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Research Article

EFFECTS OF CLIMATE CHANGE ON LIVESTOCK PRODUCTION AND MITIGATION STRATEGIES – A REVIEW

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ABSTRACT
Climate change is a long-term shift in the statistics of the weather such as temperature, radiation, wind and rainfall characteristics of a particular region. Climate change has profound effect on livestock. The anticipated rise in temperature due to climate change is likely to aggravate the heat stress in livestock, adversely affecting their productive and reproductive performance. The predicted negative impact of climate change on agriculture would also adversely affect livestock production by aggravating the feed and fodder shortages. The livestock sector which will be a sufferer of climate change is itself a large source of methane emissions, an important greenhouse gas. The paper mainly reviews the contribution of livestock to climate change and impacts of climate change on livestock milk production, reproduction, livestock diseases and mitigation strategies to counteract climate change effects.

Keywords*: *Anthropogenic Influence, Carbon Sequestration, Global Warming, Production, Reproduction

INTRODUCTION
The world's population has reached seven billion people (Tollefson, 2011). Currently, we emit over 29 billion metric tons of CO_2 in our atmosphere each year (Boden *et al.*, 2009). Most climatologists agree that the increase in green-house gases in our atmosphere is causing an increase in air temperature (Ta) and that future increases in temperature pose a clear and present danger to the distribution and abundance of animal and plant populations worldwide (Thompson, 2010). Even though a large number of people doubt the reality of global warming, and others simply choose to ignore it, the increase in the earth's air temperature over the last 100 years seems incontrovertible, as does the fact that these increases are not a result of natural phenomenon (Thompson, 2010; Oerlemans, 2005; Thompson *et al.*, 2009; Briffa *et al.*, 2002; Crowley and Lowery, 2000; Moberg *et al.*, 2005). In the decades to come, if they are to survive, species will need to alter their distribution patterns, change their behavior patterns, and/or make adjustments in their physiology, either by short-term acclimation through phenotypic flexibility or by longer-term evolutionary shifts in physiological phenotype by means of natural selection (Angilletta, 2009; Chown *et al.*, 2010). If scientists are to predict the consequences of global warming for animals, we will need to understand how individual animals will respond to higher air temperatures through phenotypic flexibility (Portner and Farrell, 2008; Somero, 2011). Direct effects from air temperature, humidity, wind speed and other climate factors influence animal performance: growth, milk production, wool production and reproduction (Houghton *et al.*, 2001). Indirect effects include climatic influences on the quantity and quality of feedstuffs such as pasture, forage, grain and the severity and distribution of livestock diseases and parasites (Seo and Mendelsohn, 2006a). The Earth's climate depends on the functioning of a natural "greenhouse effect." This effect is the result of heat-trapping gases (also known as greenhouse gases) like water vapor, carbon dioxide, ozone, methane, and nitrous oxide, which absorb heat radiated from the Earth's surface and lower atmosphere and then radiate much of the energy back towards the surface. Direct and indirect sources of GHG emissions in animal production systems include physiological processes from the animal (enteric fermentation and respiration), animal housing, manure storage, treatment of manure slurries (compost and anaerobic treatment), land application, and chemical fertilizers (Casey *et al.*, 2006; Monteny *et al.*, 2001). Direct emissions refer to emissions directly produced from the animal including enteric fermentation and manure and urine excretion (Jungbluth *et al.*, 2001). Specifically, livestock produce CH_4 directly as a byproduct of digestion via enteric

fermentation (i.e., fermenting organic matter via methanogenic microbes producing CH_4 as an end-product) (Jungbluth *et al.*, 2001). The climate is changing, significant changes in physical and biological systems have already occurred on all continents and in most oceans, and most of these changes are in the direction expected with warming temperature (Rosenzweig *et al.*, 2008). Of the planet's 1.3 billion poor people, at least 90% of them are located in Asia and sub-Saharan Africa, and climate change will have major impacts on the more than 600 million people who depend on livestock for their livelihoods (Thornton *et al.*, 2002). Livestock production is adversely affected by detrimental effects of extreme climatic conditions. Consequently, adaptation and mitigation of detrimental effects of extreme climates have played a major role in combating the climatic impact in livestock production (Khalifa, 2003). Housing and management technologies which can reduce climatic impacts on livestock are available, but the rational use of such technologies is crucial for the survival and profitability of the livestock enterprise (Hahn, 1981; Gaughan *et al.*, 2002).

Climate Change and Green House Gases

Climate change, defined as the long-term imbalance of customary weather conditions such as temperature, radiation, wind and rainfall characteristics of a particular region, is likely to be one of the main challenges for mankind during the present century. The earth's climate has warmed in the last century (0.74 ± 0.18°C) with the 1990s and 2000s being the warmest on instrumental record (Intergovernmental Panel on Climate Change (IPCC), 2007). Furthermore, the earth's climate has been predicted to change continuously at rates unprecedented in recent human history (IPCC, 2007). Current climate models indicated an increase in temperature by 0.2°C per decade and predicted that the increase in global average surface temperature would be between 1.8°C to 4.0°C by 2100 (IPCC, 2007). Climate change is a long-term shift in the climate of a specific location, region or planet. The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation. Many impacts of climate change are already detectable. As glaciers retreat, the sea level rises, the tundra thaws, hurricanes and other extreme weather events occur more frequently, and penguins, polar bears, and other species struggle to survive (Topping, 2007), experts anticipate even greater increases in the intensity and prevalence of these changes as the 21st century brings rises in Green House Gases (GHGs) emissions. The three main GHGs are CO_2, methane (CH_4), and nitrous oxide (N_2O) (Steinfeld *et al.*, 2006). Although most attention has focused on CO_2, methane — both are extremely potent GHGs—have greater global warming potentials (GWPs). The five warmest years since the 1890s were 1998, 2002, 2003, 2004, and 2005 (NASA (National Aeronautics and Space Administration), 2006). Indeed, average global temperatures have risen considerably, and the Intergovernmental Panel on Climate Change (IPCC, 2007c) predicts increases of 1.8–3.9°C (3.2–7.1°F) by 2100. These temperature rises are much greater than those seen during the last century, when average temperatures rose only 0.06°C (0.12°F) per decade (National Oceanic and Atmospheric Administration, 2007). IPCC's latest report (IPCC, 2007b) warns that climate change "could lead to some impacts that are abrupt or irreversible."

Anthropogenic Influences on Climate Change

Although some natural occurrences contribute to GHG emissions (IPCC, 2007c), the overwhelming consensus among the world's most reputable climate scientists is that human activities are responsible for most of this increase in temperature (IPCC, 2007a). The IPCC (2007a) concluded with high confidence that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems. Although transportation and the burning of fossil fuels have typically been regarded as the chief contributors to GHG emissions and climate change, a 2006 report, *Livestock's Long Shadow: Environmental Issues and Options* (Food and Agriculture Organization of the United Nations (FAO), 2006), highlighted the substantial role of the farm animal production sector. Identifying it as "a major threat to the environment" (FAO 2006), the FAO found that the animal agriculture sector emits 18%, or nearly one-fifth, of human-induced GHG emissions; more than the transportation sector (Steinfeld *et al.*, 2006). Of all the natural and human-induced influences on climate over the past 250 years, the largest is due to increased CO2 concentrations attributed to burning fossil fuels and deforestation (Bierbaum *et al.*, 2007). The scientific evidence of anthropogenic interference with the climate system through GHG emissions has led to worldwide research on assessing impacts that could result from potential climate change associated with GHG accumulation (Sejian, 2012).

Contribution of Livestock to Climate Change

The animal production system, which is vulnerable to climate change, is itself a large contributor to global warming through emission of methane and nitrous oxide.

There are two sources of GHG emissions from livestock:

(a) From the digestive process: Methane is produced in herbivores as a by-product of 'enteric fermentation' a digestive process by which carbohydrates is broken down by micro-organisms into simple molecules for absorption into the blood stream.

(b) From animal wastes: Animal wastes contain organic compounds such as carbohydrates and proteins. During the decomposition of livestock wastes under moist, oxygen free (anaerobic) environments, the anaerobic bacteria transform the carbon to methane. Animal wastes also contain nitrogen in the form of various complex compounds. The microbial processes of nitrification and de-nitrification forms nitrous oxide, which is emitted to the atmosphere.

Enteric Fermentation

Ruminants are unique in their ability to convert plants on non-arable land to protein. This characteristic allows ruminants to utilize land and feed that would otherwise be un-used for human food production. At the same time, ruminant livestock is an important contributor to CH_4 in the atmosphere (FAO *et al.*, 2006; IPCC, 2000; USDA, 2004). Methane is produced from the microbial digestive processes of ruminant livestock species such as cattle, sheep, and goats. Non-ruminant livestock such as swine, horses, and mules produce less CH_4 than ruminants (USDA, 2004). The primary source of CH_4 from ruminant livestock is from the process of enteric fermentation during rumination (Casey *et al.*, 2006; Jungbluth *et al.*, 2001; Kaspar and Tiedje, 1981; Sun *et al.*, 2008). Initial microbial breakdown (essential in ruminant digestion) occurs in the rumen, or large fore-stomach, where microbial fermentation converts fibrous feed into products digested and utilized by the animal (Boadi *et al.*, 2004; USDA, 2004). Rumination promotes digestion of cellulose and hemicelluloses through hydrolysis of polysaccharides by microbes and protozoa, which is followed by microbial fermentation generating H_2 and CO_2. Methane is produced as a by-product of enteric fermentation and carbohydrate digestion and is expelled through the mouth via eructation (Monteny *et al.*, 2001).

In ruminant livestock, enteric fermentation is strongly affected by quantity and quality of their diet (Johnson and Johnson, 1995). Production of CH_4 in ruminants is directly correlated to a loss of metabolizable energy and has been studied in depth during performance studies that aimed at improvements of feed efficiency (Johnson and Johnson, 1995; Jungbluth *et al.*, 2001; Mosier *et al.*, 1998b). Cattle typically lose 2–12% of their ingested energy as eructated CH_4 (Johnson and Johnson, 1995). Many factors affect CH_4 emissions from livestock including feed intake, animal size, diet, growth rate, milk production, and energy consumption (Johnson and Johnson, 1995; Jungbluth *et al.*, 2001). Diet and level of production directly affect CH_4 emission rates (Holter and Young, 1992; Jungbluth *et al.*, 2001; Sun *et al.*, 2008). For example, CH_4 outputs are estimated to range from 3.1 to 8.3% of gross energy intake for dry, non-lactating cows and from 1.7 to 14.9% of gross energy intake for lactating cows (Holter and Young, 1992). Enteric CH_4 emissions per unit of production are highest when feed quality and level of production are low (Crutzen *et al.*, 1986).

Animal Manure

The management of animal manure can produce anthropogenic CH_4 via anaerobic decomposition of manure and N_2O via nitrification and denitrification of organic N in animal manure and urine (Bouwman, 1996). Typically, when livestock manure is stored or treated in lagoons, ponds, or tanks (i.e., anaerobic conditions), CH_4 emissions are produced in higher amounts than when manure is handled as a solid (e.g., stacks or drylot corrals), or deposited on pasture where aerobic decomposition occurs thereby reducing CH_4 emissions (EPA *et al.*, 2006). Because a strong relationship exists between manure application on land and N_2O emissions (Bouwman, 1996; Jarecki *et al.*, 2008), the emissions associated with fertilization need to be considered a GHG source.

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A major factor influencing N_2O emissions from agricultural land is N application (Jarecki *et al.*, 2008). The form of fertilizer applied as well as the placement in the soil influences the flux of N_2O emissions (Breitenbeck *et al.*, 1980; Bremner *et al.*, 1981). Both CH_4 and N_2O can be produced by the decomposition of manure. However, N fertilization reduces soil CH_4 oxidation (Jarecki *et al.*, 2008).

Methane is produced via the anaerobic decomposition of manure while N_2O is produced via nitrification and denitrification of land incorporated manure (Chen *et al.*, 2008). Both CH_4 and N_2O production are influenced by multiple variables including climate, soil conditions, substrate availability, and land management practices (Chen *et al.*, 2008).With respect to management in the developed world, the increased use of liquid versus dry manure waste systems (liquid systems produce significantly more methane) in dairy and pig operations has resulted in a relative increase in methane production (FAO *et al.*, 2006).

Specifically, in the United States,CH_4 emissions from manure management increased by 34% between 1990 and 2006 primarily due to an increase in liquid manure systems (EPA *et al.*, 2006). One reason for the trend toward liquid-based systems is a response to regulations in the United States including the United States Clean Water Act, which restricts land application rates of manure. The emerging use of CH_4 digesters offers a potential mitigation of CH_4 emissions from liquid manure systems coupled with electricity, gas, and biofuel generation. Current assumptions predict a 50–75% reduction (depending on environmental conditions) in digester GHG emissions from manure when compared with the current system where the manure would otherwise be stored as a liquid slurry in a lagoon (AgStar, 2002).

Nitrogen assimilation efficiencies vary considerably among different livestock with a range between 10% in beef cattle and 38–75% for swine (Castillo *et al.*, 2001; Hoekstra *et al.*, 2007). As a result, a significant amount of N is returned to the environment through animal excretions (Clemens and Huschka, 2001; Hoekstra *et al.*, 2007). This N can re-enter the crop-production cycle, or depending on the conditions be emitted as N_2O or NH_3 (Mosier *et al.*, 1998b). Direct N_2O emissions are produced as part of the N cycle through the nitrification and denitrification of organic N in livestock manure and urine (Mosier *et al.*, 1998b). Annual N losses via N_2O have been previously calculated between 0 and 5% of N applied for manure (Jarecki *et al.*, 2008). Indirect N_2O emissions are produced from N lost as runoff, and leaching of N during treatment, storage, and transportation (Mosier *et al.*, 1998b).

With respect to animal diet, higher energy feed will have increased methane production from manure. For example, feedlot cattle fed a concentrate diet (i.e., high energy) generate manure with up to 50% higher CH_4 compared to range cattle eating a forage (i.e., low energy) diet (this trend is reversed for enteric fermentation where feedlot versus range cattle produce much less CH_4 per unit of production). Consequently, according to LLS (FAO *et al.*, 2006), the United States (highly intensive production systems) currently has the highest methane emissions factor for manure globally for both dairy and beef cattle (FAO *et al.*, 2006). However, high levels of methane emissions from manure management are typically associated with high levels of productivity (FAO *et al.*, 2006). Therefore, per unit of production, more efficient productions systems are superior in the reduction of GHG (Capper *et al.*, 2009).

Sensitivity of Livestock Production to Climate Change

Global climate change is expected to alter temperature, precipitation, atmospheric carbon dioxide 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 product (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 (Fuquay, 1981; Morrison, 1983; St-Pierre *et al.*, 2003).

There is a substantial scientific literature examining the relationship between climatic characteristics (temperature, humidity, wind speed, etc.) and animal productivity (NRC, 1981). Fundamental too much of this literature is the concept of the thermonuetral zone – the optimal range of temperatures and environmental conditions in which the animals do not need to alter behavior or physiological function to maintain a normal body temperature. At temperatures below the thermonuetral zone, livestock generally expend more energy and increase their voluntary feed intake in order to maintain their core temperature, resulting in lower feed efficiency (NRC, 1981). Maintaining an adequate temperature can be an important factor influencing design of housing and in husbandry decisions for cold susceptible animals such as poultry, swine, and young animals. Low temperatures resulting from particularly cold weather or loss of power to buildings housing confined animals, can cause economic losses from increased animal morbidity or death (Mader, 2003).

Above the thermoneutral zone, animals may experience heat stress and respond by reducing their voluntary feed intake, which reduces their weight gain and feed efficiency (Hahn, 1999; NRC, 1981; West, 1994; Cooper and Washburn, 1998; Yalcin *et al.*, 2001). Heat stress can also reduce fertility, milk production, and reproduction (Hansen *et al.*, 2001; Drost *et al.*, 1999; Renaudeau and Noblet, 2001). Extended periods of high temperature can be lethal for livestock, and a particular risk for feedlot cattle in some regions (Hahn *et al.*, 1999; Hahn and Mader, 1997). Global warming is likely to increase temperature levels and the frequency of extreme temperatures – hotter daily maximums and more frequent or longer heat waves – which could adversely affect livestock production in the warm season. In some regions, economic losses due to warmer temperatures in the summer may be offset by greater productivity in the winter (Hatfield *et al.*, 2008). A limited number of studies have used agricultural engineering models of the relationship between climatic conditions and feed intake to estimate the effects of climate change on the performance of domestic animals.

Frank *et al.*, (2001) used a model relating climate to feed intake and weight gain and milk production to estimate the response of dairy cows to predicted climate changes in the Great Plains region. The study estimated reductions in milk production of 5.1% to 6.8% by 2090 in the absence of efforts to mitigate the effects of temperature changes (e.g. by using evaporative cooling in barns). The organ systems of animals respond to physical, chemical, biological and climatic stimuli from their surroundings and work in concert to perform the essential body functions. The performance (e.g., growth, milk and wool production, reproduction), health and wellbeing of the livestock is strongly affected by climate both, directly and indirectly.

Direct Effects

Climate Change Effects on Feed Intake

Increased atmospheric temperatures will reduce the rate of animal feed intake and result in poor growth performance. Animals in a highly productive state, such as high-producing dairy cows, have feed intakes and metabolic rates that may be two to four times higher than at maintenance. Heat stress in such high producing lactating dairy cows results in dramatic reductions in roughage intake and rumination (Collier *et al.*, 1982). The reduction in appetite under heat stress is a result of elevated body temperature and may be related to gut fill. Decreased roughage intake contributes to decreased VFA production and may lead to alterations in the ratio of acetate and propionate. In addition, rumen pH is depressed during heat stress (Collier *et al.*, 1982). In contrast, ruminants adapted to hot environments are able to maintain their appetite under heat stress at near maintenance or during moderate growth. In chamber experiments, heat-stressed cows changed their feeding pattern and ate when temperatures were cooler. In temperature stress experiments with lactating cows, showed that the major decrease in milk production at high ambient temperatures is a result of reduced feed intake. Using rumen-fistulated lactating cows, the drop in milk production due to heat stress could be reduced by placing feed rejected due to thermal stress directly into the rumen.

Climate Change Effects on Livestock Milk Production

Climatic factors or seasonal changes greatly influence the behavior of animals due to neuroendocrine response to climatic elements, consequently affecting production and health of animals (Shelton, 2000; Sejian *et al.*, 2010a; Baumgard *et al.*, 2012). Climate change is a major threat to the viability and sustainability of livestock production systems in many regions of the world (Gaughan *et al.*, 2009). High production animals are subjected to greater influence by climatic factors, particularly those rose under tropical conditions, due to high air temperatures and relative humidity (Gaughan *et al.*, 2008; Martello *et* *al.,* 2010). Climatic factors such as air temperature, solar radiation, relative humidity, air flow and their inter- actions, often limit animal performance (Sharma *et al.*, 1983). Quantifying direct environmental effects on milk production is difficult as milk production is also strongly affected by other factors such as nutritional management (Fuquay, 1981), that may or may not be directly linked to environmental factors. Thatcher (1974) and Johnson (1976), however, reported declines in the productions of milk and fat as a direct result of high environmental temperatures. This may be because heat stress has negative effects on the secretory function of the udder (Silanikove, 1992). McDowell *et al.,* (1976) suggested that milk production is reduced 15%, accompanied by a 35% decrease in the efficiency of energy utilization for productive purposes, when a lactating Holstein cow is transferred from an air temperature of 18°C to 30 °C. Milk fat, solids-not-fat, and milk protein percentage decreased 39.7, 18.9 and 16.9%. In addition, Johnson (1976) attributed 3–10% of the variance in lactation milk production to climatic factors. Differences in the physiological responses of cattle to the form and duration of heat stress have been reported and differences have also been noted in productive responses.

Cows maintained under similar temperatures during the day but at 25°C at night did not decrease milk production beyond that normally expected under temperate conditions (Richards, 1985). The point on the lactation curve at which the cow experiences heat stress is also important for the total lactation yield. Cows are less able to cope with heat stress during early lactation. Heat stress at the initiation of lactation negatively impacts the total milk production. Furthermore, Sharma *et al.,* (1983) concluded that climatic conditions appeared to have maximum influenced during the rest 60 days of lactation. This early lactation period is when high producing cows are in negative energy balance and make up for the deficit by mobilizing body reserves. Catabolic processes are associated with metabolic heat production over and above that already induced by high nutrient intake. Under Mediterranean climatic conditions, summer calvers produce less milk per lactation than winter calvers (Barash *et al.*, 1996). Summer temperatures in the Mediterranean region generally are above the TNZ of dairy cows and result in heat stress. At 40°C, dietary intake may decline by as much as 40% (National Research Council, 1989).

Heat stress causes the rostral cooling center of the hypothalamus to stimulate the medial satiety center which inhibits the lateral appetite center, resulting in reduced dietary intake and consequently lower milk production (Albright and Alliston, 1972). Animals in a highly productive state, such as high-producing dairy cows, have feed intakes and metabolic rates that may be two to four times higher than at maintenance (National Research Council, 1989).

Climate Change Effects on Livestock Reproduction

Reproductive functions of livestock are vulnerable to climate changes and both female and males are affected adversely. Heat stress also negatively affects reproductive function (Amundson *et al.,* 2006; Sprott *et al.*, 2001). The climate change scenario due to rise in temperature and higher intensity of radiant heat load will affect reproductive rhythm via hypothalamo- hypophyseal–ovarian axis. The main factor regulating ovarian activity is GnRH from hypothalamus and the gonadotropins i.e. FSH and LH from anterior pituitary gland (Madan and Prakash, 2007). Gilad *et al.,* (1993) and Wise *et al.*, (1988) reported the decrease in LH pulse amplitude and frequency in heat stressed cattle. Plasma inhibin content was lower in heat stress cows (Wolfenson *et al.*, 1995) and cyclic buffaloes (Palta *et al.*, 1997). The effects are more pronounced in buffaloes than cattle which may be due to high thermal load in this species as a result of difficulty in heat dissipation due to unavailability of place for wallowing and lesser number of sweat glands (Vaidya *et al.,* 2010; Shashikant *et al.,* 2010). Therefore, heat mitigation measures and strategies need to be adopted not only to reduce thermal stress but also to curtail fertility losses and other health consequences on animals. It is likely that the direct impact of global warming on mammalian reproduction will be more severe for domestic animals. The potential impact of heat stress on a mammalian population can be seen by examining seasonal trends in reproductive functions of livestock species. Indeed, the effects of summer in lowering fertility is much less in non-lactating heifers and low producing cow compared with high yielding cows as reported by Badinga *et al.*, (1985) and Al- Katanani *et al.*, (1999). The expression of estrus and conception rate was recorded low during summer in crossbred cattle and buffaloes. Low estradiol level on the day of estrus during summer period in buffaloes may be the likely factor for poor expression of estrus in this species (Upadhyay *et al.,* 2009). During heat stress by climate change, motor activity and other manifestations of estrus reduced (Nobel *et al.,* 1997) and the incidence of anestrus and silent ovulation are increased (Gwazdauskas *et al.,* 1981). Due to these effects a reduction in the number of mounts during heat stress compared to cold weather, leading to poor detection of estrus (Pennington *et al.,* 1985). Studies based on projected global climate change models, showed that changes in climate would lead to decrease in milk yield and conception rate in dairy cows (Hahn *et al.,* 1992; Klinedinst *et al.,* 1993). Hahn (1995) further reported that conception rates in dairy cows were reduced 4.6% for each unit change in THI, when the THI reaches above 70. Amundson *et al.,* (2005) reported decrease in pregnancy rates of Bos Taurus cattle of 3.2% for each unit increase in average THI 70, and a decrease of 3.5% for each increase in average temperature above 23.4° C. Amundson *et al.,* (2006) further reported that the environmental variable i.e. minimum temperature of the day had the greatest influence on the percent of cows getting pregnant were not adapted to these conditions.

The number of changes in reproductive performance due to further global warming will include:

- Decreased duration and intensity of the estrus period.
- Decreased conception (fertility) rate.
- Decreased size and development of ovarian follicles.
- Decreased fetal growth and calf weight at calving.
- Increased risk of early embryonic losses.
- Increased number of artificial insemination per conception.
- Increased incidence of silent heat in buffaloes.

Ehnert and Moberg (1991) reported that thermal stress affects the preovulatory release of LH, expression of estrus behavior and causes delay in ovulation. High ambient temperature reduces the circulating estradiol–17â concentration and sometimes increases the adrenocorticotropin secretion, which itself can block estradiol induced estrus behavior (Hansen and Arechiga, 1999). The preovulatory release of LH and the expression of estrus behavior seem to be especially sensitive to stress (Dobson and Smith, 2000). The thyroid gland also plays a role in decreasing the reproductive activity during thermal stress (Farghaly, 1984) with a decrease in the level of triiodothyronine (T3) and thyroxin (T4) hormone. Putney *et al.,* (1988) and Alfujairi *et al.,* (1993) reported adverse effect of hot summer on the ovulation rate in cows. In cattle, as for other species, exposure of pregnant females to heat stress during the embryonic period leads to embryonic loss (Ealy *et al.*, 1993). Heat shock leads to embryonic death, at least in part, because protein synthesis is reduced (Edwards and Hanseen, 1997) and concentration of free radicals increases. Heat stress drastically reduces the pregnancy rates (Hahn *et al*., 2003). In addition to effects on embryonic mortality heat stress reduces the duration and intensity of sexual behavior and estrus incidences (Naqvi *et al*., 2004). During heat stress redistribution of blood flow from the viscera to the periphery increases for dissipation of heat, which leads to reduce blood supply to placentas (Alexander and Williams, 1971) and retards fetal growth (Collier *et al.,* 1982). The likely impacts of global warming under climate change scenarios indicate that projected temperature rise will increase duration of thermal stress on lactating cattle and negatively impact gonadal functions.

Climate Change Effects on Disease Occurrence in Livestock

The impacts of changes in ecosystems on infectious diseases depend on the ecosystems affected, the type of land-use change, disease specific transmission dynamics, and the susceptibility of the populations at risk (Patz *et al.,* 2005a) – the changes wrought by climate change on infectious disease burdens may be extremely complex. Climate change will affect not only those diseases that have a high sensitivity to ecological change, but there are also significant health risks associated with flooding. The major direct and indirect health burdens caused by floods are widely acknowledged, but they are poorly characterized and often omitted from formal analyses of flood impacts (Few *et al.*, 2004).

Effects on pathogens: Higher temperatures may increase the rate of development of pathogens or parasites that spend some of their life cycle outside their animal host, which may lead to larger populations (Harvell *et al.,* 2002). Other pathogens are sensitive to high temperatures and their survival may decrease with climate warming.

Effects on vectors: There may be several impacts of climate change on the vectors of disease (midges, flies, ticks, mosquitoes and tsetse are all important vectors of livestock disease in the tropics. It has also been shown that the ability of some insect vectors to become or remain infected with viruses (such as bluetongue) varies with temperature (Wittmann and Baylis, 2000). The feeding frequency of arthropod vectors may also increase with rises in temperature. As many vectors must feed twice on suitable hosts before transmission is possible (to acquire and then to transmit the infection), warmer temperatures may increase the likelihood of successful disease transmission.

Other Indirect Effects

Climate change may also affect the abundance and/or distribution of the competitors, predators and parasites of vectors themselves, thus influencing patterns of disease. Rogers (1996) looked at possible climate change impacts on the distribution of the brown-ear tick, Rhipicephalus appendiculatus, the primary vector of East Coast Fever. Thornton *et al.,* (2006a) investigated climate-driven changes in habitat suitability for the tsetse fly vector. While climate will modify habitat suitability for the tsetse fly, the demographic impacts on trypanosomiasis risk through bush clearance are likely to outweigh those brought about by climate change. A similar result was found in a modelling study of changes in malaria distribution in Africa by Hay *et al.,* (2006). Bluetongue, which mostly affects sheep and occasionally goat and deer, will spread from the tropics to mid-latitudes (Anon, 2006).

Potential climate change also has a bearing on livestock diseases. Climate-driven models of the temporal and spatial distribution of pests, diseases and weeds have been developed for some key species e.g. the temperate livestock tick Haemaphysalis longicornis and the tropical cattle tick Boophilus microplus (Ralph, 1987). Potential climate change impacts on buffalo fly and sheep blowfly have also been inferred (Sutherst *et al.,* 1996). Climate scenarios in New Zealand and Australia have suggested increased incidence of epidemics of animal diseases as vectors spread and extension of cattle tick infestations, both of which are directly related to changes in both temperature and rainfall (Sutherst, 1995). Research studies from India have found that meteorological parameters like temperature, humidity and rainfall explain 52 and 84% variations in the seasonality of Foot and Mouth (FMD) disease in cattle in hyper-endemic division of Andhra and meso-endemic region of Maharashtra states, respectively (Ramarao, 1988). The outbreak of the disease was observed to be correlated with the mass movement of animals which in turn is dependent on the climatic factors (Sharma *et al.,* 1991).

Singh *et al.,* (1996) reported higher incidence of clinical mastitis in dairy animals during hot and humid weather due to increased heat stress and greater fly population associated with hot–humid conditions. In addition, the hot–humid weather conditions were found to aggravate the infestation of cattle ticks like, Boophilus microplus, Haemaphysalis bispinosa and Hyalomma anatolicum (Singh *et al.,* 2000; Basu and Bandhyopadhyay, 2004; Kumar *et al.,* 2004). The most economically important parasitic helminths of livestock in temperate climes include the nematodes Haemonchus contortus, Teladorsagia circumcincta and Nematodirus battus, and the trematode Fasciola hepatica. The increase in these helminths in recent years (Mitchell and Somerville, 2005; de Waal *et al.,* 2007; Kenyon *et al.,* 2009; Pritchard *et al.,* 2005, Van Dijk *et al.,* 2008) has been attributed to climate change, since the survival of the free-living stages is chiefly affected by temperature and moisture, and larval development rate is highly temperature dependent (O'Connor *et al.,* 2007; Coyne *et al.,* 1992; Barnes *et al.,* 1988; Armour, 1980). Despite the deleterious impacts of helminths on the livestock industry and their dependence on climatic conditions, predictions of long-term threats to animal health from climate change have so far concentrated on heat stress (Beatty *et al.,* 2008; García-Ispierto *et al.,* 2007; Harle *et al.,* 2007; Kendall *et al.,* 2006; Nardone *et al.,* 2006; Gregory, 2010) and viruses spread by volant vectors, such as blue tongue (Caligiuri *et al.,* 2004; de Koeijer *et al.,* 2007; Gubbins *et al.,* 2008; Pili *et al.,* 2006; Purse *et al.,* 2004; Racloz *et al.,* 2007). Although there have been a number of studies aiming to link the recent changes in helminthiasis abundance and distribution with environmental change (Mitchell and Somerville, 2005; Kenyon *et al.,* 2009; Pritchard *et al.,* 2005; Van Dijk *et al.,* 2008; Abbott *et al.,* 2007; Mas-Coma *et al.,* 2008; O'Connor *et al.,* 2006) there is a lack of predictions for future helminth risk to livestock. Finally, we need to keep in mind that preventive action has clear economic, environmental and social benefits, because it anticipates the potential impact and minimizes the threats to ecosystems and human and animal health. The institutionalization of risk management therefore provides an appropriate instrument for minimising these threats, thereby contributing to the necessary adaptation to climate change.

Indirect Effects

Besides the direct effects of climate change on animal and animal production, there are profound indirect effects as well, which include climatic influences on quantity and quality of feed and fodder resources such as pastures, forages, grain and crop by-residues, and the severity and distribution of livestock diseases and parasites.

Effect on Feed Resources

Historic data from the United Kingdom on grassland production from sites at which grassland production has been measured over a run of years with contrasting weather are a valuable resource (Hopkins, 2000) that indicates some of the effects of hot, dry seasons for different types of grass-growing environments. Results show that lowland sites in relatively low rainfall areas have the greatest reduction of herbage yield in dry seasons. The predicted negative impact of climate change on Indian agriculture (Dinar *et al.,* 1998) would adversely affect livestock production in the country and further limit the possibility of rearing the animals economically. As a result of poor availability of pasture and grazing lands in India (only 3.4% of the area in India is under permanent pasture and grazing land), animals either subsist on poor quality grasses available in the pastures and non-pasture lands or are stall-fed, chiefly on crop by-residues. The feed and fodder deficit in the country is already of the order, 22% for dry fodder, 62% for green fodder and 64% for concentrates (GOI, 2002). These shortages would be further aggravated by the adverse effects of climate change on agricultural production. However, adverse consequences would be inflicted on livestock in regions where high temperatures could be associated with decline in rainfall, increased evapo-transpiration or increase in the incidence of droughts.

Climate change can be expected to have several impacts on feed crops and grazing systems, including the following (Hopkins and Del-Prado, 2007):

- Changes in herbage growth brought about by changes in atmospheric CO_2 concentrations and temperature;
- Changes in the composition of pastures, such as changes in the ratio of grasses to legumes;
- Changes in herbage quality, with changing concentrations of water-soluble carbohydrates and nitrogen at given dry matter (DM) yields;
- Greater incidences of drought, which may offset any DM yield increases;

Greater intensity of rainfall, which may increase nitrogen leaching in certain systems.

Management Strategies to Counteract Climate Change

Grazing Management

Grazing can be optimized by balancing and adapting grazing pressure on land and can provide increase grassland productivity, mitigation and adaptation benefits. However, the net influence of optimal grazing is variable and highly dependent on baseline grazing practices, plant species, soils and climatic conditions (Smith *et al.,* 2008). Perhaps the most clear cut mitigation benefits arise from soil carbon sequestration when grazing pressure is adapted to stop or revert land degradation (Conant and Paustian, 2002). In these cases enteric emission intensities can also be lowered, because under lower grazing pressures animals have a wider choice of forage, and tend to select more nutritious forage which is associated with more rapid live weight gain (LWG) rates (Rolfe, 2010). By restoring degraded grassland, these measures can also enhance soil health and water retention, increasing resilience of the grazing system to climate variability. However, if grazing pressure is reduced by simply lowering animal numbers, then total output per hectare may be lower except where baseline stocking rates are excessively high (Rolfe, 2010). Rotational grazing to adjust the frequency and timing of grazing and better match grazing needs and pasture resource availability is one of the main strategies for increasing the efficiency of grazing management. This enables maintenance of forages at a relatively earlier growth stage, improving the quality/digestibility and productivity of the system, reducing methane emissions per unit of LWG (Eagle *et al.,* 2012).

Pasture Management & Nutrition

Pasture management measures, additional to grazing management, include the sowing of improved varieties of pasture, typically the replacement of native grasses with higher yielding and more digestible forages, including perennial fodders, pastures and legumes (Bentley *et al.*, 2008). For example, in tropical grazing systems of Latin America, substantial improvements in soil C storage and productivity benefits, as well as reductions in enteric emission intensities of animal production, are possible through the replacement natural cerrado vegetation with deep rooted pastures such as Brachiaria (Thornton and Herrero, 2010). There are, however, far fewer opportunities for sowing improved pastures in arid and semi-arid grazing systems. The intensification of pasture production though fertilization, cutting regime and irrigation practices may also enhance productivity, soil C, pasture quality and animal performance. These approaches may not always reduce GHG emissions: improved pasture quality from N fertilization may involve a tradeoff between lower CH4 emissions and higher N2O emissions (Bannink *et al.*, 2010). Also, after accounting for energy-related emissions and N2O emissions associated with irrigation, the net GHG emissions of this practice may be negative on grazing lands (Eagle *et al.*, 2012). Grass quality can also be improved by chemical and/or mechanical treatments and ensiling. With increasing variability in climatic conditions (e.g. increasing incidents of drought) due to climate change, there may be an increase in the frequency of periods where forage availability fall shorts short of animal demands. In these situations supplemental feeding can be an important adaptation strategy.

Animal Breeding

Animal breeding to select more productive animals is a further strategy to enhance productivity and thereby lower CH4 emission intensities. There has been recent research on the mitigation benefits of using residual feed intake (RFI) as a selection tool for low CH4 emitting animals, but findings have so far been inconclusive Waghorn and Hegarty (2011). There is also evidence that cross breeding programs can deliver simultaneous adaptation, food security and mitigation benefits. For example, composite cattle breeds developed in recent decades in tropical grasslands of northern Australia, have demonstrated greater heat tolerance, disease resistance, fitness and reproductive traits compared with pure shorthorn breeds which previously dominated these harsh regions (Bentley *et al.*, 2008). In general, cross breeding strategies that make use of locally adapted breeds, which are not only tolerant to heat and poor nutrition, but also to parasites and diseases (Hoffmann, 2008), which may become more common with climate change .

Agro-forestry Practices

Agro-forestry is an integrated approach to the production of trees and of non-tree crops or animals on the same piece of land. Agro-forestry is important both for climate change mitigation (carbon sequestration, improved feed and hence reduced enteric methane) as well as for adaptation by improving the resilience of agricultural production to climate variability through the use of trees for intensification, diversification and buffering of farming systems. Shade trees have impacts on reducing heat stress on animals and contribute to improve productivity, improved forage value and productivity and body condition of animals, reduced overgrazing and hence land degradation (Thornton and Herrero, 2010).

Improved Waste Management

Most methane emissions from manure derive from swine, beef cattle feedlots, and dairies, where production is concentrated on large operations, and manure is stored under anaerobic conditions. Methane mitigation options involve the capture of methane by covered manure storage facilities (biogas collectors). Captured methane can be flared or used to provide a source of energy for electric generators, heating, or lighting (which can offset CO2 emissions from fossil fuels). Anaerobic digestion allows CH4 emissions from animal storage to be reduced while at the same time producing biogas that can substitute for fossil fuel energy. The technology has shown to be highly profitable in warm climates (Gerber *et al.*, 2008). Recent developments in energy policy have also enhanced its economic profitability in countries such as Germany and Denmark (AEBIOM, 2009). Manure application practices are also available to reduce N2O emissions. Improved livestock diets as well as feed additives can substantially reduce CH4 emissions from enteric fermentation and manure storage (Steinfeld *et al.*, 2006). Energy-saving practices have also shown to be quite effective in reducing the dependence of intensive systems on fossil-fuel energy.

Carbon Sequestration

The success of strategies of greenhouse gas mitigation depends on the use of appropriate tools to reduce carbon losses and to increase carbon sequestration. Soussana *et al.,* (2010) reviewed a set of management practices that help achieve these objectives. We report below some of these practices that refer to grassland carbon sequestration:

- Avoiding soil tillage,
- Moderately intensifying nutrient-poor permanent grasslands,
- Avoid heavy grazing,
- Grass-legumes association rather than grass only.

Methane Mitigation through Nutritional Management Strategies

Dietary Manipulation

The chemical composition of diet is an important factor which affects rumen fermentation and methane emission by the animals. Improvement in the digestibility of lignocellulose feeds with different treatments also resulted in lower methanogenesis by the animals (Agrawal and Kamra, 2010). Wheat straw treated with urea (4kg urea per 100kg DM) or urea plus calcium hydroxide (3kg urea+3 kg calcium hydroxide per 100kg DM) and stored for 21 days before feeding, reduced methane emission from sheep. The treatment of straw with urea and urea molasses mineral block lick caused a reduction of 12-15% methane production and the molar proportion of acetate decreased accompanied with an increase in propionate production (Agrawal and Kamra, 2010). On inclusion of green maize and berseem in the ration, methanogenesis decreased significantly. By increasing the concentrate level in the paddy straw based diet there was a depression in methane production accompanied with an increase in propionate concentration in the rumen liquor. Castor bean cake and karanj cake inhibited methanogenesis significantly, but these two oil cakes also affected in vitro dry matter degradability of feed adversely, which might be due to the presence of antinutritional factors (Kumar *et al.*, 2007).

Increased Proportion of Concentrates in the Diet

A higher proportion of concentrate in the diet leads to a reduction in CH4 emissions as a proportion of energy intake (Yan *et al.*, 2000). The relationship between concentrate proportion in the diet and methane production is curvilinear (Sauvant and Giger-Reverdin, 2007) with a marked decrease in methane observed when dietary starch is higher than 40%. Replacing plant fiber in the diet with starch induces a shift of VFA production from acetate towards propionate occurs, which results in less hydrogen production (Singh, 2010). The metabolic pathways involved in hydrogen production and utilization and the activity of methanogens are two important factors that should be considered when developing strategies to control methane emissions by ruminants. Reduction of hydrogen production should be achieved without impairing feed fermentation. Reducing methanogens activity and/or numbers should ideally be done with a concomitant stimulation of pathways that consume hydrogen to avoid the negative effect of the partial pressure increase of this gas. Many mitigating strategies proposed have indeed multiple modes of action (Martin *et al.*, 2008). Hydrogen gas produced during microbial fermentation of feed is used as an energy source by methanogens, which produce methane. Efficient H_2 removal is postulated to increase the rate of fermentation eliminating the inhibitory effect of H_2 on the microbial degradation of plant material (McAllister and Newbold, 2008). The rate of CH_4 formation is determined by the rate at which H_2 passes through the dissolved pool, and the amount of CH_4 formed is determined by the amount of H_2 that passes thought the pool. The absolute amount of CH_4 formed per animal on different diets is related to characteristics of the feed in complex ways incuding the nature and amount of feed, the extent of its degradation, and the amount of H_2 formed from it (Singh, 2010).

Adding Lipid to the Diet

Dietary fat seems a promising nutritional alternative to depress ruminal methanogenesis without decreasing ruminal pH as opposed to concentrates (Sejian *et al.*, 2011b). Addition of oils to ruminant diets may decrease CH_4 emission by up to 80% in vitro and about 25% in vivo (Singh, 2010). Lipids cause depressive effect on CH_4 emission by toxicity to methanogens, reduction of protozoa numbers and therefore protozoa associated methanogens, and a reduction in fibre digestion. Oils containing lauric Acid and myrstic acid are particularly toxic to methanogens. Beauchemin *et al.*, (2008) recently reviewed the effect of level of dietary lipid on CH_4 emissions over 17 studies and reported that with beef cattle, dairy cows and lambs, for every 1%(DMI basis) increase in fat in the diet, CH_4 (g/kg DMI) was reduced by 5.6 %. In another review of fat effects on enteric CH_4, (Martin *et al.*, 2010) compared a total of 67 in vivo diets with beef, sheep and dairy cattle, reporting an average of 3.8% (g/kg DMI) less enteric CH_4 with each 1% addition of fat (Singh, 2010).

Bacteriocins

Some bacteriocins are known to reduce methane production in vitro (Callaway *et al.*, 1997; Lee *et al.*, 2002). Nisin is thought to act indirectly, affecting hydrogen producing microbes in a similar way to that of the ionophore antibiotic monensin (Callaway *et al.*, 1997). A bacteriocin obtained from a rumen bacterium, bovicin HC_5, decreased methane production in vitro up to 50% without inducing methanogens adaptation (Lee *et al.*, 2002). Klieve and Hegarty (1999) also suggested the use of archaeal viruses to decrease the population of methanogens.

Ionophores

Ionophores (e.g. monensin) are antimicrobials which are widely used in animal production to improve performance. Tadeschi *et al.*, (2003) reported in a recent review that on feedlot and low forage diets, tend to marginally increase average daily gain whilst at the same time reducing DMI, thus increasing feed efficiency by about 6%. Monensin should reduce CH4 emissions because it reduces DMI, and because of a shift in rumen VFA proportions towards propionate and a reduction in ruminal protozoa numbers (Singh, 2010). In vivo studies have shown that animals treated with monensin emit reduced levels of CH4 (e.g. McGinn *et al.*, 2004; Van-vugt *et al.*, 2005) but others have reported no significant effect (e.g. Waghorn *et al.*, 2008; van Vugt *et al.*, 2005). Monensin causes a direct inhibition on H-producing bacteria (Russell and Houlihan, 2003) that results in a decrease in methane production due to shortage of molecular H. Monensin also favours propionate producing bacteria (Newbold *et al.*, 1996).

Conclusion

The growing human population and its increasing affluence will increase the global demand for livestock products. But the expected big changes in the climate globally will affect directly or indirectly the natural resource base, the animal productivity and health and the sustainability of livestock-based production systems. Global warming is expected to introduce an additional level of pressure for livestock production systems in dry areas. Livestock production system is sensitive to climate change and at the same time itself a contributor to the phenomenon, climate change has the potential to be an increasingly formidable challenge to the development of the livestock sector.

Responding to the challenge of climate change requires formulation of appropriate adaptation and mitigation options for the sector. Although the reduction in GHG emissions from livestock industries are seen as high priorities, strategies for reducing emissions should not reduce the economic viability of enterprises if they are to find industry acceptability. As the numbers of farm animals reared for meat, egg, and dairy production increase, so do emissions from their production. By 2050, global farm animal production is expected to double from present levels.

The environmental impacts of animal agriculture require that governments, international organizations, producers, and consumers focus more attention on the role played by meat, egg, and dairy production. Mitigating and preventing the environmental harms caused by this sector require immediate and substantial changes in regulation, production practices, and consumption patterns.

The livestock development strategy in the changing climate scenario should essentially focus on minimization of potential production losses resulting from climate change, on one hand, and on the other, intensify efforts for methane abatement from this sector as this would also be instrumental in increasing production of milk by reducing energy loss from the animals through methane emissions. Constant research, education and sensitization are needed in order to adapt to and combat the possible effects of climate change.

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