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Sufferer and cause: Indian livestock and climate change

Smita Sirohi · Axel Michaelowa

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Abstract Climate change poses formidable challenge to the development of livestock sector in India. The anticipated rise in temperature between 2.3 and 4.8°C over the entire country together with increased precipitation resulting from climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their productive and reproductive performance, and hence reducing the total area where high yielding dairy cattle can be economically reared. Given the vulnerability of India to rise in sea level, the impact of increased intensity of extreme events on the livestock sector would be large and devastating for the low-income rural areas. The predicted negative impact of climate change on Indian 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. In India, although the emission rate per animal is much lower than the developed countries, due to vast livestock population the total annual methane emissions are about 9–10 Tg from enteric fermentation and animal wastes.

The scientific evidence of anthropogenic interference with the climate system through greenhouse gas (GHG) emissions has led to worldwide research on assessing the impacts that might result from potential climate change associated with GHG accumulation. As the ecosystems are sensitive to changes in climate, it is necessary to examine the likely impact of climate change on various sectors within the ecosystems to be able to comprehensively understand the effects of climate change. The agricultural sector has generated considerable interest in this regard and most international studies that examine the impact of climate change on this sector due to global warming conclude that in many instances agriculture will be disadvantaged (Reilly 1996; Cline 1992; Evenson 1999; Rosenzweig and Iglesias

S. Sirohi (✉)
Dept. of Dairy Economics, Statistics & Management, National Dairy Research Institute,
Karnal, Haryana 132001, India
e-mail: smitasirohi@yahoo.com

A. Michaelowa
International Climate Policy, Hamburg Institute of International Economics,
Neuer Junfernstieg 21- 20347, Hamburg, Germany

1998; Saseendran et al. 2000). A more recent study predicts unequal impacts of global warming on agriculture across regions (Mendelsohn 2003). For a mid-range temperature rise of 2.5°C, the agriculture in tropical countries is likely to suffer while the temperate and cooler countries may benefit from temperature increase. However, these studies are largely limited to impact assessment on crop yields or net revenue from crop husbandry; only minor attention has been given to the livestock sector, which is a sub-sector of agriculture, particularly in the case of developing countries.

This article reviews the sensitivity of livestock production to climate change in general, while attempting to highlight some important aspects of the likely effect of climate change on Indian livestock, in particular. As the animal production system which is vulnerable to climate change is itself a large contributor to potential global warming through emission of methane and nitrous oxide, the paper also presents a comprehensive review of the GHG emissions from livestock in India.

1 Sensitivity of livestock production to climate change

The organ systems[1] 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 well-being of the livestock[2] is strongly affected by climate both, directly and indirectly.

1.1 Direct effects

Livestock are homeotherms, which means, that they must regulate their body temperature within a relatively narrow range to remain healthy and productive. The ambient temperature below or above the thermoneutral range creates stress conditions in animals. The approximate thermal-comfort zone for optimum performance of adult cattle is reported to be 5–15°C (Hahn 1999). However, significant changes in feed intake or in numerous physiological processes will not occur within the range of 5–25°C (McDowell 1972). The upper critical temperature of dairy cattle is lower than other livestock species (Wathes et al. 1983). Hot and humid environmental conditions cause heat stress in cows. For air temperature below skin surface temperature of an animal, increasing ambient temperature decreases the gradients driving convective, radiation and conductive heat loss and consequently increases reliance on evaporative cooling (sweating and panting) to dissipate body heat. However, high relative humidity reduces the effectiveness of evaporative cooling and during hot, humid summer weather the animal cannot eliminate sufficient body heat and body temperature rises. Heat stress induces behavioural and metabolic changes, which include reduced feed intake and metabolic activity and thereby a decline in their productivity (e.g., cattle: NRC 2001). In fact, when the magnitudes (intensity and duration) of adverse environmental conditions exceed threshold limits with little or no opportunity for relief

[1] An organ is a group of tissues in a living organism that have been adapted to perform a specific function. In higher animals, organs are grouped into organ systems. In the advanced animals there are usually 10 organ systems: integumentary, skeletal, muscular, nervous, endocrine, digestive, respiratory, circulatory, excretory and reproductive.

[2] Livestock is here defined as domesticated animals raised for food, fibre or work (e.g. cattle, sheep, goat, horses, swine, camels etc. but not including birds). Bovines (cattle and buffaloes) being the predominant livestock species in the world, our discussion will focus largely on this livestock species.

(recovery), animal functions can become impaired by the resulting stress, at least in the short term (Hahn and Becker 1984; Hahn 1999). Short-term extreme events (e.g., summer heat waves, winter storms) can result in the death of vulnerable animals (Balling 1982; Hahn and Mader 1997), which can have substantial financial impacts on livestock producers (Box 1).

Although the vulnerability of the farm animals to environmental stresses varies with the genetic potential, life stage and nutritional status of the animals, the studies unambiguously indicate that the performance of farm animals is directly sensitive to climate factors. Klinedinst et al. (1993) combined previously developed and evaluated biological response functions with three widely known Global Circulation Models [GCMs] (Goddard Institute for Space Studies [GISS], Geophysical Fluid Dynamics Laboratory [GFDL] and United Kingdom Meteorological Office [UKMO]) and found substantial reductions in dairy cow performance with projected climate change. Hahn et al. (1992) point out that, in the United States, summer weather already reduces production of high-producing dairy cows and beef animals in feedlots. Also the conception rates of dairy cows are reduced by as much as 36% during summer season. With global warming as predicted by these GCMs, an additional decline in milk production of about 5–14% (beyond expected summer reductions) may occur particularly in the hot/hot–humid southern regions of the United States.

Box 1

Heat waves and mortality of livestock: some evidence

July 1995: Heat wave in the mid-central USA caused extensive feedlot cattle death and performance losses with an estimated $28 million economic damage.

http://www.ars.usda.gov/is/pr/1997coolanimals0597.htm

July 1999: 3,000 cattle with a value of $2 million died from heat in Nebraska (USA) feedlots. Economists estimate that feeders lose about 10 times that amount as their surviving cattle become listless, do not eat and lose weight.

Omaha World Herald, July 31, 1999

http://hpccsun.unl.edu/nebraska/owh-july31.html

August 2003: Thousands of pigs, poultry and rabbits in the French regions of Brittany and the Loire died of heat

http://lists.envirolink.org/pipermail/ar-news/Week-of-Mon-20030804/004707.html

1.1.1 The Indian context

The anticipated negative impact of global warming on the climate of India is large (Nordhaus 1998). India possesses the largest livestock population in the world (520.6 million), and accounts for the largest number of cattle (world share 16.1%), buffaloes (57.9%), second largest number of goats (16.7%) and third highest number of sheep (5.7%) in the world (FAOSTAT). The livestock production is an integral part of mixed farming systems practiced in the entire length and breadth of the country.

Dairy Cows While vulnerability of animal production to climate change has hardly been documented in the context of India, experimental studies have been conducted on effects of season and climate on production, performance and other physiological parameters of dairy animals. These studies have shown milk yield of crossbred cows in India (e.g., Karan Fries, Karan Swiss and other Holstein and Jersey crosses) to be negatively correlated with temperature-humidity index (Shinde et al. 1990; Kulkarni et al. 1998; Mandal et al. 2002a). The average daily milk yield of the crossbred animals in the hot–humid eastern part of the country was significantly reduced by the rise in minimum temperature and not maximum temperature, as rise in minimum temperature crossed the critical temperature of comfort while the maximum temperature was already above the comfort zone (Kale and Basu 1993). The influence of climatic conditions on milk production is also observed for local cows which are more adapted to the tropical climate of India. The rising temperature decreased the total dry matter intake and milk yield in Haryana cows (Lal et al. 1987). The productivity of Sahiwal cows also showed a decline due to increase in temperature and relative humidity (Mandal et al. 2002b).

Buffaloes Another important species in India are the buffaloes. The morphological and anatomical characteristics of buffaloes make them well-suited to hot and humid climates, but heat stress has detrimental effect on the reproduction of buffaloes (Kaur and Arora 1982; Tailor and Nagda 2005).

Potential impact of climate change From the macro perspective, a systematic research study is required to examine the impact of climate change on animal production system in India; however, it is appropriate to highlight some important points.

The livestock development policy in India has emphasised crossbreeding of Indian cattle with exotic sires since the inception of planning in India in early fifties. The goal was increased milk production; as a result, about 17.5% of the dairy cattle in the country are now crossbred, starting from a negligible proportion three decades ago. Research studies have shown that the crossbred animals, on account of their higher milk yield, are economically most suitable for farmers. However, cross-sectional data shows that, in general, the productivity of crossbred cattle is lower in areas where mean annual temperature is higher (Table 1). The significant negative correlation ($r = -0.66$) between the two variables in the Table is indicative that rising temperature is likely to lower the productivity potential of crossbred animals. This is further emphasised by the observed seasonal changes in air temperature and milk productivity (Table 2). The milk yield generally declines when summers set in after winters and recovers with the onset of rainy season, although, the magnitude of change in milk yield in three seasons varies in different locations and is not solely dependent on seasonal variations in air temperature.

The average annual temperature in most parts of the country is 25°C or higher (Fig. 1), which is at or above the thermal-comfort zone of cattle and buffaloes for maximum milk yield. In India, the upper temperature limit of comfort zone for maximum milk production is 27°C (Dutt et al. 1992), about two degrees higher than the same reported in temperate countries. This is perhaps, because the crosses of some exotic breed (eg. Brown Swiss, Jersey and Friesian) with native Indian breeds have to some extent, adapted to climatic conditions in the country. However, the average annual temperature is higher than this upper critical limit also in several parts of the country, particularly southeastern region comprising of state of Andhra Pradesh and Tamil Nadu. For India, climate change projections with a doubling of carbon dioxide concentration in the atmosphere suggest temperatures are expected to increase between 2.3 and 4.8°C, along with increased precipitation (Lonergan 1998, p. 40). Further, the temperatures are expected to rise for all the months of the year. These conditions, especially the more hot–humid climatic conditions and the rise in summer (April to June) temperature (which already ranges from 25 to 45°C maximum daily temperature in most parts of the country), would plausibly aggravate the heat stress in animals and further adversely affect their productive and reproductive performance. A likely consequence would be reduction of the total area where high yielding dairy cattle can be economically reared. The proactive management counter-measures during heat waves (e.g. providing sprinklers or changing the housing pattern, etc.)

Table 1 Average annual temperature and productivity of crossbred cows in India: selected districts

Districts	Annual mean temperature (°C)	Average daily milk yield of crossbred cows (l)
Ongole	29.74	3.98
Kurnool	29.05	3.02
Anantpur	28.61	3.21
Chennai	28.27	4.65
Ahmadabad	27.86	5.56
Cuttack	27.72	3.15
Rajkot	27.14	5.28
Tiruvanthapuram	27.10	5.65
Jodhpur	27.09	3.27
Kolkatta	26.98	5.48
Balasore	26.88	3.57
Nagpur	26.85	3.29
Hyderabad	26.10	4.86
Patna	25.58	3.50
Jaipur	25.17	5.45
Aurangabad	25.04	3.78
Lucknow	25.01	4.00
Agartala	24.86	5.50
Bhopal	24.85	6.01
Pune	24.79	6.28
Ranchi	24.33	6.00
Guwahati	24.21	5.85
Banglore	23.80	6.34
Ludhiana	23.50	7.58
Ambala	23.45	6.44

Source: (1) Indian Meteorological Department (2) Directorate of Animal Husbandry, *various states*.

or animal nutrition strategies to reduce excessive heat loads are often expensive and beyond the means of small and marginal farmers who own most of the livestock in India.

Given the spatial and seasonal variations in the expected temperature increase, some positive impacts can also be associated with climate change, since a moderate increase in temperature in high altitudes or winter months may decrease the maintenance requirement

Table 2 Seasonal variations in air temperature and productivity of crossbred cows

Region/districts	Seasonal normal temperature (°C)			Seasonal milk yield (l/day)		
	Winter	Summer	Rainy	Winter	Summer	Rainy
Southern India:						
Tiruvanthapuram	26.93	28.35	26.74	5.68	5.62	5.70
Belgaum	22.50	27.12	23.50	3.72	3.50	3.64
Northern India:						
Karnal	15.87	30.80	28.87	10.30	8.47	9.10
Western India:						
Akola	23.04	32.01	27.71	3.96	3.80	3.86
Kota	19.5	31.88	29.33	3.07	2.83	2.93

Source: (1) Indian Meteorological Department (2) Directorate of Animal Husbandry, *various states*.

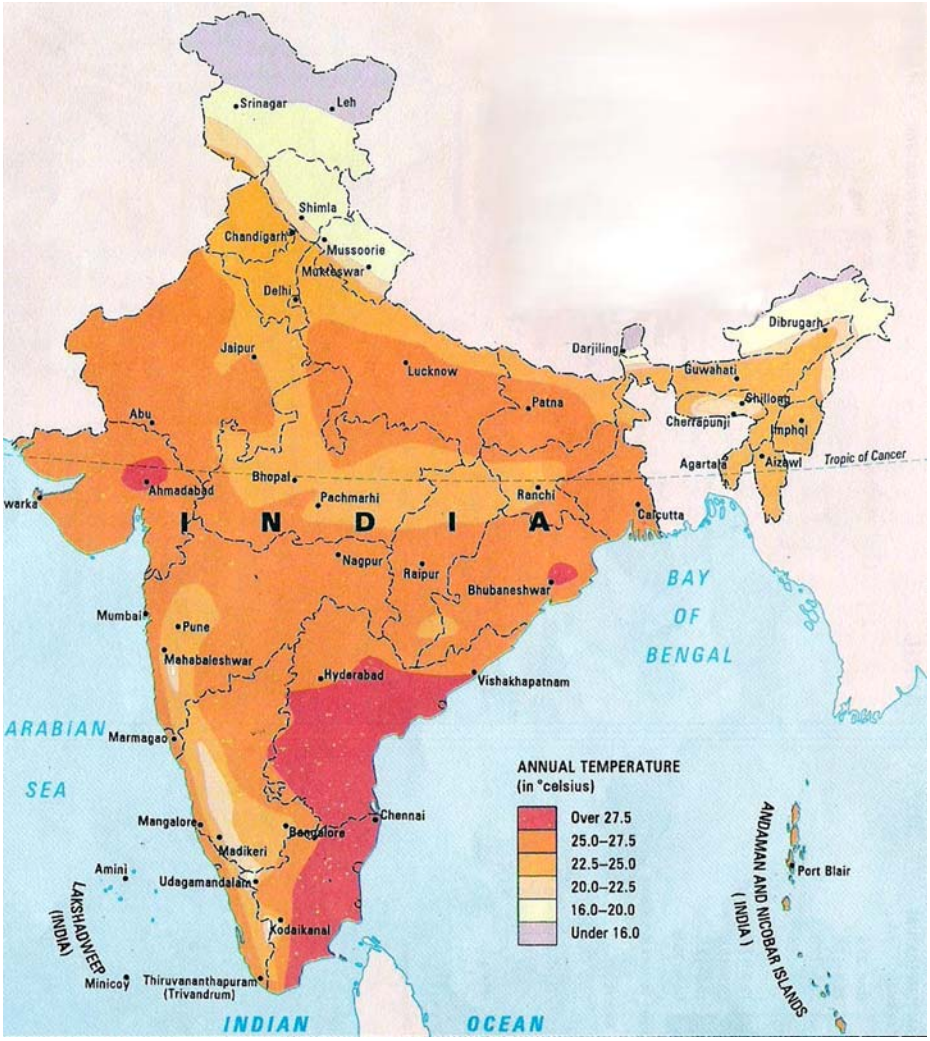

Fig. 1 Average annual temperature of India

of animals. Possible benefits of climate change during cooler seasons, though not well documented, are likely to be less than the consequential negative hot weather impacts (Hahn et al. 1992), especially if the cold season is much shorter than the hot one.

Besides being susceptible to a general temperature increase from climate change, cattle in India are also exposed to an increased risk of extreme events. UNEP (1989) identifies India among the 27 countries that are most vulnerable to sea level rise and warns that the impacts of any increase in the frequency and intensity of extreme events, such as storm surges, could be disproportionately large, not just in heavily populated coastal areas, but also in terms of the paralyzing devastation in low-income rural areas. The extreme significance of impacts related to climate variability were demonstrated in the 1999 tropical cyclone that hit the state of Orissa, on the eastern coast of the country, which resulted in a death toll of about 55,000 cattle (CSO 2000, p.189). Every year thousands of cattle are lost due to heavy rains, floods and cyclones in various parts of the country. During 1953–1997, about 93.7 thousand cattle were lost on an average each year due to floods. In 2000, heavy rains and flooding during the Southwest monsoon, caused the death of nearly 93 thousand cattle, of which 83.6 thousand died in the state of West Bengal, situated near Bay of Bengal (CSO 2000, p.188). Thus, the broad effect of climate change on animal production will follow the general trend of unequal distribution of changes, with both positive and negative impacts depending up the region and season.

1.2 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.

1.2.1 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. On-going research is also showing that enhanced CO_2 may modify the responses to temperature and water. Weeds in grasslands, and pests and diseases of grasses and forage legumes, may also respond to climate changes and confound assumptions of the effects on forage yield. For example, warming may lead to increased damage by clover stem nematode (Harmens et al. 2001; Clifford et al. 1996).

Results from Queensland, Australia also suggest that changes in the ‘safe’ livestock carrying capacity can vary by −35 and +70%, without including carbon fertilization effect, depending on location and ±10% changes in rainfall. Including the effect of doubled CO_2, suggest changes in ‘safe’ carrying capacity might range from −12 to +115% (Hall et al. 1998).

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, p. 48,52). These shortages would be further aggravated by the adverse effects of climate change on agricultural production.

From the precipitation forecasts, it is not clear whether the envisaged increase in precipitation in India resulting from climate change would occur in the entire length and breadth of the country, since the micro-scale modelling of climate systems is not advanced enough to make reasonable projections at the local scale. 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.

A drought in 1987, affected over 168 million cattle in India, due to decline in feed and fodder availability and serious water shortages. In one of the worst draught affected state of Gujarat, 18 million cattle out of 34 million were reported to have died before it rained the next year. A 1999–2000 drought in the arid state of Rajasthan in the north-western part of the country, which is highly drought-prone affected 34.5 million cattle; in the subsequent year about 40 million cattle were affected by drought (CSO 2000, p.186, 190). The draught damaged 7.8 million ha of cropped area in the state and fodder availability fell from 144 to 127 million tons. Any increase in the frequency and intensity of droughts in the arid and semi-arid regions in India would perhaps have the greatest impact on the pastoral families, as they have to migrate to arable areas to secure their livelihoods. Pastoralists' adopt several strategies to cope against draught such as selling of livestock and other assets, sending of animals to Government run cattle-camps, working in scarcity relief programs etc. but a large number of them resort to migration. In Banni grassland region of Gujarat state, 45% pastoral families migrate with livestock during draught (Geevan et al. 2003). Migration often entails significant dislocation costs, in terms of, making provision for human and livestock settlements in destinations, foregone earnings due to costs involved in establishing new marketing channels for their livestock products and psychological cost of dislocation. The costs of migration are largely borne by the migrants themselves (Mosse et al. 2002) but in case of large scale migrations Government may also have to incur expenditure on migrant support programmes.

1.2.2 Effect on diseases

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 dependant 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).

2 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[3],' a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream.
(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.

2.1 Enteric emissions

The global annual emission of methane from all sources has been estimated as 500–600 Tg[4]/year of which over 300 Tg/year comes from anthropogenic activities (IPCC 2001). Livestock farming has been found to be the most important anthropogenic activity that results in methane emissions. The estimates of methane emissions from domesticated animals made during the mid 1970s and 1980s, have varied widely from 70 to 220 Tg/yr (Baker-Blocker et al. 1977; Sheppard et al. 1982; Blake 1984; Ehhalt 1974). Such large variations in the estimates are partly attributable to the differences in reference year of the estimates and hence the animal population. However, the differences in the assumptions about the emission rate per animal made in the studies are also critical factors accounting for the variations in methane emissions.

In a comprehensive summary of the methodology to derive methane emission rates from ruminants and the associated uncertainties, Crutzen et al. (1986) estimated that animals produced 72–99 Tg methane in 1983 from enteric fermentation, with an overall uncertainty of ±15% in their estimates. Broadly using the emission rates derived by Crutzen et al. (1986), an attempt was made by Lerner et al. (1988) to look into the geographical distribution of the emissions from the animal source, which is crucial for using geographic variations in atmospheric methane to infer information about the global budget. The study found that in 1984 about half of the annual global emission of 75.8 Tg from enteric fermentation came from only five countries; viz. India (10.27 Tg), the erstwhile USSR (8.05 Tg), Brazil (7.46 Tg), the USA (6.99 Tg) and China (4.37 Tg). Species-wise, cattle contributed 75%, buffaloes 8%, sheep 9% and goats 3% to the total emission from animal sources.

India emerged as the largest contributor to the livestock methane budget, simply because of its enormous livestock population, although the emission rate per animal in the country was much lower than in the developed countries. For instance, the annual methane production per animal was estimated to be 95 kg for the dairy cows in Germany, nearly three fold higher than 35 kg for the Indian cattle (Crutzen et al. 1986). The default enteric fermentation emission factors for cattle recommended by Inter-Governmental Panel on Climate Change (IPCC) for national GHG inventories (Tier I method[5]) are also much

[3] Enteric fermentation is the anaerobic fermentation of polysaccharides and other feed components in the gut of animals. Methane is produced as a waste product of this fermentation process.

[4] 1 Tg=10^{12} g=1 million tons

[5] IPCC recommends two approaches fro inventory of methane from enteric fermentation, Tier I and Tier II. The Tier I is a simplified approach that relies on default emission factors drawn from previous studies (e.g. Gibbs and Johnson 1993 and Crutzen et al. 1986). Tier II approach is recommended for countries with large livestock population and requires detailed information on the animal and feed characteristics.

Table 3 Enteric fermentation emission factors for cattle

Region	Annual methane emission (kg/head)	
	Dairy cattle	Non-dairy cattle
North America	118	47
Western Europe	100	48
Eastern Europe	81	56
Oceania	68	53
Latin America	57	49
Africa and Middle East	36	32
Indian Subcontinent	46	25

Source: IPCC: 1996, Revised Guidelines for National Greenhouse Gas Inventories, Reference Manual, pp 4.11.

higher for the developed countries compared to the Indian sub-continent (Table 3). The differences in per head emissions are due to lower level and poor quality of feed intake in India. Methane production in livestock is related to the level of intake and digestibility of feed. The livestock characteristics (age, weight and species), health and living conditions influence the energy requirement. Higher methane production results from higher energy requirement and feed intake. The energy requirement of Asian cattle species *Bos indicus* is about 10% lower than European and North American cattle species *Bos Taurus* (NRC 1996). In Indian conditions the animals are mostly fed on poor quality roughages of low digestibility and emit less methane than exotic cattle of developed countries fed with highly digestible good quality feed.

The estimates of total enteric emissions from Indian livestock vary widely from 6.17 to 10.4 Tg/year, for the same reason stated earlier (differences in reference year of the estimates and in emission rates used to arrive at the total emissions). The lowest estimate was by Bandyopadhyay et al. (1996) for the year 1987 (6.17 Tg); however, the methodology or source of emission rates used to arrive at total emissions was not stated. For the same reference year, viz, 1987, using Tier II methodology[6] as outlined by the IPCC, Mitra (1996) calculated total emissions as 6.91 Tg. From the Tier II emission rates worked out by ALGAS (1998) the total emissions were reported to be 7.5 Tg in 1990, while for the same reference year, the study arrived at much higher total emission of 10.3 Tg/year from the IPCC default emission rates (Tier I). Even USEPA (1994) estimated all-India methane emissions as 10.4 Tg in 1991, as it broadly used the emission rates from IPCC. An all-India district level study which uses the methane emission coefficients by Mitra (1992) reports national level emissions as 7.26 Tg/year for 1995 (Garg et al. 2001).

In a study by Singh (1998) where emission factors are based on laboratory experiments, the emissions were estimated to be 9.0 Tg/annum in 1996. The estimates were later revised by author to 8.9 Tg/annum (Singh 2001). Another study of total enteric emissions in India, based on the emission rates observed in controlled laboratory experiments, estimates methane emissions of 10.07 Tg/year in 1994 (Singhal and Madhu Mohini 2002).

2.2 Emissions from manure management

The total global methane emissions from livestock manure management have been estimated as 9.3 Tg/year (Scheehle 2002), of which the developed countries contribute about 52%. The sharply different manure management practices in India, as compared to the western countries, lead to much lower methane emissions from manure. Cattle and

[6] See footnote 5.

buffalo manure is extensively used in the country as fuel and is largely managed in dry systems. The emissions for India are estimated to be 0.905 Tg/year in 1990 (ALGAS 1998; Scheehle 2002), and about 1.27 Tg in the year 1994 (Singhal and Madhu Mohini 2002).

India's contribution to nitrous oxide emissions from manure management in 1990 is estimated to be 0.017 Tg/year, which is projected to increase to 0.022 Tg by 2020 (Scheehle 2002).

3 Summing up

Given that the 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 in India. This sector has a very important role to play in the economic progress of the country as it contributes over one-fourth (26%) to the agricultural GDP and provides employment to 18 million people in principal or subsidiary status. Responding to the challenge of climate change requires formulation of appropriate adaptation and mitigation options for the sector.

The animals employ physiological mechanisms to counter the heat stress. The adaptation to higher temperature is also complemented by the behavioural process, such as buffaloes prefer wallowing during summer to reduce thermal loads and maintain thermal equilibrium. However, to counter the adverse effect of climate change on animal production and health, human intervention for physical modification of the environment and improvement in nutritional management practices would be additionally required (Beede and Collier 1986; West 1999).

Several mitigation options are available for methane emissions from livestock (CAST 2004). In India, the possibility of capturing or preventing emissions from animal manure storage is limited as it is extensively used as fuel in the form of dry dung cakes. Hence, the scope of decreasing methane from livestock largely lies in improving rumen fermentation efficiency. There are a number of nutritional technologies for improvement in rumen efficiency like, diet manipulation, direct inhibitors, feed additives, propionate enhancers, methane oxidisers, probiotics, defaunation and hormones (Moss 1994). Field experiments in India involving some of these options have shown encouraging results with reduction potential ranging from about 6 to 32%. Dietary manipulation through increased green fodder decreased methane production by 5.7% (Singhal and Madhu Mohini 2002). Increasing the concentrate in the diet of animals reduced methane by 15–32% depending on the ratio of concentrate in diet (Singh and Madhu Mohini 1999). The methane mitigation from molasses urea supplementation was 8.7% (Srivastava and Garg 2002) and 21% from use of feed additive monensin (De and Singh 2001).

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.

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