Journal of Agriculture, Environmental Resource and Management
ISSN2245-1800(paper) ISSN 2245-2943(online)
5(5)650-1220; Jan.2023; pp728-734

www.saerem.com

# Climate Change Impact and Mitigation Strategies on Livestock Production in Nigeria: A Review

**Ikoro, S. G. and Kalio, G.A***

Department of Animal Science and Fisheries, Faculty of Agriculture, Ignatius Ajuru University of Education, Ndele Campus, P.M.B. 5046, Port Harcourt, Nigeria.* **ag.kalio@yahoo.com**

**ABSTRACT**

*Global demand for livestock products is expected to double by 2050, mainly due to improvement in the worldwide standard of living. Meanwhile, climate change is a threat to livestock production because of its impact on quality of feed crop and forage production, water availability, animal and milk production, livestock diseases prevalence, animal reproduction, and loss in biodiversity. This study reviews the global impacts of climate change on livestock production, the contribution of livestock production to climate change, and specific climate change and mitigation strategies in the livestock sector. The livestock sector contributes 14.5% of the global greenhouse gas (GHG) emissions, driving climate change further. Hot environment impairs production (growth, meat and milk yield and quality, egg yield, weight, and meat quality) and reproductive performance, metabolic and health status, and immune responses. Regarding livestock systems, it will be strategic to optimize productivity of crops and forage (mainly improving water and soil management), and to improve the ability of animals to cope with environmental stress by management and selection. To guide the evolution of livestock production systems under the increase of temperature and extreme events, better climate smart mitigation strategies is needed regarding biophysical and social vulnerability, and this must be integrated in agriculture and livestock components.*

**Key words:** Climate change, Greenhouse gas, Livestock production, Performance, Mitigating strategies.

## INTRODUCTION

Climate change is the complex and multidisciplinary change in global or regional climate patterns, which pose a significant risk for human and natural systems (IPCC 2007). The most intricate multifactorial global challenge, which jeopardizes human and natural system, is seemingly threatened livestock production and productive performance. The considerable spatial heterogeneity of climate change impacts has been widely studied; global average temperature increases marks considerable differences in temperature rise between land and sea and between high latitudes and low; precipitation increases are very likely in high latitudes, while decreases are likely in most of the tropics and subtropical land regions (IPCC 2007). Increasing frequencies of heat stress, drought and flooding events are projected for the rest of this century, and these are expected to have many adverse effects over and above the impacts due to changes in mean variables alone (IPCC 2013). It is projected that as the planet warms, climate and weather variability (surface temperature) will be increased by about 3.7°C (likely range of 2.6°C–4.8°C) (IPCC, 2013), and with changes to the frequency, intensity and duration extreme weather events will be evident (Howden et al., 2008). Such changes will directly and indirectly impact the production and health parameters of livestock and include a complex set of interacting biophysical parameters that will influence growth performance such as, meat and milk yield and quality, egg yield, weight, and quality, reproductive performance, metabolic and health status, and carcass traits (Henry et al., 2012). The world population is projected to grow by 33% from 7.2 to 9.6 billion by 2050 (UNDESA, 2017). Hence, it is estimated that up to 70% of increases in agricultural productivity will be required to meet the future demand for standard of living and food security (O'Mara, 2012). As an example, the global demand of milk and meat production predicted for 2050 to meet the global demand is estimated to increase by 1,077 and 455 million tonnes, respectively, equating to almost double that of 2006 production (Alexandratos and Bruinsma, 2012). Global climate change represents a major challenge to achieve the predicted productivity growth required to meet these future demands. Livestock play a major role in the agricultural sector in developing nations, and the livestock sector contributes 40% to the agricultural GDP. Global demand for foods of animal origin is growing and it is apparent that the livestock sector will need to expand (FAO, 2009). Livestock are adversely affected by the detrimental effects of extreme weather. Climatic extremes and seasonal fluctuations in herbage quantity and quality will affect the well-being of livestock, and will lead to declines in production and reproduction efficiency (Sejian, 2013).

Nigeria has one of the highest population density (people per sq. km of land area) in the world, with a unique geographical location in the African continent. It is dominated by floodplains, with significant expanses of low elevation, making it vulnerable to rising sea levels and flooding (World Population Review, 2019). Currently, new generations in Nigeria are suffering from mounting adverse effects comparatively from the previous generations. Nigeria is considered to be one of the developing countries with high energy demand and spotted low carbon print, as well as low carbon emission (World Bank, 2014). However, it is identified as one of the nations in the world vulnerable to global climate change (UNDESA, 2017).

Nigeria's livestock and agriculture resources are considered an important part of food security for the nation, and with one of the world's largest growing economies, the impacts of climate change are worsened. The livestock sector in Nigeria consists millions of cattle, buffalo, sheep, goats, chickens, and ducks. This sector has contributed to the animal protein production predominantly, milk, meat, and eggs.

Nigeria's climate structure mirrors the African and global climate system in terms of its complex weather pattern and subdivision into sub-climatic zones: humid rainforest, savanna, derived savanna and arid/sahelian zones characterized by different rainfall and temperature regimes. Changing climate is considered as a threat to livestock production because of the impact on the quality of concentrate and roughage feeds, availability of clean drinking water, meat and milk production, disease prevalence and incidence, reproduction, and biodiversity (Henry et al., 2012).

Climate change with its attendant shifts in natural climatic systems is therefore, of considerable economic importance to agricultural systems (crop and animal farming) in Nigeria. Drought, elevated temperatures, high humidity, variable and unpredictable rainfall pattern and other adverse weather conditions including extreme events (heat waves, hurricanes, flood, erosion, rain and sand storms, etc) are important limiting factors to livestock production in Nigeria and climate change will intensify their negative effects (BNRCC, 2008). This is in addition to the impacts of shifts in the epidemiology and dynamics of animal diseases, pests and vectors (Thomson et al., 2004). Globally, it is estimated that livestock disease reduces productivity by 25% with the heaviest burden falling on the poor (Grace et al., 2015).

The present review highlights the myriad of probable climate change impacts on livestock production in Nigeria. This is aimed at sensitizing policy makers at all levels and stakeholders in the livestock sub sector to the need to integrate climate change adaptation and mitigation measures into livestock production systems in Nigeria.

## POTENTIAL IMPACT OF CLIMATE CHANGE ON LIVESTOCK

The potential risk 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). When combined performance level and environmental influences create a low level of vulnerability, there is little risk. As performance levels (e.g., rate of gain, milk production per day, eggs/day) increase, the vulnerability of the animal increases and, when coupled with an adverse environment, the animal is at greater risk. Combining an adverse environment with high performance pushes the level of vulnerability and consequent risk to even higher levels. Inherent genetic characteristics or management scenarios that limit the animal's ability to adapt to or cope with environmental factors also puts the animal at risk. At very high performance levels, any environment other than near-optimal may increase animal vulnerability and risk.

The potential impacts of climatic change on overall performance of domestic livestock can be determined using defined relationships between climatic conditions and voluntary feed intake, climatological data, and General circulation model (GCM) output. Because ingestion of feed is directly related to heat production, any change in voluntary feed intake and/or energy density of the diet will change the amount of heat produced by the animal (Mader et al. 1999). Ambient temperature has the greatest influence on voluntary feed intake. However, individual animals exposed to the same ambient temperature will not exhibit the same reduction in voluntary feed intake. Body weight, body condition, and level of production will affect the magnitude of voluntary feed intake and ambient temperature at which changes in voluntary feed intake begin to be observed. Intake of digestible nutrients is most often the limiting factor in animal production. Animals generally prioritize available nutrients to support maintenance needs first, followed by growth or milk production, and then reproduction.

## INDIRECT IMPACTS OF CLIMATE CHANGE ON LIVESTOCK PRODUCTION

Sustainable livestock production relies heavily on the availability of livestock feed crops. Profitable ruminant animal production in intensive holdings, on pasture and range lands depend on the availability of quality grains and forages in enough quantities (Hatfield et al., 2008). Key quality parameters include fiber content, crude protein, mineral, non-structural carbohydrates and secondary toxic compounds and these will vary under different climate scenarios (AIACC, 2006; FAO, 2009). Yield responses under increased warming will vary, with species of grain crops according to each crops cardinal temperature requirement (Lobell and Field, 2007; Hatfield et al., 2008). Crops that have optimal range at cooler temperatures will exhibit significant decreases in yield as temperature increases above the upper range. The response to rising temperatures by grain crops may however, be more complicated because biological response to temperature is non-linear and linear changes in temperature do not produce linear responses (Hatfield et al., 2008). Again, under the global climate change scenarios, many climate change factors interact to affect a biological entity. For instance, higher temperatures are often associated with decreases or lack of rainfall in many sub climates and this complication can exacerbate the effects of rising temperature (Hatfield et al., 2008).

Grain crops vary in their response to carbon dioxide ($CO_2$) enrichment of the atmosphere according to whether they are carbon (III) (C3) or carbon (IV) (C4) crops. Simulation studies (Ziska et al., 2005; Morgan et al., 2007) have shown that for most C3 crops (wheat, rice, legumes) there was significant increase in average yield under $CO_2$ enrichment. The increase in yield was expressed as increased number of tillers-branches, panicles-pods, and number of seeds with minimal effect on seed size. Carbon (iv) crops (maize, millet, sorghum) increased their yield insignificantly under the same $CO_2$ volume (Anderson et al., 2001). The beneficial effect of increased $CO_2$ volume on yield is however, negated under elevated temperature (heat stress) at the reproductive phase of crops so that yield is compromised in the face of increased biomass accumulation (Jifon and Wolfe, 2005). Unrestricted root growth, optimum soil fertility and excellent control of weeds, pests, and diseases are also necessary to maximize the benefits of increased $CO_2$ concentration (Newman et al., 2006). The yield of forage and pasture crops (C3 and C4 photosynthetic pathways) under different climate change scenarios is determine by the interaction between the major drivers of global climate change namely precipitation (rainfall), carbon dioxide and temperature. Field results, however, indicate that rainfall change was the explanatory variable in yield changes of both pasture and range-land forage crops followed by $CO_2$ and temperature change (Thomson et al., 2004). Reduced precipitation will lead to reduced yield since the overall ecology of pasture and range lands is determined by the spatial and temporal distribution of rainfall and consequences of precipitation patterns for soil water availability (Tietjen et al., 2010). Rising $CO_2$ in the atmosphere, warming (increase in temperature) and altered precipitation pattern all impact strongly on soil water content and plant water relations (Morgan et al., 2007). Through simulation of photosynthesis and water use efficiency, rising $CO_2$ was shown to enhance plant productivity on most range lands (Hatfield et al., 2008; Tietjen et al., 2010). The sum of effects of atmospheric and climate change on forage quality is varied. Based on expected precipitation changes and known environmental effects on forage protein, carbohydrate, and fiber content, both positive and negative changes in forage quality are possible (Hatfield et al., 2008). Elevated $CO_2$ volume can increase non-structural carbohydrate content of forage crops thereby enhancing forage quality. Nitrogen and crude protein content of forages are, however, reduced under $CO_2$ enrichment of the atmosphere, especially, under poor soil nitrogen content (Milchunas et al., 2005). This counters the positive effect of enhanced $CO_2$ volume on plant production. The rising $CO_2$ level, therefore, produces poorer forages which are poorly digested and utilized by ruminant animals. Experimental warming causes reduction in tissue nitrogen concentration. Thus, under increased environmental temperature and reduced rainfall (the likely situation in the field), forage quality is expected to decline and will produce negative effects on animal growth, reproduction and health (Milchunas et al., 2005). This could render livestock production unsustainable unless ruminant diets are supplemented with nitrogen sources. Ruminants require forages with at least 17% crude protein for maintenance, 10 – 14% for growth, and 15% for lactation. Optimal rumen fermentation also requires a balance between ruminal available protein and energy. The rate at which digester passes through the rumen decreases with increasing fiber content of forages (Hatfield et al., 2008). Tropical forages are essentially of the poor quality carbon (IV) type and increased warming will lead to greater deterioration of tropical forages (Hatfield et al., 2008).

## DIRECT IMPACT OF CLIMATE CHANGE ON LIVESTOCK PRODUCTION

Ambient temperature, humidity, wind speed, thermal radiation and precipitation are the major climate parameters which constitute the thermal environment and which are the potential environmental stressors of livestock with regards to health, growth, yield and reproduction (Nienaber and Hahn, 2007; Svotwa et al., 2007). There are levels of vulnerability associated with livestock production to the potential risks due to global warming (Hatfield, 2009). These levels are associated with levels of productivity, as well as other environmental factors and genetic attributes of individual animals, species and breeds (Hatfield, 2009). As performance levels increase, the vulnerability of the animal increases and, when coupled with other adverse environmental factors (e.g. poor nutrition), the animal is at greater risk (Hatfield, 2009). Inherent genetic characteristics or management scenarios that limit the animal's ability to adapt to or cope with thermal stress also put the animal at risk. At high performance levels, any environment other than near optimum may put the animal at greater risk (Mader et al., 2009).

## MITIGATING THE IMPACT OF CLIMATE CHANGE ON LIVESTOCK PRODUCTION

The following strategies could be adopted to reduce greenhouse gas (GHG) emissions to mitigate climate change impact on livestock production as follows:

i. There should be a decrease in emission of GHGs especially methane ($CH_4$) by producing animals with low $CH_4$ production abilities. This is because, methane production from individual animals may vary over time, even when animals are fed a constant amount of the same quality feed each day (Afshar et al., 2015).

ii. There should be a reduction in livestock numbers, since methane emissions from livestock are the predominant source of GHG emissions. This can be achieved through effective normal market processes by understanding the demand for specific animals. For example, in New Zealand sheep farming has become less profitable over the past ten years and farmers have reduced sheep numbers and used the land for alternative enterprises, such as forestry a possibility (Ulyatt and Lassey, 2001).

iii. There should be an improvement of animal productivity. As part of the improvement in production efficiency, a greater portion of the energy in the animal feed should be directed towards the creation of useful products (milk, meat, power) so that methane emissions per unit product are reduced. This increase in production efficiency will also lead to a reduction in the size of the herd required to produce a given level of methane emissions (FAO, 2010)

iv. Allowing older animals to stay for a longer life span (longevity). For instance, the longer a cow stay in a herd, the lower number of replacements required, and thus the lower the total farm methane emissions (O'mara, 2004).

v. Improving pasture quality is often cited as a means of reducing GHG emissions, especially in less developed regions, because of improvements in animal productivity, as well as a reduction in the proportion of energy lost as $CH_4$ due to a reduction in dietary fiber swards (O'mara et al., 2008).

vi. The use of methanogen vaccine to reduce methane emissions. The vaccine stimulates antibodies, which are active against the methanogens. This vaccine is found to significantly reduce *in vitro* methane emission (Reyenga and Howden, 1999).

## CONCLUSION

Climate change is a major threat to the sustainability of livestock systems globally. Climate change may manifest itself as rapid changes in climate in the short term (a couple of years) or subtler changes over decades. Generally, climate change is associated with an increasing global temperature which can affect livestock directly or indirectly. Consequently, mitigation of the detrimental effects of extreme climates has played a major role in combating the climatic impact on livestock.

## REFERENCES

Afshar, M., Naser M., S. S., & Nader, J. (2015). Factors Affecting Mitigation of Methane Emission from Ruminants: Management Strategies. *Ecologia Balkanica*, 7(1), 171-190.

Alexandratos, N., & Bruinsma, J. (2012). World agriculture towards 2030/2050: the 2012 revision. ESA Working Paper No. 12–03. Available via http://www.fao.org/3/a-ap106e.pdf

AIACC (2006). Climate change and variability in the mixed crop/livestock production systems of the Argentinean Brazilian and Uruguayan pampas. Final Report: In: Gimenez, A. (Ed). The International START Secretariat, 2000 Florida Avenue, NW Washington, DC 20009 USA.

Anderson, I.J., Maherali, H., Johnson, H.B., Polley, H.W., & Jackson, R.B. (2001). Gas exchange and photosynthetic acclimation over sub ambient to elevated $CO_2$ in a C3 – C4 grassland. *Global change Biology*, 7, 693 – 707.

BNRCC. (2008). Climate change in Nigeria: Vulnerability, Impacts and Adaptation. Available online at htt://www.nigeriaclimatecange.org/ccinfo.php.

FAO (2009). The state of food and agriculture, Rome, Italy http://www.fao.org/docrep/012/i0680e/i0680e.pdf

FAO. (2010). Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment. Food and Agriculture Organization of the United Nations, Rome, Italy.

Grace, D., Bett, B., Lindahl, J., & Robinson, T. (2015). Climate and livestock disease: assessing the vulnerability of agricultural systems to livestock pests under climate change scenarios. CCAFS Working Paper no. 116. Available via, https://ccafs.cgiar.org/publications/climate-and-livestock-disease-assessing- vulnerability-agricultural-systems-livestock-0#.XYi8vEYzbIU

Hahn, G. L. (1995). Environmental management for improved livestock performance, health and well-being. *Japanese Journal of Livestock Management*, 30, 117-127.

Hatfield, J. L. (2009). The effects of Climate Change on Livestock Production. Production Management Feature Articles. Available on line at The pigsite.com

Hatfield, J., Boote, K., Fay, P., Hahn, L., Izaurralde, C., Kimball, B.A., Mader, T., Morgan, J., Ort, D., Polley, W., Thomson, A., & Wolfe, D. (2008). Agriculture. In: The effects of climate change on agriculture, land resources, water resources, and biodiversity. A Report by the U.S. Climate change science programme and the subcommittee on Global Change Research, Washington, DC., USA, 362pp.

Henry, B., Charmley, E., Eckard, R., Gaughan, J.B., & Hegarty, R. (2012). Livestock production in a changing climate: adaptation and mitigation research in Australia. *Crop Pasture Science*, 63,191–202.

Howden, S.M., Crimp, S.J., & Stokes, C.J. (2008). Climate change and Australian livestock systems: impacts, research and policy issues. *Australian Journal of Experimental Agriculture*, 48,780–788.

IPCC (Intergovernmental Panel on Climate Change) (2007). Climate change: synthesis report. In: Pachauri, R.K., & Reisinger A, (Eds). *Contribution of working groups I, II and III to the fourth assessment report of the intergovernmental panel on climate change*. Geneva, Switzerland.

IPCC (Intergovernmental Panel on Climate Change) (2013). Summary for policymakers. In: Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., & Midgley P.M. (Eds). *Climate change: the physical science basis.* Cambridge, UK: Cambridge University Press.

Jifon, J., & Wolfe, D. W. (2005). High temperature-induced sink limitation alters growth and photosynthetic acclimation response to elevated $CO_2$ in beans. *Journal of the American Society for Horticultural Science*, 130, 515-520.

Lobell, D. B., & Field, C. B. (2007). Global scale climate-crop yield relationship and the impact of recent warming. *Environmental Research Letters*, 2, 1-7.

Mader, T.L., Frank, K.L., Arrington Jr. J.A., Hahn, G.L., & Nienaber, J.A. (2009). Potential climate effects on warm season livestock production in the Greats plains. *Climate change*, 97, 529 – 541.

Milchunas, D. G., Mosier, A. R., Morgan, J. A., LeCain, D. R., King, J. Y., & Nelson, J. A. (2005). Elevated $CO_2$ and defoliation effects on a shortgrass steppe: forage quality versus quantity for ruminants. *Agriculture, Ecosystems and Environment*, 111, 166-184.

Morgan, J. A., Milchunas, D. G., LeCain, D. R., West, M. S., & Mosier, A. (2007). Carbon dioxide enrichment alters plant community structure and accelerates shrub growth in the shortgrass steppe. *Proceedings of the National Academy of Sciences*, 104, 14724-14729.

Newman, Y. C., Sollenberger, L. E., Boote, K. J., Allen, Jr. L. H., & Litell, R. C. (2001). Carbon dioxide and temperature effects on forage dry matter production. *Crop Science*, 41, 399-406.

Nienaber, J.A., & Hahn, G.L. (2007). Livestock production system management response to thermal challenge. *International Journal of Biometeorology*, 52, 149 – 157.

O'Mara, F.P. (2012). The role of grasslands in food security and climate change. *Annals of Botany*, 1263–1270.

O'mara, F. (2004). Greenhouse gas production from dairying: Reducing methane production. *Advances in Dairy Technology*, 16, 283-295.

O'mara, F.P., Beauchemin, K., Kreuzer, M., & Mcallister, T.A. (2008). Reduction of greenhouse gas emissions of ruminants through nutritional strategies. - In: Rowlinson P., M. Steele, & Nevzaoui, A. (Eds.): *Livestock and Global*

*Climate Change*. England. Cambridge University Press, pp. 40- 43.

Reyenga, P.J., & Howden, S.M. (1999). Meeting the Kyoto Target: Implications for the Australian Livestock Industries. - In: Reyenga P.J., & Howden, S.M. (Eds.). *Workshop proceedings*. Canberra. Bureau of Rural Sciences, Canberra, pp. 100-116.

Sejian, V. (2013). Climate change: Impact on production and reproduction, Adaptation mechanisms and mitigation strategies in small ruminants: A review. *The Indian Journal of Small Ruminants*, 19(1),1-21.

Svotwa, E., Makarau, A., & Hamudikuwanda, H. (2007). Heat tolerance of Mashona, Brahman and Simmental cattle breeds under warm humid summer conditions of natural region II area of Zimbabwe. *Election Journal of Environmental, Agricultural and Food Chemistry*, 6(4), 1934 – 1944.

Tietjen, R., Jeltsch, F., Zehe, E., Classen, N., Groengroeft, A., Schiffers, K., & Oldeland, J. (2010). Effects of climate change on the coupled dynamics of water and vegetation in drylands. *Eco hydrology*, 3, 226 – 237

Thomson, M.C., Connor, S.J., Ward, N., & Molyneux, D. (2004). Impact of climate variability on infections disease in West Africa. *Eco Health*, 1, 138 – 150.

Ulyatt, M.J., & Lassey, K.R. (2001). Methane emissions from pastoral systems: the situation in New Zealand. - *Arch. Latinoam. Prod. Animal*., 9(1), 118-126.

UNDESA. New York: United Nations Department of Economic & Social Affairs (2017). World population prospects, the 2017 Revision, Volume I: comprehensive tables. 2017. Available via http://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html

World Bank. World Bank data on CO2 emissions (metric tons per capita) (2014). https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?most_recent_value_desc=false

World Population Review. (2019). http://worldpopulationreview.com/countries/bangladesh-population/

Ziska, L. H., Reeves, J. B., & Blank, B. (2005). The impact of recent increases in atmospheric $CO_2$ on biomass production and vegetative retention of Cheat grass (*Bromus tectorum*): implications for fire disturbances. *Global Change Biology*, 11, 1325-1332.