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Sheep husbandry under changing climate scenario in India: An overview

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ABSTRACT

In agriculture and animal production, controlling and decreasing emission of harmful gases has become important for environmental protection. India possesses the largest livestock population in the world and although emission rate per animal is much lower than the developed countries, due to huge livestock population, the total annual methane emission is about 9–10 Tg from enteric fermentation and animal wastes. Sheep husbandry is a source of livelihood and economic sustenance among poor farmers of dry plain, mountain, and hilly regions of the country. India has 42 established sheep breeds with more in process of evaluation and characterization. In the present scenario of climate change, sheep husbandry in the country is expected to undergo dramatic changes. The frequent drought and famine situations and continuous declining of grazing resources both in terms of quality and quantity could be the reasons for decline of sheep in certain states as compared to others. Impact of climate change on sheep husbandry is visualized as changes in breed composition, population and distribution, feed and fodder scarcity, shrinkage of grazing land, spread of diseases, market trend for wool and meat, reproductive and productive disorders, poor performances, consumer demand etc. Hence while aiming at sustainable sheep production, it is imperative to concentrate on reducing the effects of climate change. The mitigation strategies can be grouped under 3 genetic, managemental and nutritional strategies. Given that sheep 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 sheep sector in India.

Key words: Carbondioxide, Climate change, GHGs, Livestock, Methane, Nitrous oxide, Sheep

The scientific evidence of anthropogenic interference with the climate system through greenhouse gas (GHG) emissions has led to worldwide research on assessing the impacts on livestock 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 possible impact of climate change on various sectors within the ecosystem so as to comprehensively understand effects of climate change (Sejian *et al*. 2011a). The agricultural sector has generated considerable interest in this regard and majority of international studies that examine the impact of climate change on this sector due to global warming, conclude that in several instances, agriculture will be at disadvantage (Rosenzweig and Iglesias 1998, Evenson 1999, Saseendran *et al*. 2000). The anticipated negative impact of global warming on the climate of India is severe (Nordhaus 1998, Sirohi and Michaelowa 2007).

Global warming is an environmental catastrophe that has threatened the world. India needs to take a serious view of this impending danger, which will bring about disastrous consequences. The rise in temperature due to global warming became apparent since 1990. In India, 2009 was especially warm due to deficiency of rainfall in both monsoon and winter. India saw 0.5° mercury rise in 100 years. This century is going to witness soaring temperature, erratic weather patterns with more intense monsoons, increased cyclonic activities, severe droughts, floods, melting glaciers and rise in sea levels (Singh and Shinde 2006). India's sheep husbandry depends largely on the monsoon grasses (Shinde and Bhatta 2002) and changing rainfall pattern in western and central India would cause scarcity of grazing resources. The dry area will become drier and wet will become wetter. There will be lengthier droughts in dry areas, which will subsequently affect grazing resources, water scarcity and hamper sheep husbandry activities.

In India, although the emission rate per animal is much lower than the developed countries, because of huge livestock population, total annual methane emission is about 9–10 Tg from enteric fermentation and animal wastes (Sirohi and Michaelowa 2007). India possesses the largest livestock

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population in the world 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. The livestock production is an integral part of mixed farming systems practiced all over the country. The potential impacts of climate change on livestock sector in India are: (i) 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 on sheep, adversely affecting their productive and reproductive performance; (ii) given the vulnerability of India to rise in sea level, impact of increased intensity of extreme events on livestock would be large and devastating for low-income rural masses; (iii) the predicted negative impact of climate change on Indian agriculture adversely affecting livestock production by aggravating the feed and fodder shortage. Given the importance of climate change affecting livestock productivity, this overview collates and synthesizes literature on effect of changing climate on sheep production in Indian scenario and the mitigation strategies that need to be practiced to counter such environmental extremes.

Importance of minimizing climatic change on livestock husbandry

In agriculture and animal production, controlling and decreasing emission of harmful gases has become important for environmental protection (Klinedinst *et al.* 1993). It should be noticed that certain gases released in agriculture/ animal husbandry production, such as methane, carbon dioxide, nitrous oxide and ammonia, directly affect global climate change which influences development of social economy by acting on agriculture, animal husbandry and water resources (Ashutosh *et al.* 2001). If the global warming is continually accelerated, it is possible that occurrence of flood and drought will further increase. On account of the deterioration in water supply, demand of agriculture and pasture, shortage of water will become more serious and the quantity and quality of herbage will largely decline (St-Pierre *et al.* 2003). The increase of temperature will lead to decline in yield of crops which inturn will decrease the forage for livestock resulting in decrease of livestock production and reproduction to different degrees (Mader *et al.* 2006). Climate change will also influence etiological bacteria and parasites of sheep. Therefore to avoid environmental crisis and deterioration, maintaining and controlling the density of greenhouse gases in atmosphere is a vital matter of immediate urgency.

Climate change and its mitigation will bring about major structural change in the agriculture, forestry and other land use sectors. With effective collaborative global efforts, climate change mitigation would become the most important force for change. A rising carbon price will alter the cost of land management practices and commodities, depending on their emissions profiles. Domestic food production in developing countries like India will be at immediate risk of reduction in agricultural productivity due to crop failure, livestock loss, severe weather events and new patterns of pests and diseases (FAO 2006). Climate change could disrupt ocean currents, which would have serious ramifications on the availability of fish, a major protein source. Farmers in developing countries posses lesser options to adapt to and effectively manage these risks due to the higher proportion of small-scale and subsistence farms, poorly developed infrastructure and lesser availability of capital and technology. These impacts, together with the considerable increases in population and food demand, will lead to an increase in food prices in India.

Sheep population and production status in India

India is host to 65 million heads of sheep with slaughter rate of 32% and average carcass weight of 10 kg and contributes 208 million kg meat, 28 million pieces of skin and 47 million kg wool to GDP (Karim and Sejian 2010). The relatively lower slaughter rate and population growth of Indian sheep is primarily due to relatively lower reproductive efficiency in farmers' field (65– 70%). Earlier, sheep were reared for wool as the primary produce but with advent of quality, manmade apparel fibre, gradually mutton has replaced wool as the primary produce. Organized survey in dominant sheep producing zone of the country indicated that about 75% of the farmers earning is realized from selling of animals for meat production while in peninsular India with hairy sheep breeds, the realization through meat is still higher.

India has 42 established sheep breeds with more in process of evaluation and characterization; as per World Watch List, there are 50 approved breeds. These genotypes can be categorized in 3 broad headings, viz. large, medium and small stature. Majority of Indian sheep breeds are medium stature carpet wool or hairy type. Efforts to change the breed composition to medium fine wool or heavier mutton breeds by crossbreeding with established breeds imported from temperate locations largely failed because of their poor adaptability to prevailing hot environmental conditions and low plane of nutrition for most part of the year. Accordingly, the breeding programmes were reoriented to maximize productivity of promising native sheep breeds by intensive selection, organized feeding management and health coverage.

Genetic merits of sheep source

Sheep husbandry, a source of livelihood and economic sustenance among poor farmers, is practiced in almost all climates of the country ranging from cold climate of Jammu and Kashmir and Himachal Pradesh to hot and dry climate of Rajasthan and Gujarat and hot and humid climate of Odisha and West Bengal. Climate plays an important role in nature of produce from sheep. Prolific sheep breeds in hot and humid coastal region of West Bengal and Odisha, excellent carpet wool breeds in hot and dry western part of Rajasthan, fine wool breeds in cold and dry temperate climate, and mutton breeds in hot and humid plains of southern states evolved through the process of adaptation. Open fleece in hot and humid region facilitates the dissipation of body heat while close fleece in temperate region helps in conservation of body heat, both the fleece character plays an important role in balancing heat dynamics in 2 different sets of condition. Similarly, prolificacy trait in coastal sheep breeds is associated with higher temperature coupled with humidity. Fine wool breeds of temperate countries performed poorly in the tropics because of unfavorable climate, which does not allow them to sustain and produce. It has been realized from earlier attempts that fine wool production is feasible in temperate locations of the country.

The adaptation of sheep breeds to different location/ climates depends upon temperature, humidity, vegetation and wool cover and resistance/susceptibility to various diseases. Sheep breeds can tolerate wide range of climate and convert poor quality forage into quality animal protein. These characters favour their rearing under extensive system among poor rural people in harsh climate (Karim and Shinde 2007). It is expected that present scenario of climate change, may cause shifting of sheep from one region to other, change in breed composition, change in livelihood and nutritional security of farmers, shifting trend of sheep breeds from wool to mutton type, emergence, reemergence of newer diseases etc.

Sheep husbandry under changing climate scenario in India

The current shift in sheep population from Rajasthan to Andhra Pradesh indicated the effect of climate change. The sheep population in 1997 in Rajasthan was 10.62 million, which declined to 10.05 million in 2003 livestock census with overall reduction of 5.72%. On the other hand, the sheep population in Andhra Pradesh increased by 13.99%. The frequent drought and famine situations and continuous declining of grazing resources both in terms of quality and quantity could be one of the reasons for decline of sheep in Rajasthan during the period. Further, poor appreciation of wool price during the last decade has diverted the interest of farmers from sheep husbandry to some other occupations. The growth rate of sheep population during the inter census period is given in Table 1. The growth rate of sheep during 1997–2003 was almost negative in most of the dominating states except Andhra Pradesh, Tamil Nadu and Jammu and Kashmir.

The sheep, in relation to other livestock species, is well adapted to different climatic conditions and its vagaries. Sheep can escape from drought or famine affected areas to other areas by migration and withstand its adverse effect. Sheep migration predominantly depends on traditional folk, culture and life style of shepherds in the desert and dry climatic zones. However, in prevailing situation of climate change, migration becomes hard and harsh for the farmers. Although they are aware of these facts, they are absorbing its effect by compromising their flock production primarily due to lack of alternate resources. The climate change and its effect on precipitation in the arid and semiarid regions of Rajasthan force the farmers to migrate round the year with their flock and live a nomadic life. In addition, poor land holding of sheep farmers and deteriorating forage yield of common property resources (CPR), stubbles and other fallow lands in neighborhood of their villages, compel them to go for migration. However, resistance of local people for grazing of sheep on common property resources *en route* migration is one of the hurdles which creates conflicts between pastoral communities and local people. In recent past, reduction of area under grazing land and stubble due to intensive cropping pattern in neighboring state and shifting crop pattern, made the situation all the more vulnerable. Trend of sheep migration in Rajasthan is given in Table 2. The number of sheep on migration is mainly associated with drought and famine like situation in the region (Dubey *et al.* 2002).

Climate change and its subsequent effect on rainfall and grazing resources adversely affects the young stock and need

Table 1. Sheep population and growth rate in sheep dominating states

States	Inter census growth rate (% per annum)		
	1987–92	1992–97	1997–03
Andhra Pradesh	2.53	4.58	13.99
Gujarat	5.40	1.25	–0.76
Himachal Pradesh	–0.66	0.07	–2.53
Jammu and Kashmir	3.39	1.48	1.23
Karnataka	2.81	8.07	–1.62
Maharashtra	1.39	1.82	–1.40
Rajasthan	4.70	2.75	–5.72
Tamil Nadu	–0.11	–1.68	0.67

Government of India Livestock census 2003.

Table 2. Trend in migration of sheep in Rajasthan (Government of Rajasthan 2007)

Year	Temporary migration	Permanent migration
1996–97	4.63	15.71
1997–98	2.36	6.17
1998–99	3.31	15.35
1999–00	14.88	5.68
2000–01	6.47	8.43
2001–02	9.73	6.68
2002–03	20.01	6.10
2003–04	2.81	5.79
2004–05	4.43	21.07
2005–06	10.54	22.35
2006–07	2.39	15.75
Mean (lakh)	7.41	11.73
Growth rate (%)	0.12	0.73

supplementary feeding to protect them from vagaries. Now, supplementing grain is offered by farmers to their young stock to sustain and protect them from vagaries of nutritional crisis especially energy in *en route* migration. With the low availability of grazing resources due to climate changes, supplementation of grains to young and lactating sheep becomes inevitable. However, such a situation adds a huge financial burden on the farmers. Further, climate change influences the input cost and market trend for wool and mutton. At present, wool and meat price in the market does not commiserate with input cost. However, in the recent past, meat price showed an increasing trend but wool price still remains static.

Impact of climate change on sheep husbandry

Impact of climate on sheep husbandry is visualized as changes in breed composition, population and distribution, feed and fodder scarcity, shrinkage of grazing land, spread of diseases, market trend for wool and meat, reproductive and productive disorders, poor performances, consumer demand etc. Sheep rearing contributes to livelihood security of poor farmers in drought-affected regions and act as adaptation and coping instrument to reduce shocks and vulnerabilities. The sheep reared by farmers is not just for production but also for its multiple (livelihood, social, environmental) contributions (Suresh and Gupta 2010). In a country, where more than 60% of the geographical area is under arid and semi-arid regions and prone to drought and famine, sheep husbandry contributes towards risk reduction and adaptation to climate variability.

Breed composition and distribution: The indigenous sheep breeds in different agro-ecological niches have evolved over a period through natural selection. They are well adapted to climate, feed, fodder, and diseases of native tract. These breeds would be of great use in near future in the context of increasing climatic variability. Farmers prefer sheep breeds which can withstand thermal and nutritional stresses and able to walk long distance during migration. In view of climate change, many breeds are shifting from native tract, changing their production and other characteristics in new environment. Magra breed found in and around Bikaner, known as Bikaneri Chokla, produce excellent carpet wool with fibre diameter of 32–35μ and lustrous character. However, their population reduced sizably because of inter-mixing of breeds due to migration. Farmers are taking initiative for adopting breeding strategies to cope with the changing climate. Kheri sheep, developed by crossing Malpura with Marwari, are hardy, produce carpet type wool, have better walking efficiency and thrive well under migratory system. With the increasing demand of mutton and wool in the market, farmers are inclining to cross Malpura sheep with the Pattanwadi to produce heavier breed, which can ultimately yield more meat and milk. In changing feed resources, climate and market demand, breeding strategies of farmers for animals are changing for better sustainability and productivity. In the recent past, more efforts were made to develop prolific sheep breeds in the country for enhancing mutton production. At NARI, Phaltan, Suwarna strain of Deccani sheep developed to make sheep production system more sustainable in the changing demographics, economic, and agricultural milieu. Similarly, at the CSWRI, Avikanagar, 3 breeds cross of Malpura, Garole, and Pattanwadi is under progress, which can produce twins/triplets with higher milk yield and higher body weights and can withstand the harsh climate of arid and semiarid region in the country.

Other effect of climate change is witnessed in the declining flock size of sheep over the period, farmers are reducing herd size, changing breed composition and relying more on own resources rather than CPR. Flocks size is declining sharply over the period, average flock size was 100–120 in 1990, which has reduced to 70–80 in 2000 and 35–40 in 2008 in semiarid region of Rajasthan.

Grazing resources situation: Common property resources (CPR) are main source of forage for sheep in the country. CPR includes village pastures, grazing ground, revenue common lands or wastelands, community forest and other forest within a reasonable distance from village, riverbanks, common threshing ground, village ponds/tanks, river, and riverbeds. Total grazing resource includes 14.63 million ha cultivable waste, 11.3 million ha permanent pasture, 23.5 million ha fellow, and 3.66 million ha tree crop, groves (Department of Statistics and Economics, Ministry of Agriculture, GOI). Besides, 38.5 million ha (50% of 77 million ha) forest area is also available for grazing of animals. Thus, a total area of over 91 million ha is available for grazing of animals in the country. Permanent pastures account for 3.4% of geographical areas and declined from 3.9% in 1980–81 to 3.4% in 2004–05. In arid and semiarid regions of the country, 45–50% of the land is utilized for grazing purpose and in extreme arid region of Rajasthan, 90% of the land is utilized for grazing purpose. The area of CPRs has declined by 26 to 63% during last 3 decades mainly due to large-scale privatization to help the poor. However, 49–86% of the privatized CPR ended up in the hands of the non-poor in different areas (Jodha 1986). Despite a rapid decline in area and productivity, common property resources constitute an important component of community assets in dry areas (Singh *et al.* 2005) and community's livelihood in combating the scarcities and stresses created by agro-climatic conditions. They are sources of a range of physical products, offering employment, and income generation opportunities, and providing broader social and ecological benefits (Jodha 1992). The extent of decline in CPR in dry region of India is depicted in Table 3.

CPR produce 2–3q/ha of dry fodder yield under normal rainfall and reduce to 40–50% of normal with declining and erratic distribution of rain (Sankhyan *et al.* 1999). It was observed that continuous declining of total precipitation in

Table 3. Extent and decline in area of common property land in dry regions of India

States	Number of study villages	Area of common land	Common land as proportion of total village area		Decline in area of common land since		Persons per 10 in area of common land 1950–52
		1982–84	1982–84 (%)	1950–52 (%)	1950–52 (%)	1951 (No)	1982 (No)
Andhra Pradesh (3)	10	827	11	18	42	48	134
Gujarat (3)	15	589	11	19	44	82	238
Karnataka (4)	12	1165	12	20	40	46	117
Madhya Pradesh	14	1435	24	41	41	14	47
Maharashtra (3)	13	918	15	22	31	40	88
Rajasthan (3)	11	1849	16	36	55	13	50
Tamil Nadu (2)	7	412	10	21	50	101	186

[1]In parentheses is the number of districts for each state.

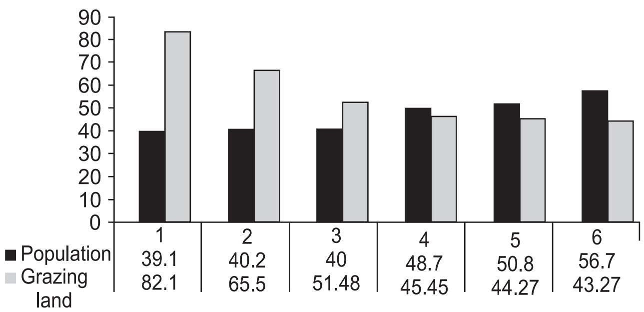

Fig. 1. Sheep population and grazing land over the year.

dry zones of the country due to climate change, sizably reduced forage yield from CPR. On the other hand, increasing livestock population over a period of time, has worsened the situation. Sheep population and grazing lands over a period is shown in Fig 1.

Sheep population increased by 45% while grazing land declined by 47% during the year 1950 to 1997 (Fig. 1). Grazing land per sheep in 1950 was 2.1 ha it come down to 0.76 ha. Stocking density was 0.47 sheep/ha in 1950, now it increased to 1.31. Land reforms introduced in most parts of the country in the early 1950s, led to decline in the area under CPR by 31 to 55%. The grazing pressure on the remaining common property is increasing as a combined result of the reduced area and growing livestock population. Further, increased pressure has over exploited and degraded the resources leading to permanent disruption or elimination of vital biophysical processes, nature's regenerative activities (energy and material flows etc.), inside and surrounding common property area as well. These disruptions reduce the efficacy of farmers' traditional strategies against environmental stress in dry regions. The rate of reduction in CPR land during last 5 years in each agro -climatic zone is given in Table 4.

Table 4. Rate of reduction in CPR land during last 5 years in each agro -climatic zone

Agro -climatic zone	Reduction in CPR land during 5 years preceding the survey (per 1000 ha)	CPR land per household (0.00 ha)
Plains (TG)	71	0.07
Upper Gangetic Plains (UG)	28	0.03
Eastern Plateau and Hills (EHg	50	0.44
Central Plateau and Hills (CHg)	15	0.65
Western Plateau and Hills (WHg)	13	0.29
Southern Plateau and Hills (DP)	43	0.18
East Coast Plains and Hills (EG)	13	0.15
West Coast Plains and Hills (WC)	0	0.16
Gujarat Coast Plains and Hills (GC)	1	0.71
Western dry region (TD)	2	4.77
All Islands (Isl)	5	0.12
India	19	0.31

Source: Report No. 452: *Common Property Resources in India*, Jan - June 1998, NSS 54th Round.

Climate stress and well-being of sheep: Sheep are exposed to ambient temperature ranging from 10–12°C in winter, to 45–46°C in summer, in arid and semiarid regions. Both cold and hot temperatures increase the energy requirement of sheep for thermoregulation to maintain homoeothermic condition. Under climate change, extreme of temperatures further increase the demand of energy for sustenance and survival, however, poor supply of forage and its quality in grazing lands restricts the energy intake leading to energy crisis, nutritional stress and loss of production and death. It is a widely accepted fact that higher temperature when coupled with high humidity aggravates thermal stress. Under such situation, close fleece sheep of temperate region, are more vulnerable whereas open fleece of native sheep are advantageous (Singh and Acharya 1977).

Increased impeachment on animals is evident due to rise in earth's temperature. Native sheep rely on energy saving cutaneous evaporation for dissipation of body heat and better walking efficiency help them to withstand the effect of long distance walking and intense solar radiation while migrating. Under such situation, native breeds are the choice for sustainable production. Sheep breed of temperate origin has little significance with respect to improving production under climate change especially in hot climate. The data generated in temperate breeds, showed that there is a linear decline in birth weight of Rambouillet lambs born to dams maintained under organized feeding and management regime over generations from VI to XI while in Suffolk lambs the effect is noticed from second generation onwards (Singh and Karim 1995).

Climate change and sheep diseases: Heat-related diseases and stresses, extreme weather conditions, adaptation process to new environment and emergence or re-emergence of infectious diseases are critically dependent on environmental and changing climatic conditions. Climate change sizably reduces the natural vegetation in grazing lands leading to metabolic disease of varying nature. The interactive consequences of rise in ambient temperature on animal health are detailed in Table 5. Poor availability of green grass, other than monsoon season increases the incidence of corneal opacity and night blindness associated with vitamin A deficiency. The deficiency of vitamins A, D, and B_1 and minerals, viz. calcium, phosphorus, zinc, copper are not only prevailing unabated but also are registering an upward trend in the recent past (Shinde and Sankhyan 2007). Copper, cobalt selenium, zinc, and iodine are some of the trace mineral deficiencies resulting in anaemia, retarded growth, and reproductive disorders. Apart from these, deficiencies of vitamins A, D_3, E, B_1 and C were also identified in the flock. The nutritional stress increases the case of pregnancy toxemia and neonatal death due to poor milk yield and immunity, prone to many infectious diseases. The increased morbidity and mortality and declined production under climate change leads to economic losses to farmer (Singh *et al.* 2010). Under climatic change, erratic rain leads to emergence of haemorrhagic septicemia, pneumonia, skin and foot diseases. Moreover, short-term fluctuations in temperature seriously cause heat or cold stress leading to increased death from respiratory diseases.

Under traditional system, breeding of sheep is associated with acacia and *khejri* pods in arid and semiarid regions. The climate changes and its effect on tree pods would adversely affect the reproduction in sheep and goats. Poor vegetation cover of CPR would provoke soil ingestion because of their close grazing habit. A study at CSWRI, Avikanagar, indicated that soil ingestion increased up to 39.10, 15.62, and 46.41% of dry matter intake in sheep during drought and famine conditions. Soil accumulates in rumen and reticulum impairs the digestion and production and causes death under prolonged exposure (Shinde *et al.* 2005).

Table 5. Interactive animal health consequences of rise in environmental temperature

Nutritional	Physiological	Thermal
Feed and water scarcity, mineral imbalances, poor intake and exhaustion during grazing/migration, high energy loss leading to lower body weights, starvation, metabolic disturbances, ketosis, secondary metabolic diseases, and starvation exposure syndrome.	Reduced body fat depots, disturbed reproduction cycles, mismothering, poor immunity, debility, stunted growth, still birth, abortion, water toxicities (nitrate, nitrite, fluorine etc).	Dehydration, hyperthermia, neonatal death, water scarcity,

Early embryonic losses increase in sheep bred during summer due to higher temperature and feed scarcity. Nutritional and thermal stress causes stunted growth and neonatal losses. The availability of safe water is declining rapidly in desert areas. In western Rajasthan, drinking water contains fluoride, nitrate and TSS more than tolerance levels, which affect health, production and reproduction of animals (Mittal and Ghosh 1984). However native sheep of desert region tolerate the saline water but climate change in desert environment would adversely affect their tolerance and production potential.

Marketing and economics: Drought- and famine-borne migration of sheep of arid region to other region, for long period of the year, may lead to socio-economic imbalances. In current scenario, shrinkage of grazing lands, scarcity of feed and fodder from grazing lands, as a result of climate change, farmers resort to early disposal of lambs for mutton purposes. Earlier, farmers sold their lambs at 9–12 month of age weighing 20–22 kg body weight. Now, they are selling at an age of 3–4 months when they hardly attain body weight of 12–14 kg due to scarcity of feed and fodder, better price for lamb and fear of mortality losses (Shinde and Sankhyan 2010). Such practice resulting from climate change is a colossal loss of prime germplasm and mutton production in the country.

Farmers are shifting from wool to mutton type sheep with growing demand of meat and price in the domestic market. In prevailing situation of stagnation in wool price, declined demand and limited scope of fine wool production in tropical climate, farmers are shifting to heavier sheep, yielding more meat. This is evident from the Table 6 that wool production during the year 2001 to 2006 had a negative trend.

Flocks were managed earlier on grazing resources alone without any kind of grain supplementation. In present climate change scenario, grain supplementation to young stock as

Table 6. Indigenous wool production and growth rates

Indigenous wool production			Growth rate
1991–92	41.60	1991–92 to 1995–96	0.84
1996–97	44.40	1996–97 to 2000–01	2.23
2001–02	49.50	2001–02 to 2005–06	–2.97
2005–06	45.30	1991–92 to 2005–06	–1.70

Source: *Government of India* (2006).

protection against vagaries of nutritional stress adds to higher cost of production. Poor nutrition and immunity to emerging and reemerging of diseases increase cost of treatment and cause economic losses from morbidity and mortality. The cost of production would increase in changing climate and farmers would have to spend more money on feed and treatment.

Mitigation strategies for climate change effect

Climate change plays a critical role in reducing the productive and reproductive efficiency of sheep. Hence, while aiming at sustainable sheep production; it is imperative to concentrate on reducing the effects of climate change. The mitigation strategies can be grouped under 3 broader headings, namely genetic, management and nutritional strategies. Any mitigation strategy must be confined to the following general framework such as development priority, product demand, infrastructure, livestock resource and local resources. The most attractive mitigation projects must balance the needs in all of these areas, so that none of the factors become a constraint in continued improvement of production efficiency. Within this framework, climate change mitigation options for sheep can encompass a wide range of activities across these areas. However, underlying these activities must be specific options for improving the production efficiency of sheep. The different strategies available to counteract climate change effect on sheep productivity are given in Fig. 2.

Genetic intervention: The sheep sector is relatively small, though the social contribution is huge, both in terms of the production of quality, healthy red meat and through the use of sheep as a positive environmental management tool. Promotion of sustainable sheep production will be vital to ensure that the impact of climate change is minimized on the sheep farmers. This will involve rearing of animals which are more sturdy, heat tolerant, disease resistant, and relatively adaptable to the adverse conditions (Moran *et al.* 2006). In such situation, some of the indigenous breeds will be able to cope much better than the crossbred, as crosses containing higher exotic inheritance exhibit problems of survival when compared to indigenous breeds.

Since climatic changes would result in increase of heat and nutritional stresses, native sheep breeds (Chokla, Malpura, Marwari, and Magra), well-adapted to hot arid ecology would be better choice in arid and semiarid region of the country. Certain sheep breeds are resistant to diseases and parasites in comparison to others. The resistant line does not require drenching and reduces the problem of drug resistance, drenching cost and drug residues in meat and milk (Swarnkar *et al*. 2009). This breed may be multiplied and propagated in the region. In dry zones, sheep milk contributes to nutritional security and economic sustenance of shepherd families. Pattanwadi and Malpura sheep yields 1,200–1,400g and 600–700g of milk daily. The crossbreeding of Awassi sheep well adapted to dry and hot conditions, with Pattanwadi or Malpura to improve milk yield of native sheep appear to be better options. Fat tail sheep breeds are not found in the country. They can withstand the harsh climate change effect and can serve as source of income for poor farmers. Moreover, there is growing demand of fat tail sheep during festivals and fetches prime price in the market.

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 (Ravagnolo and Misztal 2000). There are additional possibilities for meeting this goal. Identification of specific genes that control traits related to thermo tolerance makes it possible to select for thermal resistance (Khoei *et al.* 2004). Possibly, there are also genes controlling cellular resistance to heat shock. Integration of marker-assisted selection into animal breeding systems should make selection for traits conferring thermo-tolerance more rapid.

Management strategies: Extensive basic knowledge is available on the interaction between heat stress, sheep production, reproduction, and health traits. The implementation of the knowledge, for the welfare of animals maintained under extensive management systems, is difficult because of objective limitations to monitor heat stress and economic compulsions in applying measures to ameliorate heat stress (Hansen and Arechiga 1999). From welfare point of view, ideally, the animals should be raised in the zone of optimal thermal well being. However, these would be almost impracticable goal to attain in dominant grazing system of India. The following recommendations are general rules that can be applied under extensive conditions: (i) provision of shade shelter in areas where typical ambient temperature during summer exceeds the normal; (ii) provision of water: it is recommended that the distance between watering spot and grazing area be such that grazing sheep are able to access the water spot at least once a day (Hahn *et al.* 2001, Collier *et al.* 2003). To avoid negative interactions with other stressful factors, particular emphasis should be given for adequate supplementation and provision of clean water (Mader and Davis 2004).

Shade against direct solar radiation can be provided by either trees like banayan or house made of straw and other locally available materials. Animals kept outside during summer are comfortable under tree shade which protects them from direct sun light during peak hours of the day (Buffington *et al.* 1983). A properly designed shading structure provides the most adequate protection to the livestock not only in hot summer but also in winter (Armstrong 1994). For tropical climate condition, loose housing system is considered most appropriate (Hahn 1981). The longer side of the animal shelter should have an east-west orientation. This reduces the amount of direct sunlight shining on side walls or entering the house (Ugurlu and Uzal 2010).

Nutritional intervention: At present, area under fodder

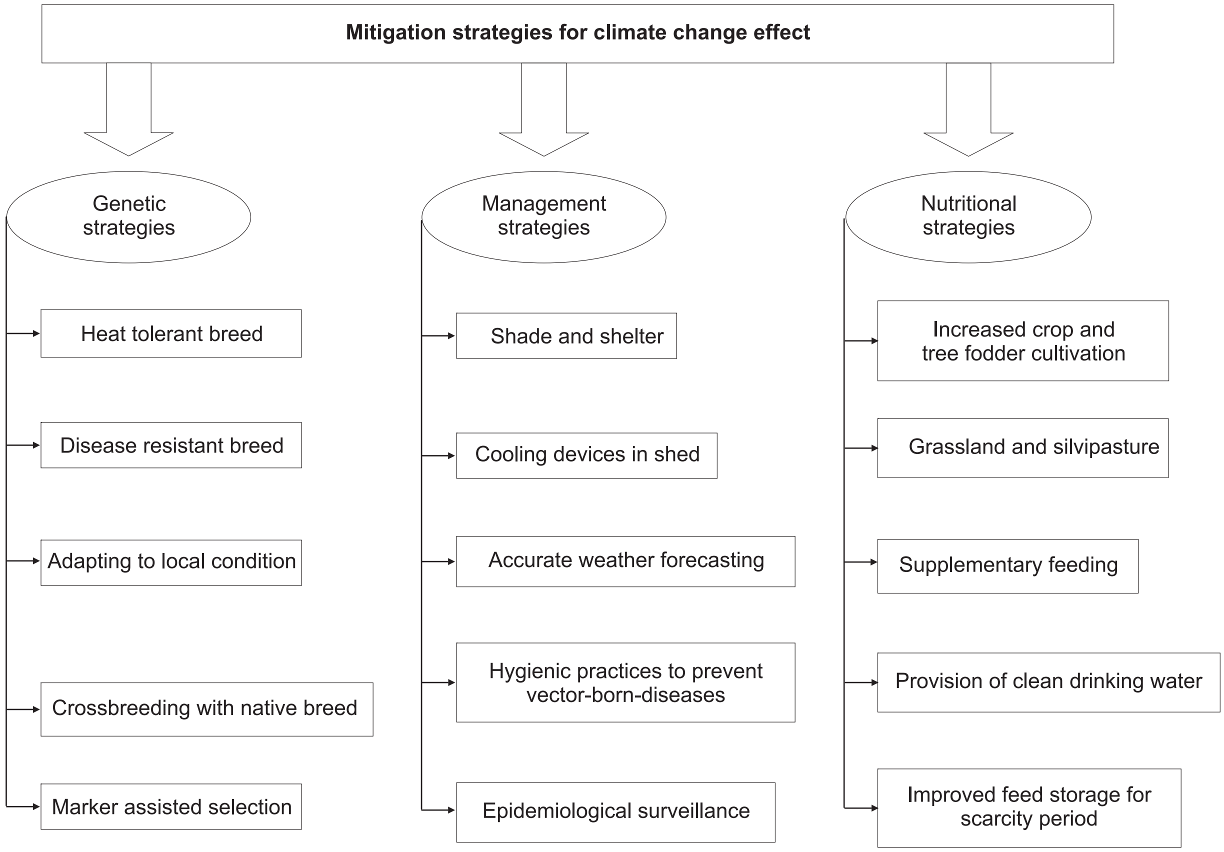

Fig. 2. Salient mitigation strategies for countering climate change effect.

cultivation is 4% of total geographical area in the country. With the increase in livestock population, the area should increase to 8% so to meet growing demand of fodder for livestock. Since sheep and goats maintain on grazing resources alone in the country, decline in CPR yield and area under climate change is a serious concern. Rehabilitation of grazing lands by perennial grasses resistant to water scarcity in dry areas, development of silvipasture, planting suitable fodder trees, bushes, and grasses for round the year forage supply to animals will ease the fodder scarcity in dry zones (Jakhmola *et al.* 2005). The cultivation of pearl millet in erratic and poor rainfall region and conservation in the form of hay or silage for feeding animals during scarcity is a better option for mitigating fodder scarcity. Supplementary feeding of sheep can counteract nutritional stress during lactation and pregnancy. The growing lambs are more vulnerable to nutritional deficiency in migration system, farmers *en route* migration offer jugglery and vegetable oil as a source of energy to suckling lambs, which is economical and cheaper energy source for lambs during nutritional crisis. The concept of fodder bank/depot may be strengthened in drought prone areas as mitigating strategy for supplying fodder to animals during scarcity period. Agro-forestry system incorporating grasses, grain crops and tree may be propagated for improving yield per unit of land and ensuring fodder security of animals. Lambs born *en route* migration require special attention with respect to their rearing. Alternative system of rearing may be developed, where lambs at 2–3 months of age are removed from migratory flock and raised under stall-feeding on feeds and fodder. This system would ease the pressure on lands and improve the mutton production.

Sheep grazing under hot arid and semi-arid environment face extreme fluctuations in the quantity and quality of feed throughout the year. Climate change imparts multiple stresses simultaneously on sheep. There are reports which suggested that when thermal stress is coupled with nutritional stress, it had severe impact on the productive and reproductive functions in contrast to subjecting to either thermal or nutritional stress separately in sheep (Sejian *et al.* 2010, Sejian *et al.* 2011b). Hence, developing nutritional strategies, which not only support yield but also address metabolic and physiologic disturbances induced by heat stress, will help the sheep to maintain a normal metabolism for enhancing performance (NRC 2001). These findings are very valuable in improving economy of sheep farms as thermal stress and feed scarcity often occur simultaneously and are the major predisposing factor for the low productivity of sheep under hot arid and semi-arid tropical environment.

Prevention of disease occurrences: Climate change is strongly associated with many emerging and re-emerging animal diseases. Increasing temperature supports the expansion of vector, redistribution of disease vector, vector-borne diseases, helminthes infection, heat related mortality and morbidity. The delivery of animal health services to shepherds and marginal farmers need to be strengthened. Sustained control of these diseases requires: socio-political stability, access to livestock by veterinary professionals, input of resources to supply and deliver vaccines, maintenance of effective surveillance system to detect suspected cases at an early stage, provision of trained workers and resources to implement diseases control strategies in the event of outbreaks.

For prevention, monitoring and control of sheep diseases, good data exchange mechanism are required at both state and national level. These should cover the distribution of animal diseases, ecological conditions including climate, and associated drugs and chemotherapeutants (Colebrook and Wall 2004). In this context, epidemiological surveillance is a critical component which not only involves the early identification of emerging diseases and trends, but also accounts resource planning and measuring the impact of control strategies.

Manure management: Sheep manure is rich in NPK and has long lasting effect in improving the soil fertility. Moreover, pellet nature of manure produce less methane in the environment than cattle and buffaloes and their slurry. Under traditional practices, land owners provide money to sheep farmers in lieu of herding their flocks in the owners' field during night hours. Sheep manure may be used in orchards and floriculture.

Manure mitigation includes both low-tech strategies like covering and cooling manure lagoons during storage and alternative techniques for manure dispersion and application (Weiske *et al.* 2006, IPCC 2007). More advanced technologies include frequent manure removal from animal housing into covered storage using scraping systems (Weiske *et al.* 2006) as well as farm scale or centralized digesters for biogas generation and utilization (DeAngelo *et al.* 2006, USEPA 2006). In small-scale farm digesters, biogas from local manure may be used for electricity and/or heat production. Larger, centralized digesters can also take in additional organic wastes. There are many different digester designs ranging from low-tech small-scale to high-tech, large-scale models, for example, polyethylene bag or covered lagoon digesters for cooking fuel, light flexible-bag digesters, and large-scale dome digesters (USEPA 2006). With the use of liquid-based systems, the primary method for reducing emissions is to recover the methane before it is emitted into the air. Methane recovery involves capturing and collecting the methane produced in the manure management system. As most of the manure facility methane emissions occur at large confined animal operations (primarily dairies and hog farms), the most promising options for reducing these emissions involve recovering the methane at these facilities and using it for energy.

Extension activities and technological intervention: In many parts of the country, the current practice is to purchase sheep many months ahead of its sale on an arbitrarily settled price. Consequently, the shepherd has no control on what price they get for their stock and at what age they are required to sell them. Invariably, most stock is sold by the time they are 3-months-old, weighing around 10 to 12 kg while the recommended standard weight for sale should not be less than 25–30 kg if these animals have to fetch commercially attractive price. One of the reasons for early sale of animals by the shepherds is non-availability of required credit leaving farmers at the mercy of traders. There is a need to unite them in cooperative society for organized production, value addition, marketing, protecting them from traders and helping them to get appropriate share of consumer price. Rural abattoir may be established in the cluster of villages with the provision of cold chain facilities involving progressive farmers by making self help group (SHG) for offering better price to producer.

Sheep farmers belong to poor strata of society and in recent past government scheme for protecting them by ensured employment scheme in the villages has diverted the interest of farmers for sheep rearing activities. Moreover, the CPRs, which are major source of forage to sheep, are declining rapidly in the villages. Pasture development activities may be taken up under National Rural Employment Guarantee Scheme. Under climatic change and thermal stress, farmers adopt 3 shearing regime to reduce stress on animals but it affects yield and fibre length and ultimately market value of wool. Machine and processing techniques may be developed for appropriate utilization of short staple length fibre and technology for appropriate utilization of value added short fibre may be strengthened.

Future perspectives

Scientific research can help livestock sector in battle against climate change. Animal scientists must collaborate closely with agronomists, physicists, meteorologists, engineers, economists, to tackle the problem from all aspects. Till now the effort in selecting animals has been primarily oriented toward productive traits, but now onwards, must be planned toward robustness, and above all adaptability to heat stress. Molecular biology could allow to directly achieve genotypes with the necessary phenotypic characteristics. Research must continue developing new techniques of cooling systems such as thermo-isolation and concentrating on techniques requiring low energy expenditure. New indices that are more complete than THI to evaluate the climatic effects on each animal species must be developed and weather forecast reports must also be developed with these indices, to inform the farmers in advance. Above all, to beat the climate change or in any case not to let the climate beat livestock systems, researchers must be well acquainted with technologies of water conservation.

People all over the world are facing two emerging issues—climate change and food security. While livestock's role in contributing to food security is very well acknowledged, its negative impacts by way of contributing to GHG in the atmosphere raise criticism. Given that sheep 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 development of sheep sector in India. This sector has a very important role to play in economic progress of the country as it contributes considerably to the agricultural GDP and provides employment to few million poor farmers, in principal. Responding to the challenge of climate change formulation of appropriate adaptation and mitigation options are required for this sector. The projected trend of population growth indicated that sheep population will increase tremendously over the next few years and hence creating a database for GHG inventory is an important indicator for studying the future impact of sheep on climate change. The grazing and mixed rain-fed systems, which count on the availability of pastures and farm crops, will be the most damaged by climate change. Damage could be considerable, since grazing and mixed rain-fed systems raise almost 70% of all ruminants in the world. The positive trend, both in the number of heads and in productivity observed in recent decades could slowdown or even become negative, if an effort is not made to adapt to the climate change.

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