FEED PRODUCTION CONSTRAINTS, CLIMATE RESILIENCE AND LIVESTOCK PRODUCTION

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Keywords: adaptation, carbon sequestration, climate change, climate resilience, greenhouse gases, genomic selection, GWAS, heat stress, heat shock proteins, marker assisted selection, micro environment, silage, SOC, SOM, thermoregulation

Contents

Summary

This chapter is an attempt to collect and synthesize information pertaining to climate change associated feed production constraints for livestock and also addresses in detail the various concepts associated with climate resilient livestock production. The chapter would give an overview on the subject and the information generated and presented should be very useful for different stakeholders involved in climate change associated livestock production.

Apart from contributing significantly to the gross domestic product (GDP) of many countries, the livestock industries also ensure food and nutritional security. The associated adverse impacts of climate change in particular the projected increases in temperature are predicted to be more severe in tropical regions, especially in developing countries that rely heavily on livestock and other agricultural sectors. Therefore, this chapter attempts to collate and synthesize information about the climate change associated feed production constraints that limit livestock production.

Increased temperature, photoperiod and rainfall changes associated with climate change can hurt animal production. Climate change can result in multiple environmental stressors, which if manifested will severely hamper animal production. The altered temperature and precipitation patterns, increased frequency of extreme temperature and precipitation events, and the invasion pressure of weeds, pest and pathogens can offset pasture availability. Factors such as deterioration of soil characteristics, lack of

inventories for feed resources, and insufficient water for producing livestock feed are attributed to negatively influencing feed and fodder resources available for animal production.

Screening of indigenous livestock breeds for climate resilience would aid in identifying agro-ecological zone-specific breeds, which can ensure maximum output to farmers. Advances in biotechnology and animal breeding have led to identifying potential biomarkers to incorporate into advanced animal breeding programs like marker-assisted selection (MAS) and genomic selection (GS) for inducing climate-resilient potential in livestock. Further, to ensure the optimum economic return to the farmers, climate-smart livestock production needs to be practiced by integrating crops, livestock, fishery, forestry, horticulture, and other activities related to agriculture. Finally, the policy makers need to focus on developing adaptation strategies comprising improving fodder production, water conservation, nutritional interventions, shelter management, and refining the existing breeding programs with more diversified traits to sustain livestock production in the changing climate scenario.

1. Introduction

Climate change is one of the major environmental challenges faced by all countries of the world. Globally there are increased concerns over the devastating effects of climate change, which threatens the livelihood of economically weaker sections of populations. The agricultural sector is the economic backbone of many countries, especially in developing regions because agriculture provides a source of income to many. This sector has a unique feature of both contributing to climate change and also being affected by it. In developing nations, livestock plays a major role in the agricultural sector, and it plays a crucial role in the nation's overall economy. Rural poor communities rely on animal agriculture for their survival, and animal agriculture is considered to be amongst the most climate-resilient economic sectors. The adverse effects of climate change associated with heat stress are predicted to have major impacts on developing countries in the tropics primarily due to a lack in farmer-friendly technologies for adapting the livestock production systems to the changing climate scenario.

Climate change is resulting in a shifting of livestock from one region to other, change in breed composition, change in livelihood and nutritional security of farmers, and the emergence of new diseases etc. Therefore, while aiming for sustainable livestock production; it is imperative to reduce the effects of climate change. Given that the livestock sector is sensitive to climate change and is a contributor to the phenomenon, climate change has the potential to be an increasingly formidable challenge to the maintenance and development of this sector worldwide. Therefore, developing adaptation strategies is an essential part of ensuring that countries are well prepared to deal with any adverse impacts of climate change. The adaptation strategies designed must be targeted to equip economically weaker and resource-poor vulnerable populations with the tools and incentives that will enable them to cope with the adversities associated with climate change (Gaughan et al., 2018).

As per the Intergovernmental Panel on Climate Change (IPCC), the earth's average surface temperature is predicted to rise by 1.4 to 4.8° by the end of 2100.Adverse impacts of the projected increase in temperature are predicted to be more severe in the tropical regions, especially in developing countries that rely heavily on livestock and other agricultural sectors. Such rapidly changing climatic conditions are becoming a major threat, and challenging life on earth. It adversely affects livestock leading to negative impacts on their welfare, productivity, greenhouse gas (GHG) emissions and health. In addition to these direct effects on animals, the deleterious impacts of climate change also hamper humans' livelihood and health across the globe. Nevertheless, livestock possess particular innate adaptive abilities to combat to the adverse effects of climate change. However, these adaptive potentials exhibited by animals vary among species, breeds and between individuals. Unequivocally, the indigenous livestock breeds in developing countries appear to be highly adaptive to climate change, especially its major consequence, the heat stress, compared to the European breeds.

Climate change causes both direct and indirect impacts on livestock production. By far, the production losses are incurred due to indirect impacts such as reduced pasture feed, fodder and water availability, and sudden disease outbreaks (Cullen et al., 2009). This is true particularly in developing parts of the world where indigenous germplasm predominates. Such animals can withstand heat stress quite effectively if their feed is not compromised. Thus, the major limitation to livestock production in tropical countries is the lack of feed and fodder resources. Livestock breeds in many regions developed in response to available feed and water availability (and quality). Nutritional inputs in these regions are often poor, resulting in animals that survive, but have lower productivity (growth, reproduction) relative to breeds developed in regions where feed resources were not compromised. Therefore, this chapter attempts to collate and synthesize information pertaining to the climate change associated feed production constraints that limit livestock production. The chapter also highlights the importance of identifying climate-resilient livestock, paving way for sustainable livestock production in the changing climate scenario.

2. Climate Change and Livestock Production

The livestock sector provides a substantial source of income for a vast number of people across the globe. Apart from contributing significantly to the gross domestic product (GDP) to many countries, the livestock industry also ensures food and nutritional security. The rapidly changing environmental conditions are posing a threat to various sectors. Heat stress, a major outcome of climate change, adversely affects livestock production, causing reductions in milk and meat production, reproduction and increased disease outbreaks. Severe economic losses in livestock production have been reported around the world by heat stress. This can negatively affect the livelihood of millions of poor and marginal farmers across the globe.

3. Direct Impacts of Climate Change on Livestock Production

Increased temperature, photoperiod and rainfall associated with climate change can have an adverse impact on animal production. Climate change-induced heat stress is the major environmental factor that plays a significant role in negatively influencing livestock production. The effects of heat stress on livestock production depend on both the magnitude and duration of heat stress to which the animals are exposed. Furthermore, it is well established that there are wide variations among species and breed in response to heat stress. Increased environmental temperature can affect animals' growth performance by directly influencing the somatotrophic axis that governs growth. The adverse impact of heat stress on growth performance can be reflected or measured in terms of changes associated with body weight gain, body condition scoring, allometric measurements, and various endocrine factors that govern growth in animals. Heat stress can also influence reproductive performance in both male and female animals. Summer season-induced infertility is a major problem, particularly in tropical regions, and the negative effect will be enhanced by climate change. In males, spermatogenesis is adversely affected, thereby resulting in lower semen quality, sperm concentration, mass and individual motility of sperms. Thus, there is an overall reduction in herd fertility driven by the male. In females, heat stress can reduce estrus occurrence and reproductive behavior (e.g. no overt signs of estrous). Heat stress can also affect folliculogenesis resulting in infertility and a low percentage of conception. Thus, a reduced reproductive performance due to heat stress results from adverse impacts on both males and females. Apart from growth and reproduction, heat stress can also affect meat production by reducing the quantity and quality of meat. Also, heat stress can compromise the immune system of livestock, making them vulnerable to emerging diseases.

4. Indirect Impact of Climate Change on Livestock Production

As compared to the direct impacts, the indirect impacts of climate change are highly detrimental to livestock production. Livestock are predominantly distributed in the tropical regions and there is a considerable amount of indigenous animal, which can cope with the adversities associated with heat stress. The tropical agro-ecological zones are host to several indigenous livestock breeds, which have evolved their adaptive potential over many generations. These breeds are well equipped to deal with the direct impacts of climate change. Indigenous animals can cope with heat stress effectively when the feed is not compromised. However, climate change could indirectly affect livestock production due to the reduction in the quantity and quality of fodder and natural pastures (Sejian et al., 2016). This deterioration in fodder quality could impose severe nutritional stress on grazing animals. Further, the climate change-associated reductions in water resources may severely impact livestock production. Also, the climate change associated sudden disease outbreaks may hamper the productive efficiency of livestock. By far, most of the productive losses are incurred in livestock due to indirect effects of climate change.

5. Different Environmental Stresses Impacting Livestock Production

Climate change does not just mean the impact of heat stress on animals. Climate change can result in multiple environmental stressors, which severely hampers animal production (Sejian et al., 2013). Among the various environmental stressors, heat stress is the major factor that negatively affects animal production. Climate change (heat + changes in rainfall) can reduce pastureland and reduce the amount and quality of feed and fodder available for animal consumption. This may cause severe nutritional deficiency to the grazing livestock, which hamper growth and may be detrimental for animal survival. This is because the adaptive response or thermoregulatory behavior is biologically a costly phenomenon requiring continuous energy supply. Therefore, the nutritional deficiency emerging due to reduced feed availability may be a potential threat for animal survival. Also, the animals reared in extensive grazing systems often have to walk long distances in search of limited pastures which can place extreme stress on the grazing animals. This shows that apart from heat stress, the animals reared under extensive systems are subjected to nutritional and walking stress. In most tropical regions where indigenous livestock predominates, heat stress alone may not be a cause of worry as animals generally possess body reserves that are sufficient to counter a single stress. However, when two or more stressors occur simultaneously, which happens typically in the changing climate scenario, body reserves are not sufficient. Ultimately, the animals compromise their productive functions to cope with the multiple stressors. However, most of the research attempting to quantify animal responses to climate change has only studied the effects of heat stress. This is because designing animal experimentation involving multiple environmental stressors are very complex and difficult to manage. This warrants more research efforts being directed towards quantifying multiple stressor responses in grazing livestock. Such an approach could be the ideal way to establish climate resilience in domestic livestock.

6. Livestock Feed and Fodder Resources

6.1. Climate Change Impact on Pasture Availability

The wide range of studies conducted over the past 100 years has confirmed the potential adverse impacts of climate change on the available pasture resources (Wheeler et al., 2013; Godde et al., 2019). For instance, the projections are predicting a gradual reduction in the production and yield of pasture species. This could be attributed to the climate change associated altered temperature and precipitation patterns, increased frequency of extreme temperature and precipitation events, and the invasion pressure of weeds, pest and pathogens. Further, the climate change associated increase in the atmospheric concentration of the GHG, CO_2, has a beneficial influence on photosynthesis, leading to increased plant productivity and modifications in the nutrient and water cycle. It is estimated that a surge in the level of CO_2 to around 550 ppm will result in an increased crop production of 10-20% for C_3 and 0-10% in C_4 plants. Nevertheless, the effect of elevated CO_2 level is masked by the plants' sensitivity towards the limiting factors such as increasing temperature, weeds, pest, lack of nutrients and soil water. Being one of the critical GHGs, it is obvious to expect a higher temperature, for the increase in the level of CO_2. This could indirectly affect the water demand of plants, ultimately leading to a significant drop in yield.

Additionally, almost 100 percent of the total available pasture depends on rain for growth and expansion. Because of this critical role of water, pasture is significantly affected by the fluctuations in the frequency and intensity of precipitation events. Such changes could be happening due to short-term events like drought, flood, and inter annual temporal patterns such as El-Nino southern oscillations. These changing patterns of precipitation may lead to the eradication of many pastoral species from their native lands.

Along with the extreme weather events, the expansion of pasture land is seriously affected by ecological disturbances such as the outbreak of weeds and pests, which predominate when pasture species are stressed. Indeed, the lack of a balanced correlation between temperature and precipitation contributes to the sudden proliferation of undesirable insects and weeds. For instance, the growth of aphids, the vector for common viral diseases of plants, may increase by 10% due to the increased CO_2 and temperature levels. Additionally, the changes in the CO_2 levels prevent the production of defense compounds in pasture species, thereby recruiting natural enemies to control their growth. The increased air circulations aid the dispersal of pathogenic spores, leading to the spread of infection in pastoral species. This spread may lead to the hybridization of the native pathogens with the foreign species to create new strains of virulent pathogens having the ability to decimate pastoral communities.

6.2. Climate Change Associated Difference in the Distribution of Plant Pests

Despite the improvements in technologies, global food security is threatened by the spread of crop pests and pathogens (Sutherst et al., 2011). Of all the impacts of climate change on agriculture, the occurrence and spread of diseases are the least explored. Nevertheless, the percentile reduction in average yield caused by the infestation of pathogens calls for more research efforts in this particular aspect. Apart from the climatic factors, pathogens' occurrence and distribution are primarily facilitated by factors such as availability, susceptibility and abundance of the host species, and evolutionary changes (Bebber et al., 2013). However, all these factors act as a subset to the alterations in climate.

It is known that, for any species to grow and flourish in an ecological niche, favorable weather is required. Likewise, the dissemination of pests or pathogens is highly determined by the prevailing climatic conditions. Although these impacts are expressed at various levels, the most proximate reason for the pests' distribution pattern is due to the direct alterations in abundance and vulnerability of the host species. Meta-analysis and weather variables projections are pointing towards a gradual but undesirable increase in the annual average temperature across the latitudes. This anticipated general trend may influence the availability of the host species. Therefore, it is expected to have a latitudinal shift in the distribution of crop pests in search of their temperature optima.

The northern hemisphere, and in particular northern tropics, is home for almost two-thirds of the total pest population. Of these species, more than two-thirds of the crop pests have become global and are now seen extensively beyond the tropics. This could be attributed to the higher thermal incidences associated with the changing climate in the tropics. Nonetheless, the shift of species to the equator is not rare. Both these shifts are likely to hamper the habitat of the native species, culminating in either their extinction or migration. Similarly, the difficulties encountered due to the alterations in the distribution patterns of crop pests are due to the occurrence of extreme precipitation events such as drought and flood. With the severity in climatic extremes, it is often found that the species cross their habitat frontiers to find a new niche.

Land use changes that hasten the changing climate have also been a significant reason for the shift in crop pests' distribution pattern. Owing to the alterations in the flow of energy, water and mineral cycles, one would expect a shift in the ecosystem towards their resource optima. Additionally, several invasive pathogens can be introduced to the new areas, leading to the competition for the host resource, forages, resulting in a marked decline in their coverage.

6.3. Projected Feed and Fodder Shortage for Livestock

Based on the projected increase in the human population, the available evidences indicate the demand for crop production to double shortly. The shifts in food consumption patterns from crop-based to animal-based diets have induced pressure on land for cereal (animal feed) and pasture production. However, without considering the inevitable influence of climate change, crop yields are expected to rise from 2.7 to 3.8 Mg/ha by 2050 through productive land utilization and expansion of agricultural land (Harrison et al., 2016). Nevertheless, a significant reduction in fodder production may occur due to the uncertainties associated with changing climate.

Although the adverse effects of climate change on pasture availability are obvious, the extent of their occurrence remain uncertain and likely to vary regionally. The interaction between the key features viz., (i) the response of each landscape to the increasing frequency of extreme climatic events, (ii) susceptibility of the plant species towards the incidence of pest attack, and (iii) response of pasture species to elevated CO_2 . Therefore, it is imperative to advance the scientific knowledge on each of these factors to have a better insight into predicting the future risks associated with the reduced availability of animal feed and fodder resources (McKeon et al., 2009).

Neglecting the occurrence of extreme weather, it is expected that pastoral communities will benefit from small temperature increases. However, this trend is observed only in some parts of the temperate zone where the increase in mean temperature and precipitation alterations are moderate. A reverse trend is experienced in tropics and semi-arid regions even with the minimal expected increase of 1.0ºC. Since almost all pastoral lands are rain fed, the areas receiving lower rainfall are expected to be impacted the most by climate change. Countries with safe carrying capacity of livestock are less exposed to the effect of seasonal reduction in the availability of pastoral resources. However, the long-term effects of reduced pastoral cover may impose serious effects on livestock production and reduce the possibility of rearing animals economically (Sirohi and Michaelowa, 2007).

The tropical countries where livestock are mainly distributed have suffered 22% and 62 % reductions in dry and green fodder resources respectively (Wheeler et al., 2013). The advancements in predicting the impact of climate change at the microenvironment scale have indicated the likely occurrence of chronic fodder shortage with the potential to cripple economies. The underprivileged rural communities will be adversely affected with the expected reductions of 25 % for dry fodder and 66% for green fodder by 2030 (Wheeler et al., 2013).

7. Feed Production Constraints

7.1. Summer Heat Waves on Fodder Deficit

Climate change can directly affect forage availability by affecting both their quantity and quality. Further, the changing climate can also offset the water available for the cultivation of forage crops. In addition, climate change can also affect the vegetation patterns of large rangelands. The adverse impact of climate change on feed and fodder availability is predominant in developing countries compared to the developed due to significant contribution of agriculture in the economies of these countries and the generally warmer baseline climates prevailing in these regions. Further, the farmers in the developing part of world are resource-poor and have less access to newer technologies. The projected climate change associated with precipitation patterns can cause warmer climates, elevated CO_2 concentration and less water availability for fodder cultivation. The interrelationship among these factors will determine the magnitude of the impact on fodder production. Elevated CO_2 can increase the dry matter content in C3 plants in comparison to C4 plants and this response is primarily determined by the interrelationship between the nature of crop, soil moisture, and soil nutrient availability. Finally, the climate change associated wider alteration in the rainfall distribution pattern also can offset the fodder production across different tropical countries.

7.2. Shrinking of Pasture Land

The livestock sector has a vital role in livelihood of farming communities in developing and developed countries. Approximately 800 million people depend on livestock reared exclusively via grazing on natural range and pasture for both income and food security. Grazing land in tropical, semi tropical, and arid regions is more vulnerable to climate change due to shortfalls in precipitation. This threatens the life of humans, plants, and animals since pasture growth depends on water and rainfall. Climatic variables play a vital role in forming the characteristics of grazing land and growth of plants/grasses in pasture land. However, abrupt changes in climatic variables such as extreme heat or cold, flood or drought, humidity, and wind speed are major concerns for pasture land worldwide since it affects the composition, quality, and quantity of pasture around the world (Godde et al., 2019).

Approximately 25% of the earth’s land area is utilized for grazing of livestock (FAOSTAT, 2019). Most of the grazing lands are marginal where growing crops is rather difficult. The consequences of climate change that are evident include extended drought conditions, unusual intense precipitation/flooding, and changes in duration of seasons. As a result, grazing of livestock is at a major risk. Therefore, it is vital to understand how changing rainfall patterns and elevated surface temperature affect the pasture lands’ extent and quality worldwide.

Pasture growth is mainly affected by temperature, sunlight, and rainfall. Pasture growth is optimal in warmer seasons provided that there is sufficient water. However, high temperature combined with reduced rainfall affect the pasture growth and its digestibility. Approximately 80% of the earth’s grazing lands are open lands like shrublands or rangelands, savannas, and prairies (FAOSTAT, 2019). Thus, pasture growth, productivity, and the area of pasture land are threatened by changes in climate variability. Importantly, rainfall patterns vary across the globe due to changing climate that ultimately affects the pasture land, affecting the sustainability of livestock production, rural economy, and food security.

The trend regarding pasture area between 2000 and 2016 was flat or declining in two-thirds of countries, including countries that have observed the decline of pasture for decades. Even countries that had large expansions of pastureland during the 20th century are facing declines of pasture area. FAOSTAT (2019) reported that the 1.4 million km^2 of pasture land is shrinking after the world reached the peak pasture point around the year 2000. In Europe and North America, pasture area has declined steadily for decades and as a result they now have less pasture land than they had in 1961. The pasture decline rate in Australia is up to 20 times the 30-year global average, which is the single largest decline of pasture area worldwide. In lower middle and lower-income countries, pasture expansion has stalled or has declined after peak pasture growth around 2000. Pasture land has declined or plateaued in almost all the major grazing areas of the world. Total agricultural land utilized for rearing ruminants to produce meat and milk has shrunk by approximately 50 Mha since 2000. The total pasture area is now less in 67 countries than it was in 1961 (FAOSTAT, 2019).

Climate change-driven increases in the variability of rainfall patterns may cause the shrinkage of pasture land. Much of the wetter and humid lands that have been used to graze livestock previously are now being used for crop production because they are most productive. A small portion of the lands is also being encroached by rapid urbanization. Therefore, with the current scenario, the grazing areas likely to be negatively impacted are more common in drier regions and two-thirds of which are in developing countries. Maintaining grazing lands is of utmost importance to sustaining food security and rural economies. The importance of livestock rearing for rural communities necessitates suitable strategies for addressing the risks related to climate change. There is also a need to identify the suitable breeds and crop varieties that will withstand harsh climates. Researchers and grazers around the world are testing management practices aimed at adapting pastures to a changing climate. This includes modified grazing practices, improved pastures where desired fodder varieties used to augment nutritive value of pasture, mobility of livestock over long distance for grazing and rearing of thermo-tolerant breeds.

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Biographical Sketches

Veerasamy Sejian is a Principal Scientist at ICAR-National Institute of Animal Nutrition and Physiology (NIANP), Bangalore, India. His major thrust area of research is on "Climate Change and Livestock Production" and handled seven projects in this field. Dr Sejian is the leader of the team which established the concept of "Multiple stresses impacting small ruminant production in the changing climate scenario". His current research focuses on identifying molecular markers for different environmental stresses in small ruminants with the primary focus to develop agro-ecological zone specific thermo-tolerant breeds.

Dr Sejian has published 149 peer reviewed research/review articles, 85 book chapters, 220 invited/lead papers, 155 conference papers and 19 technical manuals. Further, Dr Sejian has also published three International Springer books. His h-index is 33 and i10 index is 91. His total citation is 3532. Dr Sejian underwent three month International training on climate change and livestock production at The Ohio state University, USA. Dr Sejian was bestowed with Endeavour Research Fellowship by the Australian Government to pursue post doctorate at The University of Queensland, Australia. For his outstanding contribution in climate change and livestock production, Indian Council of Agricultural Research (ICAR) has bestowed him with the prestigious Lal Bahadur Shastri Outstanding Young Scientist Award. Further, Career360 an academic organization had selected Dr Sejian to be one of the top 10 scientists in India under environmental sciences category during the academic year 2017-18. Dr Sejian is also listed in world top 2% scientists by Stanford University, USA. In addition, Dr Sejian is also serving as Field Editor in Springer's International Journal of Biometeorology and Associate Editor in Elsevier's Small Ruminant Research. He has one patent to his credit and supervised 14 Masters and 2 PhD students. Presently, he is collaborating with researchers from Australia, USA, France, Italy and Brazil.

Raghavendra Bhatta is currently the Director of ICAR- National Institute of Animal Nutrition and Physiology (NIANP), Bengaluru, Karnataka, India. During his research career spanning 27 years, he has done extensive research work involving small ruminant nutrition with reference to 'plant phenolics'. He has developed the All-India state-wise inventory on enteric methane emission based on primary data and has evolved simple, eco-friendly strategies for enteric methane reduction in livestock. Dr. Bhatta was awarded the prestigious Japan Society for the Promotion of Science (JSPS) post-doctoral fellowship (2004-2006) at NILGS, Japan. He was invited to present theme papers at the Greenhouse Gases and Animal Agriculture (GGAA) Conference at Zurich, Switzerland in 2005; GGAA 2010 conference in Banff, Canada and GGAA 2016 conference at Melbourne, Australia. Dr Bhatta is the Fellow of the National Academy of Agricultural Sciences, the National Academy of Veterinary Science, and the National Academy of Diary Sciences – India. He is recipient of several research awards including the prestigious Sir CV Raman State Award from the Karnataka State Council for Science and Technology, Govt. of Karnataka, and Rafi Ahmed Kidwai Award for Outstanding Research in Agricultural Sciences, 2019 by ICAR. Dr Bhatta is recognized as one of the world's top 2% scientists by the Stanford University analysis 2020. Dr. Bhatta has published more than 100 research papers in journals and presented more than 100 papers in conferences of national and international repute and has authored 3 books, one each in Cambridge University Press, Centre for Agriculture and Bioscience International and Springer. Has written 45 chapters in books, He has two patents to his credit. He has guided two PhD students.

John Gaughan is an Associate Professor in the School of Agriculture and Food Sciences at The University of Queensland, Gatton, Australia. He has authored or co-authored 22 book chapters, 76 refereed publications, 57 conference proceedings, and 20 research reports. He has been supervised 8 PhD graduates and 3 MPhil graduates. He is recognized as a leader in cattle heat stress research in Australia and internationally, and has attracted over $11 million in research funding. He is part of an international team (team leader) which has recently developed new thermal stress indices for livestock (intensive and extensive systems), a heat stress risk assessment model for feedlot cattle, grazing cows and their calves, and is currently developing a heat stress risk assessment model for dairy cows, sheep, working dogs and horses. His worked has largely focused on gaining an understanding of animal's physiological responses to both acute and chronic heat stress, the development of management and nutritional strategies to ameliorate the impact of high heat load, and the likely impact of current and future climatic conditions on animal production. John is also part of a team investigating nutritional strategies to ameliorate the effects of high heat load on feedlot cattle, and has on-going collaborative projects with colleagues in Australia, India and the USA. Dr Gaughan is also the team leader for the Environment Portfolio of the Northern Australian Business Programme (NB2). Dr Gaughan has a H-Index 36, his i10 index is 76, and he had a citation rate of 580 in 2020.

Frank Dunshea is a Redmond Barry Distinguished Professor and Chair of Agriculture at the University of Melbourne in Australia and Professor of Animal Growth and Development at the University of Leeds in the UK. Frank has a more than 35-yr research career in growth physiology and nutrition and the use of domestic animals in nutritional and biomedical research. He has published over 900 journal, conference, book, or technical articles and has high citation metrics (h-index = 58, I_{10} index = 273; total citations >13600; Google Scholar, April 2021) and is ranked in the top 1% of scientists globally for citations in Agriculture and All fields over the past 10 years (Web of Science, April 2021). His research has had a high scientific impact, with many of the results being rapidly adopted by industry. Frank is a respected research leader in global livestock industries and is committed to ensuring that livestock industries operate responsibly and sustainably. Much of his work has focused on improving efficiency through reducing inputs and outputs while maintaining product quality and consumer health, with a particular recent emphasis on the role of antioxidants and plant-derived phytochemicals in animal health and productivity in a changing climate scenario. Frank has received many international awards, including the American Society of Animal Science (ASAS) awards for Growth and Development (2009), Non-Ruminant Nutrition (2013) and Meat Science (2017). Frank is a Fellow of the Australian Nutrition Society, the Australasian Pig Science Association, and the Australian Association of Animal Sciences.

Nicola Lacetera joined the University of Tuscia (Viterbo, Italy) in 1990 as assistant professor at Institute of Animal Science. Currently he is full professor and chair of the Department of Agriculture and Forest Sciences in the same University. Before joining the University of Tuscia, Prof. Lacetera graduated in Veterinary medicine at the University of Perugia (Italy). He was visiting professor at Caldwell Animal Hospital (NC, USA, 1986), Department of Microbiology at Colorado State University (CO, USA, 1988-1989), Department of Animal Health and Husbandry at University of Bristol (UK, 1994 and 1995), Laboratoire Associé de Recherches sur les Lentivirus chez le Petits Ruminants at the Ecole Vétérinaire of Lion (France, 1997), Commonwealth Scientific and Industrial Research Organization at Brisbane, Australia (2015). His main areas of research are the interactions between metabolism, immune response and health in dairy ruminants and the effects of heat stress on physiology, health and performance of dairy cows. Immunology, disease resistance and risk of death are the main topics of his research in the field of animal biometeorology. Prof. Lacetera is co-author of more than 200 publications.

Rattan Lal, Ph.D. from the Ohio State University, is a Distinguished University Professor of Soil Science and Director of the Carbon Management and Sequestration Center at The Ohio State University. He is an Adjunct Professor at the University Iceland; IARI, New Delhi, India, and holds a Chair in Soil Science and Goodwill Ambassador Positions with the Inter-American Institute of Cooperation in Agriculture, San Jose, Costa Rica. He was President of the Soil Science Society of America (2006-2008), and the International Union of Soil Sciences (2017-2018). He researches soil carbon sequestration for food and climate security, carbon footprint, eco-intensification, conservation agriculture, soil restoration, soil health, and soils of the tropics. He has authored about 1000 journal articles, mentored 360 researchers, h-index of 163, i10 index 1054 and 120190 total citations. He is laureate of the 2018 GCHERA World Agriculture Prize, 2018 Glinka World Soil Prize, 2019 Japan Prize, 2019 U.S. Awasthi IFFCO Award, the 2020 World Food Prize, and 2020 Arrell Food Prize.

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