Veerasamy Sejian · John Gaughan
Lance Baumgard · Cadaba Prasad *Editors*

Climate Change Impact on Livestock: Adaptation and Mitigation

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This book is dedicated to all who have lost their lives to the devastating effects of climate change and to all farmers around the world who rely heavily on livestock production for their principal livelihood security and to all researchers who are actively involved in research pertaining to improving livestock production in the changing climate scenario.

Preface

Climate change and food security are two emerging issues faced by almost every nation. Climate change as a result of green house gases (GHGs) emissions poses a serious threat to the environment, economy and well-being of both human and animals. While livestock's role in contributing to food security is well acknowledged, its negative impacts, by way of contributing to GHG in the atmosphere, raise criticism. Livestock agriculture accounts for significant amount of methane (CH_4) and nitrous oxide (N_2O) emitted worldwide. The negative impact of climate change is evident on all animals, but its effect on ruminant livestock are of huge concern as these animals apart from getting affected by climate change also directly contribute to the phenomenon through enteric CH_4 emission and manure management. It is therefore imperative that animal agriculture practices and the welfare of animals be considered when developing climate change policies and programmes, both as potential victims and causes. Under the changing climatic scenarios, efforts are equally needed to reduce the impacts of climate change on livestock production and reproduction as well as to identify suitable mitigation strategies to reduce CH_4 production.

With dynamic climate shifts, endeavours are needed to hoist platforms for suitable adaptation and mitigation strategies to reduce genesis of climate change. This forms the basis of this book *Climate Change Impact on Livestock: Adaptation and Mitigation*. This volume was specifically prepared by a team of multi-disciplinary scientists to be a valuable reference source for researchers as the primary target group for this compendium. In addition, the material contained in this volume is also relevant to teaching undergraduates, graduates, policy makers, politicians and other professionals involved in livestock production. With information and case studies collated and synthesized by professionals working in diversified ecological zones, this book attempts to study the climate change impact, adaptation and mitigation in livestock production system across the global biomes.

The 27 chapters provide the reader with an insight into the impact of climate change on livestock production and role of livestock in contributing to climate change. An attempt is also made to discuss the various mitigation strategies to reduce livestock related GHGs. Further, efforts have also been made to highlight several housing management and feeding practices to reduce climate change's impact on livestock production and reproduction. In addition, this book also emphasizes the various policy issues that require focus to understand in depth the impact of climate change and its mitigation by 2025. Therefore, this book is a comprehensive resource for the researchers to understand climate change impact and its management to improving livestock production.

The contributors of various chapters are world class professionals with vast experience in the chosen field supported by several peer-reviewed publications. The Editorial Committee take this opportunity to thank all the contributors from different parts of the world for their dedication in preparing these chapters, for their prompt and timely response, and for sharing their knowledge and experience with others. The efforts of many others, all of those cannot be individually listed, were also very pertinent in completing this relevant and an important volume.

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Dr. John Gaughan is an Associate Professor in the School of Agriculture and Food Sciences at The University of Queensland, Gatton, Australia. John has 129 publications, in the areas of impacts of harsh climatic conditions on livestock, modeling the impact of climate change on animal production (beef, dairy, sheep), and ruminant nutrition. He is part of an international team which has recently developed new thermal stress indices for livestock, a heat stress risk assessment model for feedlot beef cattle, and is currently developing a heat stress risk assessment model for dairy cows. He is currently focusing on the likely impact of future climatic conditions on animal production. John is also part of a team investigating greenhouse gas abatement strategies for cattle, and has on-going collaborative projects with colleagues in the USA. John is the Treasurer of the International Society of Biometeorology (ISB) and the Chair of the Animal Biometeorology Commission within ISB.

Dr. Lance Baumgard received his Ph.D. from Cornell University and joined the University of Arizona faculty as an Assistant Professor in 2001. He joined the Iowa State University faculty in 2009 and is the Norman Jacobson Professor of Nutritional Physiology. Baumgard's research focuses on the metabolic and endocrine consequences of heat stress in both ruminant and monogastric farm animals. Lance also studies the energetics and metabolism of the periparturient dairy cow. Lance has mentored or co-advised 23 graduate students and has been the PI or co-PI on over $6 million in research funding. Lance's group has published 82 peer-reviewed research articles, 150 abstracts, and 75 conference proceedings.

Dr. Cadaba S. Prasad was the Director of National Institute of Animal Nutrition and Physiology, Bangalore, India. Prior to this he was also serving as Vice Chancellor and Assistant Director General. Prasad's primary research interests have been on micronutrients augmenting production, enhancing the bioavailability of nutrients, and climate change impact on animal production. Prasad has coordinated several national and international projects like Indo-Dutch, ICAR-CSIRO, ICAR-ILRI, World Bank. Prasad's group has published more than 100 research papers in high-impact journals, 100 abstracts and 70 conference proceedings. Prasad and his team have won the ICAR Team research award thrice for outstanding contribution in animal production. Prasad has been awarded fellow of National Academy of Agriculture Science, Indian Dairy Association, Animal Nutrition Association and National Academy of Dairy Science.

Introduction to Concepts of Climate Change Impact on Livestock and Its Adaptation and Mitigation

1

Veerasamy Sejian, Raghavendra Bhatta, N.M. Soren,
P.K. Malik, J.P. Ravindra, Cadaba S. Prasad,
and Rattan Lal

Abstract

This chapter provides an overview of the impact of climate change on livestock production and its adaptation and mitigation. Animal agriculture is the major contributor to increasing methane (CH_4) and nitrous oxide (N_2O) concentrations in Earth's atmosphere. Generally there are two-way impacts of livestock on climate change. The first part is the livestock contribution to climate change, while the second part is concerned with livestock getting affected by climate change. Hence, improving livestock production under changing climate scenario must target both reducing greenhouse gas (GHG) emission from livestock and reducing the effect of climate change on livestock production. These efforts will optimize livestock production under the changing climate scenario. The role of livestock on climate change is primarily due to enteric CH_4 emission and those from manure management. Various GHG mitigation strategies include manipulation of rumen microbial ecosystem, plant secondary metabolites, ration balancing, alternate hydrogen sinks, manure management, and modeling to curtail GHG emission. Adapting to climate change and reducing GHG emissions may require significant changes in production technology and farming systems that could affect productivity. Many viable opportunities exist for reducing CH_4 emissions from enteric fermentation in rumi-

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nant animals and from livestock manure management facilities. To be considered viable, these emission reduction strategies must be consistent with the continued economic viability of the producer and must accommodate cultural factors that affect livestock ownership and management. The direct impacts of climate change on livestock are on its growth, milk production, reproduction, metabolic activity, and disease occurrences. The indirect impacts of climate change on livestock are in reducing water and pasture availability and other feed resources. Amelioration of environmental stress impact on livestock requires multidisciplinary approaches which emphasize animal nutrition, housing, and animal health. It is important to understand the livestock responses to the environment and analyze them, in order to design modifications of nutritional and environmental management, thereby improving animal comfort and performance.

Keywords

Adaptation • Climate change • Enteric fermentation • Manure • Mitigation • Shelter design

Livestock production is the world's dominant land use, covering about 45 % of the Earth's land surface, much of it in harsh and variable environments that are unsuitable for other uses. Climate change could impact the amount and quality of produce, reliability of production, and the natural resource base on which livestock production depends. Climate is an important factor of agricultural productivity. The changing climate is expected to have severe impact on livestock production systems across the world. World demand for animal protein will rise as the population and real incomes increase and eating habits change. Therefore, animal production plays and will continue to play a key role in food supply. While the increasing demand for livestock products offers market opportunities and income for small, marginal, and landless farmers, livestock production globally faces increasing pressure because of negative environmental implications particularly because of greenhouse gas (GHG) emission.

Global climate change is expected to alter temperature, precipitation, atmospheric carbon dioxide (CO_2) levels, and water availability in ways that will affect the productivity of crop and livestock systems (Hatfield et al. 2008). For livestock systems, climate change could affect the costs and returns of production by altering the thermal environment of animals, thereby affecting animal health, reproduction, and the efficiency by which livestock convert feed into retained products (especially meat and milk). Climatic changes could increase thermal stress for animals and thereby reduce animal production and profitability by lowering feed efficiency, milk production, and reproduction rates (St. Pierre et al. 2003). Climate changes could impact the economic viability of livestock production systems worldwide. Surrounding environmental conditions directly affect mechanisms and rates of heat gain or loss by all animals (NRC 1981). Environmental stress reduces the productivity and health of livestock resulting in significant economic losses. Heat stress affects animal performance and productivity of dairy cows in all phases of production. The outcomes include decreased growth, reduced reproduction, increased susceptibility to diseases, and ultimately delayed initiation of lactation. Heat stress also negatively affects reproductive function (Amundson et al. 2006). Normal estrus activity and fertility are disrupted in livestock during summer months. Economic losses are incurred by the livestock industries because farm animals are generally raised in locations and/or seasons where temperature conditions go beyond their thermal comfort zone. The livelihood of the rural poor in developing countries depends critically on local natural resource-based activities such as crop and livestock production. As a result of negative weather impact on livestock rearing, the poor shepherds/farmers whose principal livelihood security depends on these animal performances are directly on stake. Housing and management technologies are available through which climatic impacts on livestock can be reduced, but the rational use of such technologies is crucial for the survival and profitability of the livestock enterprise (Gaughan et al. 2002).

The relationship between the livestock sector and climate change is likely to greatly influence the overall nature of the approach to adaptation within the livestock sector (Havlík et al. 2014). The sector has been much maligned since the publication of *Livestock's Long Shadow* by FAO in (2006) and the allegation that the industry contributes more to climate change than the automobile industry does. However, the real relationship between livestock and climate change is much more complex, and the environmental services of extensive livestock systems have generally been overlooked. Such services could become crucial to adaptation in the sector in the future. Livestock play a critical role in rural poverty reduction; therefore, livestock development is vital for farmers in developing world in particular. Development in all sectors will be increasingly scrutinized for its "clean" credentials, and it is desirable that livestock development can be carried out without significantly contributing further to climate change. This volume is an attempt to collate and synthesize all relevant information pertaining to how livestock contributes to climate change, in addition to getting impacted by the same. Further, the volume will address in detail the various mitigation strategies available to prevent livestock-related climate change by highlighting measures to be taken to curtail greenhouse gas (GHG) emission. In addition, the volume will address in detail the various adaptation and amelioration strategies to counter the impact of climate change on livestock production. Lastly, this volume also emphasizes the importance of visioning climate change impact 2025 and addresses the various steps to be taken to increase the resilience of livestock production systems and livestock-dependent livelihoods to climate change. All these crucial information pertaining to sustaining livestock production under changing climate scenario are dealt elaborately in six different parts in this volume. Figure 1.1 describes the various concepts pertaining to climate change impact on livestock production and its adaptation and mitigation.

1.1 GHG Emission and Climate Change

Part I of this volume comprises two chapters covering in detail the general principles governing the sources and sinks of GHGs and their contribution to climate change. Special emphasis has been given to highlight the significance of agricultural-related activities' contribution to GHGs and its importance to global climate change.

The temperature of the Earth's surface and atmosphere is determined by the balance between incoming and outgoing energy. Surface temperatures rise when more energy is received than lost. The Earth's surface receives about 50 % of the incoming solar radiation (after some losses by atmospheric absorption and reflection), and this energy heats the surface. The warmed surface reradiates heat back out at longer infrared wavelengths. This radiation is known as terrestrial radiation, as opposed to solar radiation coming in from the sun. The greenhouse effect is a result of the partial absorption and reradiation back to Earth of this outgoing infrared radiation. A change in the net radiative energy available to the global Earth-atmosphere system is termed as a radiative forcing, and changes in the concentrations of GHGs in the troposphere (such as CO_2, CH_4, N_2O, H_2O, etc.) are one such forcing (Rogelj et al. 2012). Increases in the concentrations of GHGs will reduce the efficiency with which the Earth's surface radiates to space. More of the outgoing terrestrial radiation from the surface is absorbed by the atmosphere and reemitted at higher altitudes and lower temperatures. These result in a positive radiative forcing that tends to warm the lower atmosphere and surface. Because less heat escapes to space, this is the enhanced greenhouse effect – an enhancement of an effect

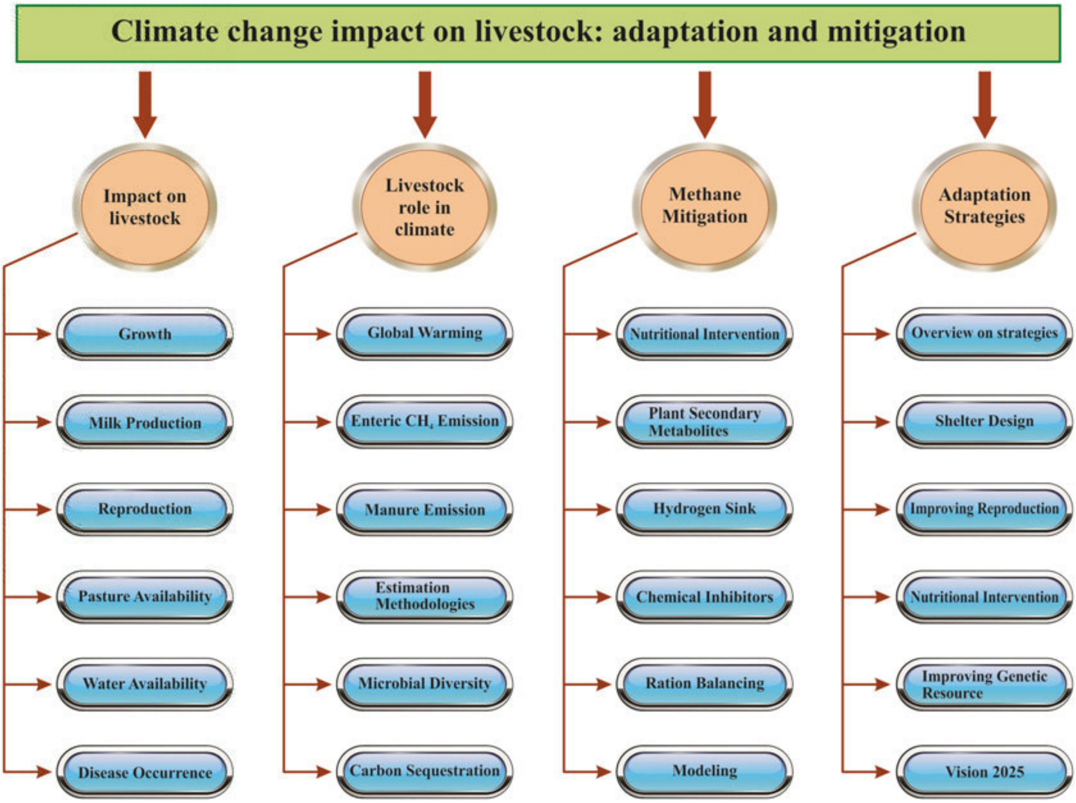

Fig. 1.1 Concepts of climate impact on livestock and its adaptation and mitigation

that has operated in the Earth's atmosphere for billions of years due to the presence of naturally occurring GHGs: water vapor, carbon dioxide (CO_2), ozone, methane (CH_4), and nitrous oxide (N_2O).

Different GHGs have differing abilities to warm the atmosphere. The net warming from an ensemble of GHGs depends on the size of the increase in concentration of each GHG, the radiative properties of the gases involved, and the concentrations of other GHGs already present in the atmosphere. Further, many GHGs reside in the atmosphere for centuries after being emitted, thereby introducing a long-term impact to positive radiative forcing. When radiative forcing changes, the climate system responds on various time scales. The longest of these are due to the large heat capacity of the deep ocean and dynamic adjustment of the ice sheets. This means that the transient response to a change (either positive or negative) may last for thousands of years. Any changes in the radiative balance of the Earth, including those due to an increase in GHGs or in aerosols, will alter the global hydrological cycle and atmospheric and oceanic circulation, thereby affecting weather patterns and regional temperatures and precipitation.

1.1.1 Different Sources of GHGs

There are two ways that GHGs enter Earth's atmosphere. One of them is through natural processes like animal and plant respiration. The other is through human activities. The main human sources of GHG emissions are fossil fuel use, deforestation, intensive livestock farming, use of synthetic fertilizers, and industrial processes. There are four main types of forcing GHGs: CO_2, CH_4, N_2O, and fluorinated gases. The main feedback of GHG is water vapor. The GHGs that humans do emit directly in significant quantities are (1) carbon dioxide – accounts for around three-quarters of the warming impact of current human GHG emissions. The key source of CO_2 is the burning of fossil fuels such as coal, oil, and gas, though deforestation is also a very significant contributor. (2) Methane – accounts for around 14 % of the impact of current human GHG emissions. Key sources of CH_4 include agriculture (especially livestock and rice fields), fossil fuel extraction, and the decay of organic waste in landfill sites. Methane doesn't persist in the atmosphere as long as CO_2, though its warming effect is much more potent for each gram of gas released. (3) Nitrous oxide – accounts for around 8 % of the warming impact of current human GHG emissions. Key sources of N_2O include agriculture (especially nitrogen-fertilized soils and livestock waste) and industrial processes. N_2O is even more potent per gram than methane.

1.1.2 Agricultural Contribution to Climate Change

Modern agriculture and food production and distribution are major contributors of GHGs. Agriculture is directly responsible for 14 % of total GHG emissions, and broader rural land use decisions have an even larger impact. Deforestation currently accounts for an additional 18 % of emissions. In this context, a historical perspective needs to be considered: Dr. Rattan Lal, professor of soil science at Ohio State University, has calculated that over the last 150 years, 476 billions of tonnes (Pg) of carbon have been emitted from terrestrial ecosystems which converted to agroecosystems through deforestation, soil cultivation, drainage, etc. since the dawn of settled agriculture.

Agriculture has significant effects on climate change, primarily through the production and release of GHGs such as CO_2, CH_4, and N_2O (Tubiello et al. 2013). Further, alterations in land cover can change its ability to absorb or reflect heat and light, thus contributing to radiative forcing. Land use changes such as deforestation and desertification together with fossil fuels are the major anthropogenic sources of CO_2. In addition, animal agriculture is the major contributor to increasing CH_4 and N_2O concentrations in the Earth's atmosphere.

The global food system, from fertilizer manufacture to food storage and packaging, is responsible for up to one-third of all human-caused GHG emissions, according to the latest figures from the Consultative Group on International Agricultural Research (CGIAR), a partnership of 15 research centers around the world. Using estimates from 2005, 2007, and 2008, the researchers found that agricultural production provides the huge share of GHG emissions from the food system, releasing up to 12 Pg of CO_2 equivalents a year – up to 86 % of all food-related anthropogenic GHG emissions. The global release of CH_4 from agricultural sources accounts for two-thirds of the anthropogenic CH_4 sources (Moss et al. 2000). These sources include rice growing, fermentation of feed by ruminants (enteric CH_4), biomass burning, and animal wastes. CH_4 is a potent GHG, and its release into the atmosphere is directly linked with animal agriculture, particularly ruminant production (Sejian et al. 2012a). Apart from this, livestock wastes also contribute enormously to the agricultural sources of CH_4 and N_2O.

1.2 Impact of Climate Change on Livestock Production

The second part of this volume addresses in detail the impact of climate change on livestock production. This part comprises of six chapters covering the direct impacts of climate change on livestock growth, milk production, reproduction, metabolic activity, and disease occurrences. This part also discusses elaborately on the indirect impacts of climate change on livestock, water and pasture availability, and other feed resources. In addition, this part highlights the significance of different inherent mechanisms by which livestock adapts to the changing climate.

1.2.1 Impact on Growth

It is known that livestock that are exposed to high ambient temperatures augment the efforts to dissipate body heat, resulting in the increase of respiration rate, body temperature, and consumption of water and a decline in feed intake (Marai et al.

2007; Sejian et al. 2010a). Apart from feed intake, feed conversion also significantly decreases after exposure to heat stress (Padua et al. 1997). Exposure of the animal to a high environmental temperature stimulates the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite center in the hypothalamus and thereby causes a decrease in feed intake (Marai et al. 2007). The decrease in feed intake could be due to the adaptive mechanism of animal to produce less body heat. Growth, the increase in the live body mass or cell multiplication, is controlled both genetically and environmentally (Marai et al. 2007). Elevated ambient temperature is considered to be one of the environmental factors influencing growth and average daily weight gain in livestock (Habeeb et al. 1992; Ismail et al. 1995). The reason for the effects of elevated ambient temperature on growth reduction could be due to the decrease in anabolic activity and the increase in tissue catabolism (Marai et al. 2007). The increase in tissue catabolism could be attributed to the increase in catecholamines and glucocorticoids after exposure to heat stress in livestock.

1.2.2 Impact on Milk Production

The effect of elevated temperature on milk production is probably most deleterious for any animal production system which forces animal to reduce feed intake, resulting in lowered milk yield (Dunn et al. 2014). The heat stress not only decreases the milk yield in the animals but it also drastically affects the quality of milk (Bernabucci and Calamari 1998). Apart from high temperature, humidity is also an important factor influencing milk yield in the animals. The Jersey crossbreds were less affected by climate than Holstein crossbreds for average milk yield per day. The decreases in milk production can range from 10 to >25 %. As much as 50 % reduction in milk yield can be due to reduced feed intake during thermal stress, and other 50 % might depend on heat-related lactogenic hormone fluctuations (Johnson 1987). Besides the thermal stress, the decline in milk yield is also dependent upon breed, stage of lactation, and feed availability (Bernabucci and Calamari 1998). The effect of heat stress is more in high-yielding cow as compared to low-yielding cow.

The cow exposed to heat stress produces milk and colostrums with lower percentage of protein and fat (Nardone et al. 1997). Milk fat, milk protein, solid not fat (SNF), and total solid percentages were lower in the summer season in dairy cows (Bouraoui et al. 2002; Ozrenk and Inci 2008). Thermal stress also appears to bring about some decrease in percentage of lactose and acidity in the milk which in turn affects the milk freezing point. In addition to this, the heat stress-exposed animals' milk has lower value of calcium (Ca), phosphorus (P), and magnesium (Mg) and high chloride (Bernabucci et al. 2013). In heat-stressed cow, the proportion of short-chain (C4–C10) and medium-chain (C12–C16) fatty acids are low, while long-chain fatty acid (C17–C18) are more in milk (Bernabucci et al. 2013). These changes in the fatty acid chain may be due to reduced synthesis of these free fatty acids (FAA) in the mammary glands as well as due to negative energy status of the cow exposed to thermal stress. Heat stress also has a negative impact on the milk casein (α- and β-casein). The lower content of α- and β-casein tends to increase the pH of milk and lower P content, during the summer months (Kume et al. 1989).

1.2.3 Impact on Reproduction

Reproductive axis is one plane where stress effects are the most pronounced and have gross economic impact. Livestock farmers in arid and semiarid environment primarily depend on their livestock for their livelihood security. The key constraints in arid and semiarid tropical environment are their low biomass productivity, high climatic variability, and scarcity of water (Sejian 2013). All these constraints make these regions a major challenge for sustainable livestock production. In particular, the reproductive potential of livestock in these areas is influenced by the exposure to harsh climatic conditions, namely, high ambient temperature, and long-distance walking in search of food and water resources. It is an established fact that reproduction processes are influenced during thermal exposure in ruminant species (Naqvi et al. 2004) and glucocorticoids are paramount in mediating the inhibitory effects of stress on reproduction (Kornmatitsuk et al. 2008). Heat stress significantly reduces the level of primary reproductive hormone estradiol (Sejian et al. 2011a, 2013). Decreased concentration of estrogen may result from diminished ovarian follicular development caused by suppressed peripheral concentration of gonadotrophins following heat stress (Gougeon 1996). The impact of heat stress on plasma estradiol concentration could be both due to reduced GnRH secretion and reduced feed intake in ewes. Further, glucocorticoids are capable of enhancing the negative feedback effects of estradiol and reducing the stimulation of GnRH receptor expression by estrogen (Adams et al. 1999; Daley et al. 1999). Glucocorticoids may also exert direct inhibitory effects on gonadal steroid secretion and sensitivity of target tissues to sex steroids (Magiakou et al. 1997). Thermal stress influence on estrous incidences and embryo production is a well-established fact (Naqvi et al. 2004; Tabbaa et al. 2008; Sejian et al. 2014a). In the changing scenario of climate change, thermal stress along with feed and water scarcity is the major predisposing factor for the low productivity of ruminants under hot semiarid environment.

Livestock grazing under hot semiarid environment face extreme fluctuations in the quantity and quality of feed on offer throughout the year (Martin et al. 2004). It has been postulated that nutrition is one of the main factors affecting ovulation rate and sexual activity in sheep (Vinoles et al. 2005; Forcada and Albecia 2006). It is generally accepted that nutrition modulates reproductive endocrine functions in many species (Polkowska 1996; Martin et al. 2004). Further, undernutrition affects reproductive function in ruminants at different levels of the hypothalamic-pituitary-gonadal axis (Boland et al. 2001; Chadio et al. 2007). Nutrient deficiency that results following reduced feed intake after heat exposure potentially acts on the reproductive process and affects estrus behavior and ovulation rate. Further, undernutrition lowers estradiol concentration in sheep (Kiyma et al. 2004; Sejian et al. 2014b).

1.2.4 Impact on Pasture and Feed Availability for Livestock

Climate change and associated environmental stress such as drought, high/low temperature, ozone, elevated CO_2, soil water logging, and salinity affect the pasture and forage availability to livestock (Dawson et al. 2014). Collectively, stresses may reduce the harvested forage yield, alter its nutritive value, and change species composition of the sward. With the current societal emphasis on climate change and its related impact, forage crop production will become more important, and thus, the scientific knowledge of how abiotic or environmental stresses limit forage production must increase.

The most important impacts of climate change on grazing lands will likely be through changes in both pasture productivity and forage quality. However, there are several other impacts on grazing lands that researchers will have to address including botanical changes in vegetation composition; pests, diseases, and weeds; soil erosion; and animal husbandry and health (Hall et al. 1998). Rising temperatures could benefit pastures in cooler and boreal climates by increasing the length of the growing season and reducing frost damage. However, increased plant growth in the cooler months could deplete soil moisture at the expense of subsequent pasture growth in the spring. Changes in seasonal patterns of forage availability could pose additional challenges for grazing management. In warmer climates, increased heat stress and increased evaporative demand would likely have negative effects on pastures (Cobon and Toombs 2007). Further, drought, an environmental stress with periods of limited or no water during the growing season, reduces forage production for grazing and haymaking. Prolonged drought forces livestock and hay producers to better manage their fields to minimize recovery after the drought ends. Modeling studies that have calculated “safe” livestock carrying capacity from resource attributes and climate data have indicated that pasture growth is sensitive to small variations in climate and that responses to rainfall are nonlinear (Scanlan et al. 1994; Day et al. 1997).

1.2.5 Impact on Water Availability for Livestock

Researches pertaining to impact of climate change on water resources for livestock are very scanty. Water resources in particular are one sector which is highly vulnerable to climate change. Climate change and variability have the potential to impact negatively on water availability and access to and demand for water in most countries. Climate change will have far-reaching consequences for livestock production, mainly arising from its impact on rainfall patterns which later determine the quantity and quality of grassland and rangeland productivity (Assan 2014). Overall, the net impact of climate change on water resources and freshwater ecosystems will be negative due to diminished quantity and quality of available water (IPCC 2013). Increasing heat stress as a result of climate change will significantly increase water requirements for livestock. Climate change can often exacerbate water problems, for instance, where climate change has led to overgrazing in some areas which then suffer rapid runoff and flooding. The impact of climate change can aggravate water problem in hot semiarid areas leading to overgrazing which ultimately culminate in rapid runoff in these areas leading to flooding. Frequent droughts might be a cause of concern in terms of disease and parasites distribution and transmission, apart from the physical losses to livestock. As a result of climate change, all water resources will dry up due to extreme temperatures, and livestock production will be severely hampered in such cases (Rust and Rust 2013). Further, the drying of water resources will create a situation where livestock need to walk long distances in search of water, creating an additional stress to these animals. Hence, it's going to be a huge challenge for livestock researchers across the globe to develop appropriate strategies to ensure access to water for livestock production.

1.2.6 Impact on Disease Occurrences in Livestock

Global climate change alters ecological construction which causes both the geographical and phonological shifts (Slenning 2010). These shifts affect the efficiency and transmission pattern of the pathogen and increase their spectrum in the hosts (Brooks and Hoberg 2007). Increased spectrum of pathogen increases the disease susceptibility of the animal, and thus climate change supports the pathogenicity of the causative agent. Heavy rainfall causes flood and increases atmospheric humidity which results in favorable condition for the proliferation of pathogen, ticks, flies, and mosquitoes. These pathogens and insects may serve as vector or invader for the transmission of diseases in humans and livestock. Recent disease outbreaks are consistent with model projections that warmer and wetter conditions lead to greater transmission potential even at high altitudes and elevations. Mosquito-borne diseases are now reported at higher elevations than in the past at sites in Asia, Central Africa, and Latin America (Epstein et al. 1998). Environmental changes caused either by natural phenomenon or anthropogenic interference change the ecological balance and context within which disease hosts or vectors and parasites breed, develop, and transmit disease (Patz et al. 2000). Climate change affects the occurrence and spread of disease by impacting the population size and range of hosts and pathogens, the length of the transmission season, and the timing and intensity of outbreaks (Epstein et al. 1998). Pathogens from terrestrial and marine taxa are sensitive to hot temperature, heavy rainfall, and humidity. Climate warming can increase pathogen development and survival rates, disease transmission, and host susceptibility (Harvell et al. 2002). Understanding the spatial scale and temporal pattern of disease incidence is a fundamental prerequisite for the development of appropriate management and intervention strategies. It is particularly important given the need to understand the elevated risks linked to climate change (Rose and Wall 2011).

Global climate change predictions suggest that far-ranging effects might occur in the population dynamics and distributions of livestock parasites, provoking fears of widespread increases in disease incidence and production loss (Morgan and Wall 2009). Climatic restrictions on vectors, environmental habitats, and disease-causing agents are important for understanding the outbreak of several animal diseases. Changes in temperature and precipitation regimes may result in spread of disease and parasites in new regions or produce high incidence of diseases with concomitant decrease in animal productivity and increase in mortality (Baker and Viglizzo 1998). Baylis and Githeko (2006) evaluated the effect of climate change on parasites, pathogens, disease hosts, and disease vectors on domestic livestock. The potential clearly exists for the increased rate of development of pathogens and parasites due to early arrival of spring and warmer winters, and such seasonal change allows greater proliferation and survivability of these organisms. Warming and changes in rainfall distribution may lead to changes in spatial or temporal distributions of diseases such as anthrax, blackleg, hemorrhagic septicemia, and vector-borne diseases that thrive in the presence of moisture.

1.2.7 Adaptation Mechanisms of Livestock to Climate Change

The process by which the animals respond to extreme climatic condition includes: genetic or biological adaptation, phenotypic or physiological adaptation, acclimatization, acclimation, and habituation (Gaughan 2012). The behavioral and physiological mechanisms are the initial response by which livestock tries to adapt when exposed to adverse environmental condition. Neuroendocrine responses to stress play an integral role in the maintenance of homeostasis in livestock. Substantial evidence suggests that neuroendocrine responses vary with the type of stressor and are specific and graded, rather than “all or none.” While acute responses have important adaptive functions and are vital to coping and survival, chronic stressors elicit endocrine responses that may actually contribute to morbidity and mortality (Sejian et al. 2010b; Mohankumar et al. 2012). Integration of these responses is possible through the network of mutual interactions that exist between the immune system, the central nervous system, and the endocrine system. A crucial component of this network is the stress axis or hypothalamic-pituitary-adrenal (HPA) axis. Activation of the stress axis is accomplished through the release of several neurotransmitters and hormones.

Heat shock response is a rapid molecular mechanism, transient, and short acting which emerges via production of heat shock proteins (HSPs), subsequent to exposure of the cells to sublethal stress (Saxena and Krishnaswamy 2012). The heat shock response involves both heat shock factors (HSFs) and HSPs. The heat shock response is induced by accumulation of mis-folded proteins in the cytoplasm and is mediated by HSFs. HSF-1, HSF-2, HSF-3, and HSF-4 have been identified to date. HSF-1 plays a major role in heat shock response, while other members (HSF-2, HSF-4) are activated after prolonged stress or participate in normal cellular processes, embryonic development, and cellular differentiation. Once activated, the HSF-1 monomer trimerizes with other HSF-1 molecules which is essential for DNA binding. The activated complex can then enter the nucleus and initiate transcription of heat shock proteins.

Genetic selection has been a traditional method to reduce effects of environment on livestock by development of animals that are genetically adapted to hot climates. Despite the strong knowledge base about the physiological aspects, the effects of heat stress at the cellular and genetic level are not clearly understood. It is the cellular/molecular level at which stress also has its deleterious effects. Thus, the adaptive response is observed at cellular level as well, and an insight into the molecular/cellular mechanism of stress relieve is important (Naskar et al. 2012). As a result of stress, there are an increased number of nonnative conformational proteins with anomalous folding. Heat shock proteins, as we know, are evolutionary conserved, and many of them act as regulator of protein folding and structural functions of proteins. There is a presence of common environment-specific response genes, making 18–38 % of the genome. These genes induce expression of classical heat shock proteins, osmotic stress protectants, protein degradation enzyme, etc.

Functional genomic research is providing new knowledge about the impact of heat stress on livestock production and reproduction. Using functional genomics to identify genes that are regulated up or down during a stressful event can lead to the identification of animals that are genetically superior for coping with stress and toward the creation of therapeutic drugs and treatments that target affected genes. Given the complexity of the traits related to adaptation to tropical environments, the discovery of genes controlling these traits is a very difficult task. One obvious approach of identifying genes associated with acclimation to thermal stress is to utilize gene expression microarrays in models of thermal acclimation to identify changes in gene expression during acute and chronic thermal stress. Further, gene knockout models in single cells also allow for better delineation of the cellular metabolic machinery required to acclimate to thermal stress. With the development of molecular biotechnologies, new opportunities are available to characterize gene expression and identify key cellular responses to heat stress. These new tools enable to improve the accuracy and the efficiency of selection for heat tolerance. Epigenetic regulation of gene expression and thermal imprinting of the genome could also be an efficient method to improve thermal tolerance.

1.3 Role of Livestock in Climate Change

Part III of this volume deals with livestock role in climate change. The primary focus of this part is to address contribution of livestock and its related activities to global climate change. Globally, ruminant livestock are responsible for about 85 Tg of the 550 Tg CH_4 released annually (Sejian et al. 2011b). This part comprises six chapters covering in depth the livestock-related sources and sinks for GHG emission, enteric CH_4 emission, enteric CH_4 emission in different feeding systems, different methodologies to estimate enteric CH_4 emission, role of metagenomics in understanding rumen microbial diversity, and opportunities and challenges for livestock C sequestration.

1.3.1 Enteric Methane Emission

Ruminant animals, particularly cattle, buffalo, sheep, goat, and camels, produce significant amounts of CH_4 under the anaerobic conditions present as part of their normal digestive processes. This microbial fermentation process, referred to as “enteric fermentation,” produces CH_4 as a by-product, which is released mainly through eructation and normal respiration, and small quantities as flatus. CH_4 production through enteric fermentation is of concern worldwide for its contribution to the accumulation of GHGs in the atmosphere, as well as its waste of fed energy for the animal. Among livestock, CH_4 production is greatest in ruminants, as methanogens are able to produce CH_4 freely through the normal process of feed digestion. Globally, ruminant livestock produce ~ 80 Tg of CH_4 annually, accounting for ~ 33 % of anthropogenic emissions of CH_4 (Beauchemin et al. 2008). CH_4 produced by cattle and other ruminants is actually a loss of feed energy from the diet and represents inefficient utilization of the feed. Enteric CH_4 is produced under anaerobic conditions in the rumen by methanogenic archaea, using CO_2 and H_2 to form CH_4, thus reducing the metabolic H_2 produced during microbial metabolism (McAllister and Newbold 2008). The amount of CH_4 produced from enteric fermentation is influenced by various factors including animal type and size, digestibility of the feed, and the intake of dry matter, total carbohydrates, and digestible carbohydrates (Wilkerson et al. 1995). Typically, about 6–10 % of the total gross energy consumed by the dairy cow is converted to CH_4 and released via the breath (Eckard et al. 2010). Therefore, reducing enteric CH_4 production may also lead to production benefits.

As animal production systems are vulnerable to climate change and are large contributors to potential global warming through CH_4, it is very vital to understand in detail the enteric CH_4 emission in different livestock species. Before targeting the reduction strategies for enteric CH_4 emission, it is very important to know the mechanisms of enteric CH_4 emission in livestock, the factors influencing such emission and prediction models, and estimation methodology for quantification of enteric CH_4 emission. The thorough understanding of these will in turn pave way for the formulation of effective mitigation strategies for minimizing enteric CH_4 emission in livestock.

1.3.2 Enteric Methane Emission Under Different Feeding System

Since CH_4 production is negatively correlated with total VFA and proportion of propionate (Wang et al. 2009), improvements in ruminal fermentation that favor propionic acid may also allow a decrease in CH_4 production, because propionic acid contains more hydrogen than other volatile fatty acids (VFA). Hence, the pattern of ruminal fermentation may be changed by the use of different cereal sources that encourage effective utilization of the other feed ingredients (Danielsson et al. 2014). The degradation rate of cereal starch differs based on the source (cornstarch less degradable than barley) which in turn may modify ruminal fermentation pattern (Schimidely et al. 1999). A higher content of fibrous carbohydrates in diets of low feeding value increases the CH_4 emitted per unit feed digested (Moe and Tyrell 1979). A higher rate or ruminal starch digestion for barley than for corn has resulted in greater efficiency of microbial synthesis for dairy ruminants (McCarty et al. 1989). An increase in the concentrate ratio may improve the nutritional status of animals and will also increase the ratio of propionic to acetic acid. Concentrate supplementation at higher levels sometimes leads to metabolic disorders, but ruminants can learn the physiological consequences of ingestion of particular feeds and can recognize the limit of feed ingredients offered as free choice according to their post-ingestive effects (Yurtseven and Gorgulu 2004) and thus can consume high concentrate feed without suffering from metabolic disorders (Fedele et al. 2002). Further, free choice system of feeding has been reported to emit lower CH_4 and CO_2 as compared to total mixed ration in sheep (Sabri et al. 2009). CH_4 production (g per unit production) is generally higher for ruminant livestock in extensive grassland-based systems than in intensive systems where diets offered are typically higher quality. In contrast, CH_4 production (g per day) is typically lower in grassland-based systems due to low levels of productivity (Sere and Gronewold 1996).

1.3.3 Estimation Methodologies for Enteric Methane Emission

Knowledge about methods used in quantification of GHG is currently needed to curtail global warming and to execute the international commitments to reduce the emissions. In the agricultural sector, one important task is to reduce enteric CH_4 emissions from ruminants. Accurate CH_4 measurements are required for identifying mitigation strategies that can discriminate among treatments relevant to on-farm conditions (Lassey 2008). Different methods for quantifying these emissions are presently being used and others are under development, all with different conditions for application (Storm et al. 2012; Bhatta et al. 2008). There are several methodologies available such as open-circuit respiration chambers, sulfur hexafluoride (SF6) tracer technique, inverse-dispersion technique, micrometeorological mass difference technique, and backward Lagrangian stochastic (bLS) dispersion technique (Sejian et al. 2011b). For researchers working with reduction of enteric methane emission, it is very important to understand the advantages and disadvantage of the different methods in use which will help them to quantify methane. Chapter 13 addresses in detail the different methodologies currently being employed and their significance in quantifying enteric CH_4 emission in ruminants.

1.3.4 GHG Emission from Livestock Manure

Livestock manure and its common use as fertilizer contribute to GHG emissions. Manure contains organic compounds such as carbohydrates