Broadening Horizons

N°26 February 2016

Feedipedia

www.feedipedia.org

Impact of climate change on livestock productivity

Veerasamy Sejian [1,2],Gaughan, J. B.[2], Raghavendra Bhatta[1] and Naqvi, S. M. K.[3]

[1] ICAR-National Institute of Animal Nutrition and Physiology, Adugodi, Bangalore-560030, India

[2] School of Agriculture and Food Sciences, The University of Queensland, Gatton 4343 QLD, Australia

[3]ICAR-Central Sheep and Wool Research Institute, Avikanagar, Rajasthan-304501, India

drsejian@gmail.com

Introduction

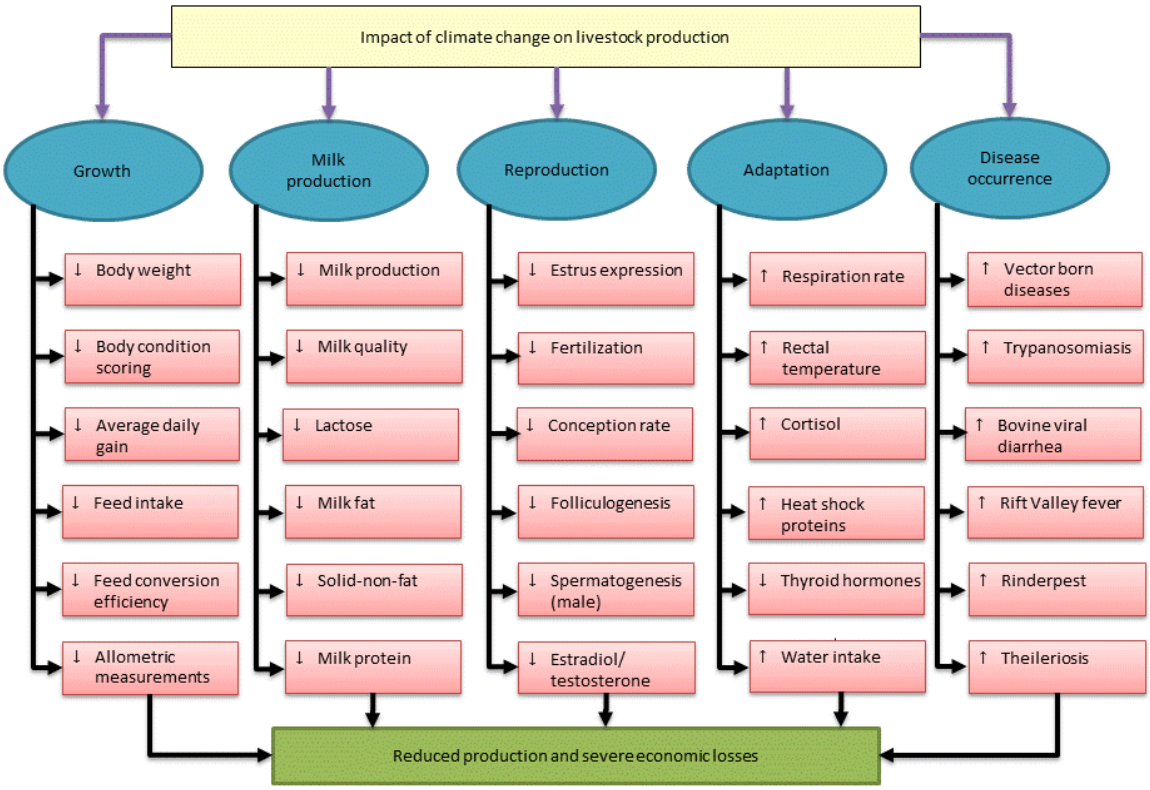
Livestock play a major role in the agricultural sector in developing nations, and the livestock sector contributes 40% to the agricultural GDP. Global demand for foods of animal origin is growing and it is apparent that the livestock sector will need to expand (FAO, 2009). Livestock are adversely affected 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).

Climate change is a major threat to the sustainability of livestock systems globally. Consequently, adaptation to, and mitigation of the detrimental effects of extreme climates has played a major role in combating the climatic impact on livestock (Sejian et al., 2015a). There is little doubt that climate change will have an impact on livestock performance in many regions and as per most predictive models the impact will be detrimental. Climate change may manifest itself as rapid changes in climate in the short term (a couple of years) or more subtle changes over decades. Generally climate change is associated with an increasing global temperature. Various climate model projections suggest that by the year 2100, mean global temperature may be 1.1–6.4 °C warmer than in 2010. The difficulty facing livestock is weather extremes, e.g. intense heat waves, floods and droughts. In addition to production losses, extreme events also result in livestock death (Gaughan and Cawsell-Smith, 2015). Animals can adapt to hot climates, however the response mechanisms that are helpful for survival may be detrimental to performance. In this article we make an attempt to project the adverse impact of climate change on livestock production.

Direct effects of climate change on livestock

The most significant direct impact of climate change on livestock production comes from the heat stress. Heat stress results in a significant financial burden to livestock producers through decrease in milk component and milk production, meat production, reproductive efficiency and animal health. Thus, an increase in air temperature, such as that predicted by various climate change models, could directly affect animal performance.

Fig.1 describes the various impacts of climate change on livestock production.



Indirect effects of climate change on livestock

Most of the production losses are incurred via indirect impacts of climate change largely through reductions or non-availability of feed and water resources. Climate change has the potential to impact the quantity and reliability of forage production, quality of forage, water demand for cultivation of forage crops, as well as large-scale rangeland vegetation patterns. In the coming decades, crops and forage plants will continue to be subjected to warmer temperatures, elevated carbon dioxide, as well as wildly fluctuating water availability due to changing precipitation patterns. Climate change can adversely affect productivity, species composition, and quality, with potential impacts not only on forage production but also on other ecological roles of grasslands (Giridhar and Samireddypalle, 2015). Due to the wide fluctuations in distribution of rainfall in growing season in several regions of the world, the forage production will be greatly impacted. With the likely emerging scenarios that are already evident from impact of the climate change effects, the livestock production systems are likely to face more of negative than the positive impact. Also climate change influences the water demand, availability and quality. Changes in temperature and weather may affect the quality, quantity and distribution of rainfall, snowmelt, river flow and groundwater. Climate change can result in a higher intensity precipitation that leads to greater peak run-offs and less groundwater recharge. Longer dry periods may reduce groundwater recharge, reduce river flow and ultimately affect water availability, agriculture and drinking water supply. The deprivation of water affects animal physiological homeostasis leading to loss of body weight, low reproductive rates and a decreased resistance to diseases (Naqvi et al., 2015). More research is needed into water resources' vulnerability to climate change in order to support the development of adaptive strategies for agriculture. In addition, emerging diseases including vector borne diseases that may arise as a result of climate change will result in severe economic losses.

Concept of multiple stressor impacts on livestock

Animals reared in tropical environments are generally subjected to more than one stressor at a time. Multiple stressors greatly affect animal production, reproduction and immune status. Most studies which have investigated the effects of environmental stress on livestock have generally studied one stressor at a time because comprehensive, balanced multifactorial experiments are technically difficult to manage, analyze, and interpret (Sejian et al., 2010). When the animals were subjected to heat and nutritional stress as separate stressors the impact of these was not as detrimental to growth and reproductive performance, as was the case when the animals were subjected to both stressors at the same time (Sejian et al., 2011). The combined stressors had major effects on growth and reproductive parameters. In addition, the adaptive mechanisms exhibited by these animals were different for individual stressors compared to combined (heat and nutritional) stressors (Sejian et al., 2010). Hence, when two stressors occur simultaneously, the impact on the biological functions necessary for adaption and maintenance during the stressful period may be severe (Sejian et al., 2013). Hence any research pertaining to climate change effects on livestock must address multiple stressors.

Table 1: Effect of thermal, nutritional, combined and multiple stresses on growth and reproductive performance of Malpura ewes

Parameters	Control	Thermal stress	Nutritional stress	Combined stresses	Multiple stresses
Body weight (kg)	39.67 ± 2.65[a]	35.19 ± 1.46[ab]	30.39 ± 1.50[b]	30.04 ± 1.35[b]	29.55 ± 1.22[b]
Average daily gain (g)	169.14 ± 0.01[a]	47.71 ± 0.07[b]	-122.57 ± 0.06[c]	-138.00 ± 0.07[c]	-88.00 ± 0.05
Ewes in heat (%)	85.71[a]	57.14 [b]	85.71 [a]	71.43[ab]	41.7[c]
Estrus duration (hour)	38.00 ± 2.41[a]	23.40 ± 3.34[b]	28.50 ± 5.68[bc]	18.75 ± 3.75[bd]	14.4 ± 2.78[c]
Estrus cycle length (day)	18.17 ± 0.31[b]	20.28 ± 0.74[ab]	18.00 ± 0.27[b]	22.25 ± 1.67[a]	23.56 ± 1.45[a]
Conception rate (%)	71.43[a]	42.86[ab]	57.14[ab]	28.57[b]	-
Lambing rate (%)	71.43[a]	42.86[ab]	57.14[ab]	28.57[b]	-
Estradiol (pg/mL)	14.58 ± 0.96[a]	12.06 ± 0.73[b]	12.80 ± 0.91[b]	10.04 ± 0.74[c]	7.19 ± 0.23[d]
Progesterone (ng/mL)	3.31 ± 0.56[c]	4.48 ± 0.32[ab]	3.98 ± 0.26[bc]	5.19 ± 0.27[a]	7.34 ± 0.28[d]

Combined stresses- thermal and nutritional stress; Multiple stresses- thermal, nutritional and walking stress. Means and SEM within a row having different superscripts differ significantly ($P<0.05$). (Source: Sejian et al., 2010; Sejian et al., 2011 ; Sejian et al., 2013).

Impact of climate change on livestock production

Animals exposed to heat stress reduce feed intake and increase water intake, and there are changes in the endocrine status which in turn increase the maintenance requirements leading to reduced performance (Gaughan and Cawsell-Smith, 2015). Environmental stressors reduce body weight, average daily gain and body condition of livestock. Declines in the milk yield are pronounced and milk quality is affected: reduced fat content, lower-chain fatty acids, solid-non-fat, and lactose contents; and increased palmitic and stearic acid contents are observed. Generally the higher production animals are the most affected. Adaptation to prolonged stressors may be accompanied by production losses. Increasing or maintaining current production levels in an increasingly hostile environment is not a sustainable option. It may make better sense to look at using adapted animals, albeit with lower production levels (and also lower input costs) rather than try to infuse 'stress tolerance' genes into non-adapted breeds (Gaughan, 2015).

Impact of climate change on livestock reproduction

Reproductive processes are affected by thermal stress. Conception rates of dairy cows may drop 20–27% in summer, and heat stressed cows often have poor expression of oestrus due to reduced oestradiol secretion from the dominant follicle developed in a low luteinizing hormone environment. Reproductive inefficiency due to heat stress involves changes in ovarian function and embryonic development by reducing the competence of oocyte to be fertilized and the resulting embryo (Naqvi et al., 2012). Heat stress compromises oocyte growth in cows by altering progesterone secretion, the secretion of luteinizing hormone, follicle-stimulating hormone and ovarian dynamics during the oestrus cycle. Heat stress has also been associated with impairment of embryo development and increase in embryonic mortality in cattle. Heat stress during pregnancy slows growth of the foetus and can increase foetal loss. Secretion of the hormones and enzymes regulating reproductive tract function may also be altered by heat stress. In males, heat stress adversely affects spermatogenesis perhaps by inhibiting the proliferation of spermatocytes.

Impact of climate change on livestock adaptation

In order to maintain body temperature within physiological limits, heat stressed animals initiate compensatory and adaptive mechanisms to re-establish homeothermy and homeostasis, which are important for survival, but may result reduction in productive potential.

The relative changes in the various physiological responses i.e. respiration rate, pulse rate and rectal temperature give an indication of stress imposed on livestock. The thermal stress affects the hypothalamic–pituitary–adrenal axis. Corticotropin-releasing hormone stimulates somatostatin, possibly a key mechanism by which heat-stressed animals have reduced growth hormone and thyroxin levels. The animals thriving in the hot climate have acquired some genes that protect cells from the increased environmental temperatures. Using functional genomics to identify genes that are up- or down-regulated during a stressful event can lead to the identification of animals that are genetically superior for coping with stress and to the creation of therapeutic drugs and treatments that target affected genes (Collier et al., 2012). Studies evaluating genes identified as participating in the cellular acclimation response from microarray analyses or genome-wide association studies have indicated that heat shock proteins are playing a major role in adaptation to thermal stress.

Impact of climate change on livestock diseases

Variations in temperature and rainfall are the most significant climatic variables affecting livestock disease outbreaks. Warmer and wetter weather (particularly warmer winters) will increase the risk and occurrence of animal diseases, because certain species that serve as disease vectors, such as biting flies and ticks, are more likely to survive year-round. The movement of disease vectors into new areas e.g. malaria and livestock tick borne diseases (babesiosis, theileriosis, anaplasmosis), Rift Valley fever and bluetongue disease in Europe has been documented. Certain existing parasitic diseases may also become more prevalent, or their geographical range may spread, if rainfall increases. This may contribute to an increase in disease spread for livestock such as ovine chlamydiosis, caprine arthritis (CAE), equine infectious anemia (EIA), equine influenza, Marek's disease (MD), and bovine viral diarrhea. There are many rapidly emerging diseases that continue to spread over large areas. Outbreaks of diseases such as foot and mouth disease or avian influenza affect very large numbers of animals and contribute to further degradation of the environment and surrounding communities' health and livelihood.

Conclusion

There is considerable research evidence showing substantial decline in animal performance inflicting heavy economic losses when subjected to heat stress. With the development of molecular biotechnologies, new opportunities are available to characterize gene expression and identify key cellular responses to heat stress. These tools will enable improved accuracy and efficiency of selection for heat tolerance. Systematic information generated on the impact assessment of climate change on livestock production may prove very valuable in developing appropriate adaptation and mitigation strategies to sustain livestock production in the changing climate scenario. As livestock is an important source of livelihood, it is necessary to find suitable solutions not only to maintain this industry as an economically viable enterprise but also to enhance profitability and decrease environmental pollutants by reducing the ill-effects of climate change.

Future perspectives

Responding to the challenges of global warming necessitates a paradigm shift in the practice of agriculture and in the role of livestock within farming systems. Science and technology are lacking in thematic issues, including those related to climatic adaptation, dissemination of new understandings in rangeland ecology (matching stocking rates with pasture production, adjusting herd and water point management to altered seasonal and spatial patterns of forage production, managing diet quality, more effective use of silage, pasture seeding and rotation, fire management to control woody thickening and using more suitable livestock breeds or species), and a holistic understanding of pastoral management (migratory pastoralist activities and a wide range of biosecurity activities to monitor and manage the spread of pests, weeds, and diseases). Integrating grain crops with pasture plants and livestock could result in a more diversified system that will be more resilient to higher temperatures, elevated carbon dioxide levels, uncertain precipitation changes, and other dramatic effects resulting from the global climate change. The key thematic issues for effectively managing environment stress and livestock production include (Sejian et al., 2015b):

- development of early warning system;
- research to understand interactions among multiple stressors;development of simulation models;
- development of strategies to improve water-use efficiency and conservation for diversified production system;
- exploitation of genetic potential of native breeds; and
- research on development of suitable breeding programmes and nutritional interventions.

The integration of new technologies into the research and technology transfer systems potentially offers many opportunities to further the development of climate change adaptation strategies. Epigenetic regulation of gene expression and thermal imprinting of the genome could also be an efficient method to improve thermal tolerance.

References

Collier, R. J., Gebremedhin, K., Macko, A. R and Roy, K. S. (2012). Genes involved in the thermal tolerance of livestock. In: Environmental stress and amelioration in livestock production. Sejian, V., Naqvi, S. M. K., Ezeji, T., Lakritz, J. and Lal, R. (Eds), Springer-VerlagGMbH Publisher, Germany, pp 379-410.

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

Gaughan, J. B. (2015). Livestock adaptation to climate change. Proceedings of the PCVC6 & 27VAM 2015 Conference, The Royale Chulan Hotel Kuala Lumpur, 23 – 27 March 2015.

Gaughan, J. B and Cawsell-Smith, A. J. (2015). Impact of climate change on livestock production and reproduction. In: Climate change Impact on livestock: adaptation and mitigation. Sejian, V., Gaughan, J., Baumgard, L., Prasad, C.S (Eds), Springer-Verlag GMbH Publisher, New Delhi, India, pp 51-60.

Giridhar, K. and Samireddypalle, A. (2015). Impact of climate change on forage availability for livestock. In: Climate change Impact on livestock: adaptation and mitigation. Sejian, V., Gaughan, J., Baumgard, L., Prasad, C. S. (Eds), Springer-Verlag GMbH Publisher, New Delhi, India, pp 97-112.

Naqvi, S. M. K., Kumar, D., Paul, R. K. and Sejian, V. (2012). Environmental stresses and livestock reproduction. In: Environmental stress and amelioration in livestock production. Sejian, V., Naqvi, S. M. K., Ezeji, T., Lakritz, J and Lal, R. (Eds), Springer-VerlagGMbH Publisher, Germany, pp 97-128.

Naqvi, S. M. K., Kumar, D., Kalyan, De, Sejian, V. (2015). Climate change and water availability for livestock: impact on both quality and quantity. In: Climate change Impact on livestock: adaptation and mitigation. Sejian, V., Gaughan, J., Baumgard, L., Prasad, C. S. (Eds), Springer-Verlag GMbH Publisher, New Delhi, India, pp 81-96.

Sejian, V., Maurya V. P. and Naqvi, S. M. K. (2010). Adaptive capability as indicated by endocrine and biochemical responses of Malpura ewes subjected to combined stresses (thermal and nutritional) under semi-arid tropical environment. International Journal of Biometeorology, 54:653-661.

Sejian, V., Maurya V. P. and Naqvi, S. M. K. (2011). Effect of thermal, nutritional and combined (thermal and nutritional) stresses on growth and reproductive performance of Malpura ewes under semi-arid tropical environment. Journal of Animal Physiology and Animal Nutrition, 95:252-258.

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.

Sejian, V., Maurya, V. P., Kumar, K. and Naqvi, S. M. K. (2013). Effect of multiple stresses (thermal, nutritional and walking stress) on growth, physiological response, blood biochemical and endocrine responses in Malpura ewes under semi-arid tropical environment. Tropical Animal Health and Production, 45:107-116.

Sejian, V., Bhatta, R., Soren, N. M., Malik, P. K., Ravindra, J. P., Prasad C. S., Lal, R. (2015a). Introduction to concepts of climate change impact on livestock and its adaptation and mitigation. In: Climate change Impact on livestock: adaptation and mitigation. Sejian, V., Gaughan, J., Baumgard, L., Prasad, C. S. (Eds), Springer-Verlag GMbH Publisher, New Delhi, India, pp 1-26.

Sejian, V., Bhatta, R., Gaughan, J. B., Baumgard, L. H., Prasad, C. S., Lal, R. (2015b). Conclusions and Researchable Priorities. In: Climate change impact on livestock: adaptation and mitigation. Sejian, V., Gaughan, J., Baumgard, L., Prasad, C. S. (Eds), Springer-Verlag GMbH Publisher, New Delhi, India, pp 491-510.

Reference

Veerasamy Sejian [1,2],Gaughan, J. B.[2], Raghavendra Bhatta[1] and Naqvi, S. M. K.[3] Impact of climate change on livestock productivity

[1] ICAR-National Institute of Animal Nutrition and Physiology, Adugodi, Bangalore-560030, India

[2] School of Agriculture and Food Sciences, The University of Queensland, Gatton 4343 QLD, Australia

[3] ICAR-Central Sheep and Wool Research Institute, Avikanagar, Rajasthan-304501, India