global needs. It is estimated that milk production may decline by 3 million tonnes per year due to global warming by2020 (The Economic times, 2017). In tropical countries, it is projected to have a negative impact on smallholder livestock production systems, which play an important role in the livelihoods of rural communities (Tubiello *et al.,* 2008; Thornton *et al.,* 2009). The threats posed by climate change are more severe for population dependent on crop and livestock production for overall household food security (Battisti and Naylor, 2009). High producing dairy cows generate more metabolic heat than low producing dairy cows and are more sensitive to thermal stress. When metabolic heat production increases due to thermal stress, milk production declines (Berman, 2005; Kadzere *et al.,* 2002). Thermal stress affects cow, ewe, goat and buffalo's milk production (Finocchiaro *et al.,* 2005; Nardone *et al.,* 2010). Thermal stress has an impact on goat milk composition and amount (Rojas-Downing *et al.,* 2017). In lactating goats, a water loss reduction mechanism is activated during hot seasons. This mechanism reduces water loss in urine in favour of milk production during seasons with limited water resources (Olsson and Dahlborn, 1989). The pulse, respiration rate and rectal temperature of buffalo are affected when exposed to high temperatures causing decline in milk production (Seerapu *et al.,* 2015). Thus, increased resource use efficiency is an important component for environmental sustainability of the livestock sector (FAO, 2013).

Meat production

One of the main causes of decreased production in the dairy and beef industry is thermal stress (Nardone *et al.,* 2010). The effect of climate change on the productivity of various animal species has been enlisted in Table 3.

Poultry production

Increase in the demand for animal products due to the growth in animal population is expected to cause higher incomes, increased urbanization and change in dietary preferences (Thornton *et al.,* 2007). The rising demand for animal products is required to cause an increase in the productivity of the agricultural system (Van Boeckel *et al.,* 2019). But the impacts of global climate change due to heat stress on poultry industry are worse. The impacts in brief are enlisted below in Table 4.

Mitigation strategies in animal agriculture to decelerate climate change

There is an urgent need to develop and implement 'climate-smart' livestock management options that can achieve the triple win scenario of increasing productivity, adapting and building resilience to climate change, and mitigating climate change through reduction of greenhouse gas emissions (FAO, 2013; Steenwerth *et al.,* 2014; Lipper *et al.,* 2014; Sejian *et al.,* 2021). Extreme climatic and weather conditions affect livestock dependent communities leading to remarkable livestock and economic losses (Patz *et al.,* 2000; Sejian *et al.,* 2021). The mitigation strategies are broadly classified into shelter management, adaptation in animals, feeding management and health/disease management (Figure 2).

Management by design of climate adapted animal shelters

Design of climate adapted animal shelters such as use misters, high speed fans, coolers, sprinklers, air conditioners, shed heights, wet gunny bags, misting and growing vegetation over the roof are the different shelter management techniques to beat the heat stress (Sejian *et al.,* 2021; Aggarwal & Upadhyay, 2012). Thermocol insulated roof, felt jackets and bamboo sheds are necessary to protect the animals from cold stress (Aggarwal & Upadhyay, 2012).

Adaptation in animals for climate resilient livestock production

Different adaptive mechanisms in terms of behavioural, physiological, morphological, molecular, cellular, hemato-biochemical, metabolic, neuro-endocrine and physiological help in the acclimatisation of the animals for production (Sejian *et al.,* 2018). Abdelnour *et al.,* 2019 suggested that increased temperature induces the expression of Heat Shocks Proteins (HSP) causing death and affecting physiochemical and immune response of livestock adversely. High temperature leads to increased inflammatory signalling in the body.

Animals have developed a phenotypic response to a single source of stress that acclimatises animals to such kind of stressor (Fregley, 1996). India is home to 39 indigenous breeds of cow and 13 indigenous breeds of buffaloes. Brazil, Australia and the United States import indigenous Indian milch breeds to develop heat-resistant species (The Economic Times, 2014).

Increasing temperature affects the productivity of the large ruminants. Acclimation results in reduced feed intake, increased water intake and altered physiological functions such as reproductive and productive efficiency and a change in respiration rate (Nardone *et al.,* 2010). The significantly lower respiration rate, rectal temperature and HSP70 gene expression in the Salem Black heat stress group animals as compared to the Osmanabadi and Malabari groups point towards the better resilient capacity of the Salem Black breed as compared to the other two breeds of Goats (Joy *et al.,* 2018). Genetic selection of animals having less sensitivity towards high temperature as well as native breeds is necessary. Recent reports suggest that not all the indigenous breeds are thermo-tolerant. Among them also species difference exists (Joy *et al.,* 2018; Sejian *et al.,* 2021). It becomes mandatory to find out the best suitable breed to recommend to the farmers for the sustainable livestock production. During breed selection one must go for holistic approach instead of considering a single parameter.

Feeding management

Improved forage quality and diet supplementation are the livestock management strategies that have huge potential to address poor livestock system performance and reduce emissions intensity (FAO, 2013). It is known fact that all the animals require macro nutrients (Lipids, proteins and carbohydrates) and micro nutrients (vitamins, minerals and trace elements) in a balanced state (Chaidanya *et al.,* 2015). Whenever nutritional deficiency arises it will have a negative effect on production potential and immune status of the animal (Soren, 2012).

Availability of feed and fodder

Inadequate feed supply is one among the major constraints faced by the livestock owners in recent years. Seasons play a critical role in the availability of feed and fodder (Chaidanya *et al.,* 2015).

Considering the problems prevalent in developing nations, Thornton *et al.,* (2009) suggested that improved management strategies should be based on a combination of factors such as feed and nutrition, genetics and breeding, health and environment, different combinations for different systems of land availability and mixed farming and inclusion of alternative feed stuffs not commonly used as forage and protein sources in farm animal feeding but have potential to reduce the enteric emission of methane into the environment.

Quality of fodder

Quantity and quality of feed is affected mainly due to an increase in atmospheric carbon dioxide levels and temperature (Chapman *et al.,* 2012). The effects of climate change on quantity and quality of feeds are dependent on livestock system, species and location (IFAD, 2010). The effects on feed and forage are:

Increase of carbon dioxide concentration results in herbage growth changes and changes in temperature and carbon dioxide levels affect the composition of pastures (Chapman *et al.,* 2012; Hatfield and Prueger, 2011; Thornton *et al.,* 2008, 2009, 2015).

Quality of feed crops and forage is affected by increased temperatures and dry conditions due to variations in concentrations of water-soluble carbohydrates and nitrogen.

Increasing temperature leads to increase lignin and cell wall components in plants (Polley *et al.*, 2013; Sanz-Saez *et al.*, 2012), which decrease digestibility and degradation rates (IFAD, 2010; Polley *et al.*, 2013), leading to a decline in availability of nutrients for livestock (Thornton *et al.*, 2009).

Floods affect form and structure of roots, change leaf growth rate and decrease total yield (Baruch and Mérida, 1995).

Impacts on forage quantity and quality depend on the region and length of growing season (Polley *et al.*, 2013; Thornton *et al.*, 2009). A 2°C increase in temperature produces negative impacts on pasture and livestock production in arid and semi-arid regions and positive impacts in humid temperate regions. The length of growing season is an important factor for forage quality and quantity because it determines the duration and periods of availability of forage (Rojas-Downing *et al.*, 2017).

Nutritional interventions

Advanced nutritional interventions through nanotechnology are necessary for reducing the negative impacts of climate change. Supplementation of curcumin/nanocurcumin to the diet improves the performance, antioxidant status and jejunal tissue health in broiler chickens reared under normal and cold stress conditions (Rahmani *et al.,* 2018). Dietary nano-Selenium helps growing rabbits to cope with the negative impacts of thermal stress through many physiological processes like enhanced growth performance, liver and kidney functions, and antioxidant status and regulates the inflammatory cytokines responses (Sheiha *et al.,* 2020; Abdel-Wareth *et al.,* 2019). Herrero *et al.,* (2002) used the ruminant model to simulate milk production and methane emissions from enteric fermentation. Farmers in Lushoto, Tanzania identified growing improved forages and supplementing with concentrate feeds to improve their livestock feeding (Lukuyu *et al.,* 2015). Vitamin-E, Vitamin-A, zinc, selenium and selenium enriched yeast help reducing the impact of thermalstress. They improve milk quality and livestock health. Vitamin-E improves the antioxidant status and lowers the incidence of mastitis, metritis, and retention of placenta during thermal stress. Supplementation of mineral mixture and antioxidants has effect on growth, reproductive performance and adaptive capability of Malpura ewes when subjected to thermal stress (Sejian *et al.,* 2014). Bin-Jumah *et al.,* 2020 suggested the potential use of chromiumin combating the adverse effects of heat stress in animals. Study reveals that outcome are higher when improved diets are coupled with improved breeds due to increased efficiency in utilization of the feed. On contrary, the intensities for methane emission are higher for farm households with local cows as compared to those with improved breeds of dairy cows under baseline diets. Improved feeding strategies lowers methane emission intensity of both types of breeds. Feeding low fiber rations and more concentrate during hot weather increase ration energy density and reduce heat increment. Low fiber and high grain diets provide more efficiently used end products. However, low fiber, high grain diets must be balanced. Feeding cactus and *Prosopis juliflora* help livestock overcome extreme drought condition (Sawal *et al.,* 2004). Ingestion of large volumes of water provides comfort to the animals by reducing the temperature of the body (Gonzalez Pereyra *et al.,* 2010). Mohamed E. Abd El-Hack *et al.,* 2020, suggested that several members of the traditional herbal wealth improve the general health state of poultry as thermoregulatory and immune-modulatory agents and counter the thermal stress-associated immunosuppressive effects.

Table.1

Sl. No.	Effect of climate change on hematobiochemical parameters	References
1	RBC, WBC, PCV, Hb, ALT, AST, Cortisol & BUN	Berian *et al.*, 2019
2	Glucose, Protein and Lipid metabolism	Bernabucci *et al.*, 2006
3	Endocrine activity	Johnson, 1980
4	Effect on metabolism	Webster, 1991
5	Oxidative status	Bernabucci *et al.*, 2002
6	Non-esterified fatty acids (NEFA)	Ronchi *et al.*, 1999
7	Saliva production and negative energy balance (NEB)	Rojas-Downing *et al.*, 2017
8	On livability & fitness.	King *et al.*, 2006

Table.2

Sl. No.	Impact of climate change on animal reproduction	References
1	Effect on oocyte growth and quality	Barati *et al.*, 2008
2	Impairment of embryo development and pregnancy rate in female animals	Hansen, 2007; Nardone *et al.*, 2010
3	Lower sperm concentration and quality in male animals	Kunavongkrita *et al.*, 2005
4	Elevated energy deficits and cattle fertility	De Rensis and Scaramuzzi, 2003; King *et al.*, 2006

Table.3

Species	Impacts of climate change in various species	References
Beef cattle	Cattle with high weights, thick coats and darker colours are more vulnerable for meat production.	Nardone *et al.*, 2010
Ruminants	Reduction in body size, carcass weight and fat thickness	Mitloehner *et al.*, 2001
Large pigs	Reduction in feed intake, growth and carcass weight	Nardone *et al.*, 2010.
Piglets	Reduction in survival (Temperature> 25°C)	Lucas *et al.*, 2000
Sow	Reduction of feed intake and milk yield	Lucas *et al.*, 2000

Table.4

Life traits	Impacts of climate change on poultry	References
Production	Low production (Temperature> 30°C)	Esminger *et al.*, 1990
Carcass traits	Heat stress on birds reduces body weight gain, feed intake, carcass weight & muscle calorie content.	Tankson *et al.*, 2001
Reproduction efficiency	Interruption of ovulation due to reduced feed intake	Nardone *et al.*, 2010
Egg quality	Egg weight and shell weight and thickness are negatively affected under hot conditions.	Mashaly *et al.*, 2004

Usage of herbs amongst the poultry farmers help in the improvement of general production and health status of birds reared under the thermal stress through enhancement of immune response and stress tolerance.

Prevention of disease outbreak

Climate change has a huge impact on the livestock diseases which largely depends on the geography, land type, diseases and susceptibility of animals (Thornton *et al.,* 2009). Animal health can be affected directly or indirectly by climate change, especially rising temperatures (Nardone *et al.,* 2010). The direct effects are related to the increase of temperature which increases the potential for morbidity and fatality. The indirect effects are related to the impacts of climate change on microbial communities, spreading of vector-borne diseases, food-borne diseases, host resistance and feed and water scarcity (Nardone *et al.,* 2010; Thornton *et al.,* 2009; Tubiello *et al.,* 2008). Rising temperature accelerates the growth of pathogens and parasites that live part of their life cycle outside of their host and negatively affects livestock (Harvell *et al.,* 2002; Karl *et al.,* 2009; Patz *et al.,* 2000). Climate change induces shifts in disease spreading, outbreaks of severe disease, or introduces new diseases which affect livestock that are not usually exposed to these types of diseases (Thornton *et al.,* 2009). Alterations in precipitation patterns and temperature affect the quantity and spread of vector-borne pests such as flies, ticks and mosquitoes (Thornton *et al.,* 2009). Disease transmission between hosts is more likely to happen in warmer conditions (Thornton *et al.,* 2009). White *et al.,* (2003) simulated the impacts of climate change on Australian livestock, finding that livestock lost about 18% of their weight due to increased tick infestations. Wittmann *et al.,* (2001) used a model to simulate the response of *Culicoides imicola* in Iberia, which is the main vector of the bluetongue virus that affects mainly sheep and sometimes cattle, goat, and deer. They reported that the vector would spread extensively with a 2°C increase in global mean temperature. These predicted spreads can be prevented by disease surveillance and technologies such as DNA fingerprinting, genome sequencing, tests for understanding resistance, antiviral medications, cross-breeding and more (Perry and Sones, 2009; Thornton, 2010). Emergence of new diseases acts as a mixing vessel between human and livestock facilitating combination of new genetic material and their transmissibility. This makes it difficult to estimate actual disease risk because of the dependence of diseases on animal exposure and interactions factors (Randolph, 2008).

Future Prospective

Sustainable livestock production needs more research, extension and demonstration. Though livestock is an important contributor to food security, it is important to maintain an efficient conversion of natural resources to human food to sustain a neutral food balance (FAO, 2011). This can be accomplished through efficient production of protein from livestock (FAO, 2013). Climate change influences this conversion by affecting the nutritional content of livestock products (Harvell *et al.,* 2002; Karl *et al.,* 2009; Patz *et al.,* 2000) and reducing livestock production (Hatfield *et al.,* 2008). The best approach by the livestock sector to contribute to food security is by addressing the necessity of food balance (FAO, 2013; FAO, 2011). This review suggests the need to promote improved feeding strategies, introduction of more efficient breeds of livestock in order to achieve improved food security, increased productivity, reduced poverty, and reduced methane emissions intensities. Policies and initiatives targeting to increase income, improve food security and animal welfare can be beneficial to farm households that own local cows if such households are encouraged to adopt improved livestock diets while those targeting to reduce poverty should aim to promote adoption of improved cow breeds. Promotion of improved livestock feeding strategies needs to be accompanied by programmes that facilitate the adoption of improved breeds. More information is needed concerning the nature and extent of how thermal stress affects feed nutrient utilization and feed intake, animal production, reproduction and health. With greater knowledge related to nutritional and metabolism processes of livestock, management practices could be adapted to increase animal performance. Agricultural by-products should be considered as potential feedstuffs for animal production by increasing the livestock efficiency and reducing the energy losses due to methane synthesis.

Improved livestock management options can increase productivity and income, improve food security, reduce greenhouse gas emission intensity and address animal welfare issues. Providing an improved breed and improved quality of livestock diets while complying to the amount of feed to the livestock has greater impacts on methane emissions reduction.

There are gains in income, food security, poverty reduction, and methane emission, when households acquire improved breeds. Thus, strengthening of livestock, their welfare and climate policies are the need of the hour.

Author Contributions

TP and JM conceptualized the idea and SSM prepared the preliminary draft of the manuscript. JM, MKB and MK contributed significantly for the final manuscript. All authors reviewed, revised and approved the final version of the manuscript.

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Conflicts of Interest

The authors declare that they have no competing interests.

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