

# Climate Change Impacts on Livestock Production and Possible Adaptation and Mitigation Strategies in Developing Countries: A Review

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## Abstract

Livestock production is an essential component of food security in developing countries across the globe. Apart from providing food, livestock production offers smallholder farmers a wide range of benefits, such as income, employment, and fuel. However, as human populations in developing countries increase, the demand for livestock production will also increase. At the same time, the world is experiencing rapid global warming, and climate change is expected to affect livestock production in multiple ways. This review paper aims to present insights on some livestock production areas, particularly beef and dairy, that are affected by climate change and will discuss possible adaptation and mitigation strategies for developing countries to adapt to and mitigate the impacts.

**Keywords:** climate change, livestock production, adaptation, mitigation

## 1. Introduction

In developing countries across the globe, livestock production is a significant component of livelihood, food and income security that directly supports smallholder farmers. In addition, livestock production offers multiple other benefits such as clothing, employment, and fuel. However, as the human population in developing countries increase, it will cause a shift in the demand for livestock production (Bekele, 2017). At the same time, the world is experiencing rapid global warming, which is responsible for causing variations in local climatic conditions. These changing climatic variations will affect the agriculture sector, particularly livestock production (Nardone et al., 2010). The risks associated with livestock production systems due to global warming can be characterized by levels of vulnerability, as influenced by animal performance and environmental parameters (Hahn, 1995).

The risks associated with livestock production are minimum when a low level of vulnerability is created by a combination of performance and environmental factors. However, the animal's susceptibility increases when their performance level rises, and when combined with a changing environment, the animal becomes more vulnerable (Nardone et al., 2010). Combining an adverse environment with high performance pushes vulnerability and consequent risks to even higher levels. Inherited genetic characteristics or management scenarios that limit their ability to adapt to environmental factors also place the animal at risk. Any environment other than near-optimal at very high-performance levels may increase animal vulnerability and risk (Thornton, 2010).

Climate change impacts livestock production through increasing temperature, drought, flooding, and variation in rainfall trends (FAO, 2015). Its potential impact on livestock production also includes changes in water availability, animal growth, milk production and quality of feed crop and forage, diseases and animal reproduction, and biodiversity (Abdurehman & Ameha, 2018). Climate change also poses significant risks to the sustainability of livestock and its production. Consequently, adaptation and mitigation strategies play vital roles in combating the climatic impacts on livestock (Sejian et al., 2015). In addition, there is a growing need to understand how climate change impacts livestock production (Aydinalp & Cresser, 2008), particularly in developing countries. It has been claimed that the most significant impacts of climate change on livestock production systems would be experienced in developing countries where communities are already living as

highly vulnerable (Thornton, 2010). This paper, therefore, reviews and examines the prospects of climate change on livestock production, particularly beef and dairy, and highlights adaptation and mitigation strategies for developing countries to adapt to and mitigate its impacts.

## 2. Increased Temperature and Effects on Livestock Production

The productivity and performance of livestock will be affected by climate change. The significant implications of climate change on livestock production include reducing livestock growth, milk production, livestock genetic resources, water availability, disease, reproduction, quality of feed, and forage resources (Henry et al., 2012). In addition, climate change will cause a reduction in body size, lower meat weight, and lessening of the fat thickness (Inbaraj et al., 2016). Thus, livestock production systems are vulnerable to climate change. There is no doubt that the vulnerability of livestock production will continue to increase, with negative consequences for rural communities, as losing livestock assets will result in poverty and jeopardize their livelihoods.

One of the significant effects of climate change on cattle productivity and performance results from heat stress. Heat stress lowers the organic and inorganic milk components produced by dairy cows, causing substantial financial burdens on the farmers (Summer et al., 2019). It affects meat production and animal health and reduces reproduction efficiency (Abdurehman & Ameha, 2018). Increased temperature due to climate change causes the environment in which the animal survives to become hot, which does not favor the optimum production levels. The hot climate impacts agricultural cattle and causes direct and indirect heat stress on livestock output. The direct impacts generally consist of effects caused by increased frequency and intensity of heatwaves due to rising temperatures. The immediate effect of heat stress causes alteration responsible for producing metabolic disturbances and oxidative stress in cattle's while indirect results of heat stress cause alteration in the availability of quality feedstuff and water for survival (Lacetera, 2019).

The reproduction efficiency of livestock is also highly vulnerable to climate change. Heat stress due to increased temperature harms livestock reproduction performance (Hansen, 2007). For example, hot conditions disrupt several reproductive processes, resulting in pronounced depression of conception rate (Wolfenson & Roth, 2019). In cows for example, increasing temperature and high heat radiation load can negatively impact the reproductive rhythm via the hypothalamic-hypophyseal-ovarian axis (Sheikh et al., 2017). The main element for the hypothalamus regulating ovarian activity is the GnRH and the gonadotropins, *i.e.*, FSH and L H., from the anterior pituitary gland, which tends to be also affected (Bekele, 2017). Heat stress also results in reduced length and intensity of the estrous period, adversely affecting their conception due to reduced estradiol secretion (Naqvi & Sejian, 2011; Naqvi et al., 2012). In addition, during pregnancy, heat stress can slow down embryonic development, resulting in reduced fetal growth and subsequently small calf size (Samir, 2017). In some instances, heat stress in dairy livestock has caused early embryonic deaths (Samal, 2013).

In bulls, the concentration of semen, the number of spermatozoa, and motile cells per ejaculation were found to have decreased in summer, often resulting from increased abnormal temperatures (Sheikh et al., 2017). It was reported that their testis temperature reached around 2-6 degrees Celsius, lower than the average body temperature. Therefore, a correct ambient temperature range (5-15 degrees Celsius) is needed to produce better fertile and healthy spermatozoa (Zhou et al., 2020). If the testicular temperature increases above average, it can lead to infertility problems in bullocks (Cardozo et al., 2006). Similarly, changes in seasonal environmental parameters can reduce the reproductive performance of males (Balic et al., 2012). Heat stress has also been noted to cause a significant reduction in conception and fertility rate per insemination of males, consequently reducing male fitness (Bhakat et al., 2014).

## 3. Impact of Climate Change on Mortality Rate in Livestock

Climate change reshapes the environment in which livestock graze. Due to increased temperature, heat-related mortality can increase in livestock (Thornton et al., 2008). For example, heat stroke, hyperthermia, heat syncope, heat cramps, and organ failure in animals are caused by increasing temperature (Lacetera, 2019). Changing precipitation and drought prone areas can also lead to increased loss of domestic livestock (IPCC, 2007). In addition, livestock diseases are likely to increase due to drought (IPCC, 2007).

Similarly, precipitation variations associated with drought can cause the untimely death of animals (Rojas-Downing et al., 2017). In areas where livestock is expansively grown, for instance, on rangelands, the impact of drought on rangeland productivity significantly impacts cattle population dynamics (Kanwal et al., 2020). Furthermore, changes in environmental variables such as warmth and humidity can induce heat stress, responsible for causing an increase in livestock mortality and contributing to lower birth rates (Howden et al., 2008). Additionally, such environmental variations can harm livestock by generating metabolic abnormalities,

causing oxidative stress, and immunological suppression, all of which can lead to livestock illnesses and death (Lacetera, 2019).

#### **4. Impact of Diseases and Parasites on Livestock Due to Climate Change**

Livestock diseases and parasites are also crucial factors affecting livestock production and productivity. The negative consequences of climate change on livestock health and welfare result from changes in air temperature, precipitation, frequency, and magnitude of extreme weather events that affect livestock (Lacetera, 2019). Climate change may induce infectious diseases, and specifically, a higher temperature may increase the rate of development of pathogens (Baylis & Githeko, 2006). On the other hand, changes in wind speed can alter the transmission of specific infections and vectors that can be deadly for livestock (Wittmann & Baylis, 2000). Additionally, pathogens and parasites that are sensitive to moist or dry environments may be affected by changing precipitation and flooding, increasing infestation and livestock mortality rates (Harvell et al., 2002). For example, McDermott et al. (2001), who researched African animal trypanosomiasis in cattle, concluded that climate change, particularly changes in precipitation, is linked with vector-borne diseases. The World Health Organization reported that climate change could indirectly influence the abundance and distribution of parasites or vectors that can affect the disease pattern and, in turn, affect livestock production (WHO, 1996). High temperature and change in rainfall patterns accelerate the spread of existing vector-borne diseases and macroparasites in livestock and introduce new diseases (FAO, 2007). For example, rising temperatures have previously resulted in new livestock diseases that affect animal health and welfare (Digambar, 2011).

#### **5. Impact of Climate Change on Livestock Feed Resources**

Climate change is expected to amplify the vulnerability of livestock feed, mainly related to quality and quantity. Climatic characteristics such as temperature and rainfall patterns greatly influence pasture quality and quantity, thus affecting the food resource availability cycle of the livestock throughout the year (Fereja, 2016). A study by Tubiello et al. (2007) revealed that high temperatures caused by climate change were responsible for increasing lignification in plant tissues, decreasing their digestibility factor. Similarly, warming and drying climatic trends were found to negatively affect rangeland productivity by lowering forages' quantity and nutritional quality (Nardone et al., 2010). In addition, Hidoso and Guyo (2017) concluded that climate change reduces rangelands' productivity and grazing capacity, causing higher levels of nutritional stress in livestock, thus affecting the farm's overall productivity. Consequently, adverse effects on the food resource of animals, resulting from changing climates, will further increase the gap between feed and fodder availability and the requirement of feed and fodder to livestock (Samir, 2017).

#### **6. Impact of Climate Change on Water Availability for Livestock Production**

Water supplies from rivers and rainfall are threatened by climate change. The impacts are related to reduced water availability for livestock production and increased drinking water demand in tropical and subtropical climates. The results are a loss in water availability and forage water content and quality due to extended exposure to high ambient temperatures or drought (Abdurehman & Ameha, 2018). Fibrous fodder can raise fermentative heat and the thermoregulatory demand for water in animals (Nardone et al., 2010). Animals exposed to hot environments drink 2-3 times more water than animals in thermo-neutral situations, putting them at risk, and changes in water pH can impact animal's metabolism, fertility, and digestion (Abdurehman & Ameha, 2018).

#### **7. Impact of Climate Change on Livestock Genetic Resource**

Livestock genetic resource is defined as genetic diversity found among or within animal species or breeds having economic or other socio-cultural values (Kantanen et al., 2015). Livestock's genetic resources play a crucial role in food security, nutrition, and livelihood and are critical components of sustainability, resilience, and adaptability in livestock production. However, livestock breeds and species are decreasing, affecting genetic biodiversity. For example, Thornton et al. (2009) highlighted that local breeds of livestock could become extinct due to climate change. In addition, climate change will enhance the growth and multiplication of new pests and diseases that will affect the livestock, particularly the local and indigenous breeds that are already highly susceptible. Likewise, Thomas et al. (2004) reported that climate change could eliminate 15 to 37% of all species globally, causing food insecurity, malnutrition, and livelihood problems among those who heavily depend on animals for survival. More specifically, a change in temperature by 2 to 3 degrees Celsius may result in 20 to 30% of biodiversity loss of livestock (IPCC, 2014). Additionally, climate-induced extreme weather events such as droughts, flooding, and hurricanes will also affect many animal species and breeds. Such events can also completely wipe out all the breed population concentration locally, such as within a limited geographical area, affecting the local breeding program (FAO, 2015).

## 8. Livestock Adaptation Strategies to Climate Change

Smallholder livestock farmers in the past have adapted to various ecological and climatic change impacts by building on their knowledge of the environment for rearing livestock (Myeki & Bahta, 2021). However, increasing population, urbanization, environmental degradation, and increased consumption of animals for foods have rendered the effectiveness of the coping mechanisms (Sidahmed et al., 2008). Moreover, the speed at which environmental-related changes occur due to global warming will likely outpace our adaptation strategies. Nevertheless, adaptation is one of the strategies that could reduce the impacts of climate change and can also be used to address the emerging risks associated with global warming. Several experts have identified the following adaptation techniques to increase adaptation in livestock production (Rischkowsky et al., 2008; Barrett et al., 2008; Kitalyi et al., 2008; Henry et al., 2012; Tiruneh & Tegene, 2018; Bernabucci, 2019). Farmers can modify and enhance their current livestock production practices through the following methods.

(I) *Intensification and diversification of pasture management*: The intensification and diversification of the pasture system will also increase grazing pressure and intensity (Cardoso et al., 2020). One way to achieve this is by planting drought-tolerant shrubs such as *Atriplex* and *Acacia* species because they are essential for rehabilitating rangeland. The shrubs can also be utilized as an ingredient in feed blocks (Estell et al., 2012). Similarly, tree forages have shown potential to increase the growth performance of livestock, and so have pasture grass cultivars that are drought tolerant (Cyriac et al., 2018). Farmers can also develop low-cost feed blocks made from agro-industrial by-products such as tomato pulp, molasses, crude olive cake, sesame cake, citrus pulp, sunflower cake, and mulberry leaves (Yang et al., 2021).

(II) *Livestock management system*: This is possible by providing farmers with efficient and cheap adaptation practices over expensive adaptation technologies, such as providing shade and water to the livestock to reduce heat stress from high temperatures. Livestock caretakers can also reduce or split the livestock herds into small manageable groups, allowing for smaller group movements of livestock into different areas for grazing purposes, ensuring the long-term productivity of rangeland. Flock management intervention can be adopted by farmers as well, as this will allow finding other suitable ways to feed the livestock, for example, during heavy droughts. Mobilizing livestock from drought-prone areas to areas that receive reasonable precipitation can act as a vital pastoralist adaptation to counter the challenges of spatial and temporal variations in rainfall. The introduction of localized and straightforward water irrigation for better management of water resources for livestock can also be implemented, for example, through the development of rainwater harvesting infrastructure and storage facilities (Sonder et al., 2003; Hilali et al., 2010).

(III) *Nutritional management in livestock*: When the temperature increases, feed intake by the livestock tend to decrease. Farmers can therefore graze their livestock during the night. Night grazing will partially fulfil the nutritional requirement, but the livestock will still exercise for normal physiological functions. To counter reduced feed intake, farmers can level up the concentration of vitamins and minerals to enhance the livestock's health. In addition, a highly digestible high energy ratio is an effective feed formulation for livestock in summer because it aids in controlling their body temperature. In the form of livestock exercise on the hottest days, the walking time could also be reduced, because livestock walking, often in herds, allows the generation of heat loads. The farmers could take the feed to the livestock preventing long walking distances of the livestock to the piled feed locations.

(IV) *Breeding and acclimatization strategies*: To counter heat stress problems due to climate change, it is crucial to breed indigenous or local livestock breeds. These breeds naturally have been found to have high heat tolerance capabilities and are adapted to the harsh realities of the environment. Farmers should improve local species through cross-breeding with heat and disease tolerant genotypes to allow better acclimatization of breeds. Farmers should also identify and strengthen local breeds that have adapted to local climatic stressors through reproduction technologies such as embryo transfer technology to increase reproduction efficiency in livestock. To increase livestock fertility during periods of heat stress, farmers should be trained to use supplementary hormones such as progesterone and improve heat synchronization in females through GnRH to improve fertility effectiveness. Livestock genetic resource management should be integrated into climate change adaptation planning at the production level to preserve local and exotic genetics.

(V) *Capacity building for livestock farmers* is integral to improving livestock keepers' capacity to understand and overcome climate change risk to livestock production by increasing their awareness about global climate change and its impacts. Furthermore, livestock producers should be trained with

agroecological approaches, methodologies, technologies, and practices to produce and conserve pasture, reducing malnutrition and mortality issues. In addition, it is vital to increase farmers' capacity to improve the management, productivity, revenue, and long-term stability of their livestock systems. This could be achieved by continuously enhancing their inventiveness, strategies, procedures, practices, and performance.

(VI) *Early warning system* is a data-gathering system that helps monitor and provide timely information on climate-related stress. The installation and implementation of early warning systems will give a strengthened rational approach to risk management and improve the prospect of sustainable livestock production through better disaster preparedness plans. In turn, this will increase the resilience capacity of livestock producers and maximize their ability to cope with external shocks and reduce their vulnerability to adversities resulting from extreme drought.

## 9. Livestock Mitigation Strategies to Climate Change

The selection and implementation of mitigation measures for livestock production, as a response to the impacts of climate change, should consider measures that are easy to implement and cost-effective to increase the capacity of local actors, particularly the smallholder livestock farmers. Livestock production systems, which are susceptible to climate change, contribute to global warming. This is because livestock themselves produce greenhouse gases, such as Methane and Nitrous oxide, majorly associated with livestock waste (Dourmad et al., 2008). The mitigation of greenhouse gas emissions and livestock waste can be achieved through possible mitigation options.

(I) *Feeding management*: There are various feed additives that reduce methane emissions. These include ionophores, antibiotics, halogenated compounds, and propionate precursors (Indira & Srividya, 2012). Feeding livestock with a higher concentration of concentrate in livestock diet can reduce methane emissions as a percentage of total energy intake (Singhal & Mohini, 2002; Sejian, 2013). Livestock farmers can also feed additives such as monensin to reduce methane emission by 21% (de Souza et al., 2021). In addition, livestock farmers can provide feed with higher efficiency and digestibility rate because it helps reduce greenhouse gas emissions (IFAD, 2009).

(II) *Better waste management* involves improving livestock waste management and disposal through various mechanisms such as covered storage to reduce GHG emissions. Disposal improvement of farmyard manure can be used for biogas production to reduce methane emissions from waste (Sejian, 2013). Manure mitigation should use low-tech measures such as covering and cooling manure lagoons during storage and alternative approaches such as appropriate manure application, handling, and storage for manure dispersion (Weiske et al., 2006). Another alternative for waste management is to change the overall bedding materials for the animals, which could affect the pH and soluble carbon and nitrogen levels in the manure, thus reducing the emission of methane (Sejian, 2013).

(III) *Grazing management*: Proper pasture management through rotational grazing would be cost-effective to mitigate GHG emissions from feed crop production (IFAD, 2009). Expressly, rotational grazing should be incorporated, as multiple smaller fields referred to as paddocks, for livestock rotation. Farmers can adjust stocking numbers and grazing duration by subdividing pastures, rotating animals, and managing their nitrogen excreta dispersion and pasture re-growth. This will also allow for the uniform distribution of urine around the paddock, potentially lowering nitrous oxide emissions (Eckard et al., 2010). Sward damage and soil compaction during wet weather can also be reduced by keeping the animals off-paddock. Excreta deposition during wet weather will also minimize nitrous oxide emissions and nitrogen leaching into the atmosphere (Luo et al., 2010).

(IV) *Lowering livestock stock and consumption*: Lowering the production and consumption of milk and meat in areas of a high standard of living can be a short-term response to GHG emissions (IFAD, 2009). A decrease in demand would mean a decrease in livestock to produce the necessary consumer items. Both industry and the government, on the other hand, want to keep output at a maximum to fulfil food demands; therefore, it is vital to use cost-effective techniques to make each livestock more productive.

(V) *Fertilizer management*: In increasing livestock feed crop production, synthesized fertilizers are used, contributing to nitrous oxide in the atmosphere. Farmers can increase nitrogen use efficiency or use organic fertilizers to overcome this problem. In addition, using enhanced fertilizers and combining the plantation of legumes with pasture may decrease GHG emissions in production (Dickie et al., 2014). In addition, farmers can design nutrient management plans to help make the best use of available fertilizers and land resources for pasture production while minimizing any adverse impact on the environment (Daniels et al., 2004).

## 10. Conclusion

Climate change is putting livestock output in jeopardy. This is because the natural pastures on which the bulk of livestock owners rely for feeding their animals are degrading—in terms of quality and quantity of fodder. Furthermore, the accessible water sources are unreliable, as they can dry up owing to high temperatures and a lack of rainfall. Excessive heat, a lack of water, nutrition, and unknown diseases have all contributed to the loss of livestock. As a result, livestock farmers need effective adaptation and mitigation strategies to reduce the impact of climate change on livestock production. These strategies will contribute to the long-term viability of livestock farming. In addition, they will build capacity for individual farmers to increase their resilience towards climate change and its impact on livestock production. Supporting livestock producers to fight the effects of climate change requires investment and planning from private and government authorities to develop climate change adaptation and mitigation policies that are efficient, affordable, and practical to smallholder livestock farmers.

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