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Adapting Smallholder Dairy Production System to Climate Change

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1. INTRODUCTION

Livestock sector is socially and economically very significant in developing countries like India due to the multi-functionality of livestock performing output, input, asset and socio-cultural functions. Rapid population growth, urbanization and income growth in developing countries is fuelling a massive increase in global demand for food from animal origin. Driven by the drivers of demand, the world agriculture is slated to witness livestock revolution in the next 20 years or so (Delgado et al., 1999). However, with looming threat of climate change posing formidable development challenge to biological production systems, concerns have emerged regarding the ability of the livestock system to sustain increase in supply for keeping pace with the burgeoning demand of livestock products. As the issues of vulnerability and adaptation of livestock production to climate change have begun to occupy the center stage for the future course of development of the sector, this chapter focuses on the coping strategies that will have to be put in place for countering the sensitivity of livestock to changing climate.

The discussion in this chapter deliberates around dairy production as dairying has predominant share in livestock production and population. The dairy sector in India produces output worth Rs. 1245.2 billion (2005-2006) that is 67% of the value of output from livestock sector and highest among all the agricultural commodities. Among the various species of livestock, cattle and buffalo account for 61% of the livestock population in the country. India possesses about 105 million dairy animals (2003 livestock census) producing 100 million tonnes of milk. With 15% of the world milk production, 16 and 58% of world population of cattle and buffaloes, respectively, it is the top ranking country in the world in terms of milk production and number of dairy animals. In this backdrop, this chapter throws light on the sensitivity of livestock production to climate change, particularly in the context of dairy production in India, and focuses on the need to target the climate change adaptation responses. A detailed discussion on the various adaptation strategies that can insulate the smallholder dairy production to climate change vulnerability is also presented.

2. VULNERABILITY OF DAIRY PRODUCTION TO CLIMATE CHANGE

Climate strongly influences the growth, production, reproduction, health and well-being of the livestock through affecting animal physiology; incidence of diseases; feed, fodder and water availability etc.

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2.1 Heat Stress

Livestock 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 to 15 °C (Hahn, 1999), however, significant changes in feed intake or in numerous physiological processes will not occur within the range of 5 to 25 °C (McDowell, 1972).

Increase in ambient temperature decreases the difference between the temperature of the animal's surroundings and its body, hence, increasing reliance on evaporative cooling (sweating and panting) to dissipate body heat. In the situation of high relative humidity the effectiveness of evaporative cooling is reduced. Thus, during hot, humid weather conditions the cow cannot eliminate sufficient body heat and suffers from heat stress. The critical values for minimum, mean and maximum Temperature Humidity Index (THI), which incorporates the combined effects of temperature and relative humidity, are determined to be 64, 72 and 76 respectively (Igono et al., 1992).

Net effect of heat stress is increase in heat loss by evaporation and decrease in heat production by metabolism. Heat stress induces physiological changes in cattle, which include reduced feed intake and metabolic activity and thereby declining their productivity (NRC, 2001). The estimated milk yield reduction per unit increase in THI was reported to range from 0.20 to 0.32 kg (Ingraham et al., 1979; Ravagnolo et al., 2000). A few studies give a much higher magnitude of decline; for instance, the milk yield for Holestins was observed to decline by 0.88 kg per THI unit increase for the two-day lag of mean THI (West et al., 2003).

Systematic studies of similar nature for the Indian dairy animals are not available; albeit the experimental 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 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). In case of buffaloes also, heat stress has detrimental effect on the reproduction of buffaloes (Kaur and Arora, 1982; Tailor and Nagda, 2005) even though the morphological and anatomical characteristics of buffaloes make them well-suited to hot and humid climates.

Some preliminary estimates of economic losses from heat stress in dairy animals, at the national and sub-national level, work out to be whopping Rs. 2661.62 crores (at 2005-06 prices), about 2% of the value of output from milk group. The economic losses were highest in UP (> Rs. 350 crores) followed by Tamil Nadu, Rajasthan and West Bengal (Fig. 1). With likely increase in temperature due to climate change the heat stress in dairy animals would accentuate, thereby, further increasing the magnitude of economic losses attributable to heat stress. The high resolution climate change scenarios and projections for India, based on regional climate modeling system, known as PRECIS (Providing REgional Climates for Impacts Studies) developed by Hadley Center for Climate Prediction and Research, shows that by the end of the century, the annual mean surface temperature is expected to rise by 2.5 to 5 °C, with warming more pronounced in the northern parts of the country (Kumar et al., 2006).

2.2 Susceptibility to Extreme Events

Besides being susceptible to increased heat stress from climate change, the cattle in India are also exposed to the increased risk of extreme events. UNEP (1989) identifies India among the 27 countries that are

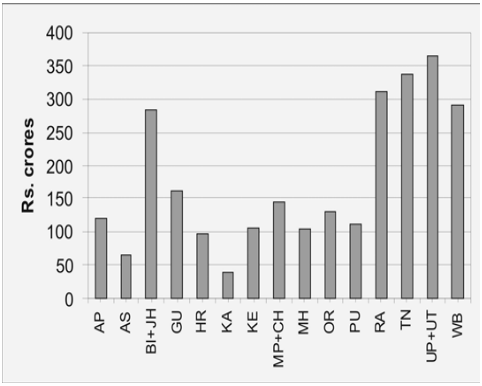


Fig. 1 Statewise value of milk production losses due to heat stress (Sirohi, 2007).

most vulnerable to increase in the frequency and intensity of extreme events, such as heat waves, storm surges, droughts, floods, etc. Simulation models show an increase in frequencies of tropical cyclones in the Bay of Bengal; particularly intense events are projected during the post-monsoon period (Sathaye et al., 2006). In the recent past, there has been an increase in the occurrence of extreme temperature events together with changes in its intensity and pattern (Dash et al., 2007). In 2003, during the 23-day heat wave period from 19 May to 10 June, the highest maximum temperature varied between 45 and 50 °C at four stations on the east coast, breaking their 100 years record in maximum temperatures. During this period, Andhra recorded the highest daily maximum temperature in the country instead of the northwest and central plains of India where such temperature peaks occur normally. Similar type of unusual severe heat waves took place in Orissa during May-June 1998.

Animal functions can become impaired when the intensity and duration of adverse environmental conditions exceed threshold limits with little or no opportunity for relief (Hahn and Becker, 1984; Hahn, 1999). The 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). In India, every year thousands of cattle are lost due to heavy rains, floods and cyclones in various parts of the country. During 1953-97, on an average about 93.7 thousand cattle were lost 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 (CSO, 2000). The extreme significance of impact related to climate variability was demonstrated in the 1999 tropical cyclone that hit the state of Orissa, which resulted in a death toll of about 55,000 cattle (CSO, 2000). Severe drought conditions 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 drought affected state of Gujarat, 18 million cattle out of 34 million were reported to have died before it rained the next year.

2.3 Incidence of Diseases

Weather has critical effect on the timing and intensity of disease outbreaks. Warm and moist conditions are conducive to the growth of insects. Also, the rates of insect biting and maturation of the microorganisms within them are temperature dependent and increase when the air warms. The potential impact of climate change on livestock diseases would be primarily on vector-borne diseases. Changes in rainfall pattern can influence an expansion of vectors during wetter years. Also, increasing temperatures have supported the expansion of vector populations into cooler areas, either into higher altitude systems or into more temperate zones. For instance, the rapid northward spread of bluetongue disease from southern Europe has been linked to changing climate patterns. Until fairly recently considered an exotic disease, the bluetongue virus (BTV) has spread to northern European countries in endemic proportions with more than 50,000 reported cases during 2007 in the EU.

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 temperature and rainfall (Sutherst, 1995).

In India, the incidence of livestock diseases and epidemics is very high. The magnitude of the economic losses due to animal diseases in India is not available, although it is generally agreed that recurring epidemic and other diseases cause phenomenal production losses. The estimated loss in milk and meat production from Foot and Mouth Disease (FMD) was estimated to be around 40-45 billion per annum during 1990-2001 (GoI, 2002). The meteorological parameters like temperature, humidity and rainfall have bearing on this livestock disease and have been found to explain 52 and 84 percent variations in the seasonality of FMD in cattle in hyper-endemic division of Andhra and meso-endemic region of Maharashtra states, respectively (Ramarao, 1988). Research studies indicate that the outbreak of the FMD is correlated with the mass movement of animals which in turn is dependent on the climatic factors (Sharma et al., 1991). Mastitis is another cattle ailment that inflicts heavy losses on the livestock producers. The production losses from clinical and sub-clinical mastitis were calculated as Rs 28 billion at 1994 prices (Sirohi and Sirohi, 2001), with sub-clinical cases accounting for 78% of the loss. The incidence of clinical mastitis in dairy animals is higher during hot and humid weather due to increased heat stress and greater fly population associated with hot-humid conditions (Singh et al., 1996). 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). Global warming will create favorable climatic conditions for the growth of causative organisms during most part of the year that will increase the probability of the spread of diseases in any season, causing heavy losses to livestock holders due to decline in milk and meat production, reduced work capacity, increase in abortions, subsequent infertility and sterility of animals.

2.4 Feed and Fodder Shortages

Dairy animals in India either subsist on poor quality grasses available in the pastures and non-pasture lands or are stall-fed, chiefly on crop residues. There is deficit of feed and fodder in the country to the tune of 22% for dry fodder, 62% for green fodder and 64% for concentrates (GoI, 2002). The low productivity of dairy animals in the country is largely attributable to the poor quality and lack of adequate availability of feed resources.

The predicted negative impact of climate change on crop production implies that such shortages would aggravate, further constraining the economic viability of dairy production. Simulations of the impact of climate change on rice and wheat yields for several stations in India using dynamic crop growth models (e.g., WTGROWS, INFOCROP, CERES) indicated that in north India, a 2 °C rise in mean temperature reduced potential grain yields of both the crops by about 15-17% (Aggarwal and Sinha, 1993; Hundal and Kaur, 2007). In Tamil Nadu, during the kharif season, the rice yields are anticipated to reduce by 10-15 percent by 2020 due to temperature and precipitation changes (Geethalakshmi and Dheebakaran, 2008). The magnitude of yield decline would aggravate further to 30-35% by 2050. Similarly, projections of climate induced decrease in yields of coarse cereals have been made (Chatterjee, 1998; Ramakrishna et al., 2000). Notably, wheat straw in the Northern India and paddy straw in the rice dominant regions constitute bulk of dry fodder fed to dairy animals. Nearly 44% of the animal feed produced in India is estimated to come from crop residues, such as rice and wheat straw, stovers of coarse cereals and about one-third comes from cultivated green fodder (NIANP, 2005). The potential decline in production of these cereal crops would decrease the dry fodder availability.

Additionally, the projected adverse effects of rising temperatures on productivity of foodgrains (Rao and Sinha, 1994; Aggarwal, 2000, 2003; Aggarwal and Mall, 2002) could mean bringing in more area under food crops to compensate for decrease in production due to yield effect. The area expansion towards food crops at the expense of fodder crops would further impinge on the availability of feed resources for livestock.

Besides being susceptible to a general temperature increase and changing rainfall pattern, feed and fodder production is also exposed to an increased risk of drought due to climate change. The 1999-2000 drought in the arid state of Rajasthan damaged 7.8 million ha of cropped area in the state and fodder availability fell from 144 to 127 million tons thus affecting about 40 million cattle (CSO, 2000). During the recent all-India drought in 2002, the total fodder production (dry + green) fell to 880 million tonnes, about 8.5% lower than the previous year.

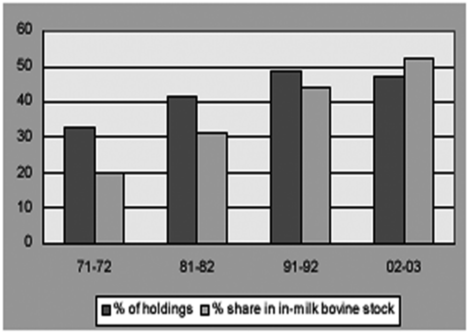
3. TARGETING ADAPTATION RESPONSES

While the overall prognosis for climate change impact on crop and livestock agriculture in tropical regions is not good, an even greater worry is the more substantial impact that will occur on pastoralists and smallholders due to their limited adaptive capacity. The dairy production in India is characterized by predominance of smallholders with the average herd size of 2-3 animals. Not only are the herd size small, 71% of the in-milk dairy animals are owned by small and marginal farmers with weak resource position (Fig. 2).

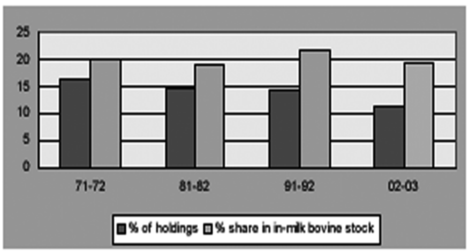
These farmers face number of constraints in dairy production, such as lack of resource for maintaining animals of high genetic potential, feeding high concentrate diet, providing advanced veterinary health care etc. However, as livestock are vital assets held by poor people and are crucial coping mechanism in variable environments, particularly in the event of weather induced shocks, it is imperative that the adaptation responses to climate change are in accordance with the wherewithal of the smallholders and pastoral families.

4. ADAPTATION STRATEGIES AND OPTIONS

Unlike the well-developed models for adaptation assessment for crops, there is a general lack of simulations of livestock adaptation to climate change. Nevertheless, a wide range of possible adaptation strategies exists—ranging from technological and management interventions for sustaining productivity of animals to market responses, institutional and policy changes for reducing the vulnerability of dairy farmers to climate change. As brought out in the previous section that most of the animals are owned by small producers, the adaptation options discussed in this section focus specifically on measures that are directly



marginal holdings



small holdings

Fig. 2 Share of marginal and small holdings in dairy stock (Source: NSSO, 2006).

relevant for these livestock keepers, while also making a mention of desired macro strategies that would have far reaching implications for adapting small holder dairy production to climate change.

4.1 Shelter Management

In the hot environment, energy exchanges by radiation are dominant, while convective energy exchanges tend to dominate in cold environments. Therefore, the first step to moderate the stressful effects of a hot climate is to protect the dairy animals from direct and indirect solar radiation. Shade against solar radiation could be provided by either trees or constructions made of straw and other locally available material. Trees are considered to be the most effective shades as their leaves are cooled by vaporization, but there are differences among the species with respect to the protection given. For instance, a research study from Brazil observes that best shade was given by the mango tree (*Mangifera indica*), with the least radiant heat load; while the worst tree type was *Pinus*, which presented high heat loads (Waldige, 1994). However, in summers the mango tree is usually avoided as a shade for cattle, because if its fruit is swallowed by a cow, it closes the oesophagus tightly, and may even cause death of the animal.

The appropriate height of the shading structure and the area of shade available per animal are also important in offering adequate protection to the animals. In areas with clear, sunny afternoons, shades should be 3 to 4.5 m high in order to permit maximum exposure to the relatively cool sky, which acts as an efficient radiation sink (Bond et al., 1967). On the other hand, in areas with cloudy afternoons, shades of 2 to 2.5 m in height are better, in order to limit the diffuse radiation received from the clouds by animals beneath the shade (Hahn, 1981). For ascertaining the area of shade that is adequate for a given location/environment, the best way is to observe the behavior of the animals in the range and record the average distance between them. The observed values can then be used in the planning of corrals and housings.

For tropical climates, generally enclosed shelters are not recommended because they decrease natural air velocity. Experimental studies have shown that thick walled, all-brick stall with a black exterior and white-washed under-surface adds to the thermal stress of sheltered crossbreds during Indian summer. Instead, straw thatched sheds or tall, simple, asbestos shades with reflective white outside and absorptive black on the under-surface of roof with plenty of shady trees in the surroundings to act as heat sinks are suitable for crossbred animals (Thomas, 1966). Under semi-arid conditions of Gujarat the thatched roof shed was found to be more conducive for buffaloes as compared to the brick walled shed (Patel et al., 1995).

In Indian conditions, generally loose housing system is presumed to be appropriate except in heavy precipitation areas. However, the loose housing system does not offer much protection during extremes of climate prevalent in northern part of India, such as in cold and chilly winter nights when temperature drops to below 10 °C and in summers when maximum temperature shoots above 40 °C. Aggarwal and Singh (2005) observed the effect of microclimate modification against extreme cold conditions on buffaloes. The feed intake and milk yield of buffaloes under open loose housing system was significantly lower than those housed in sheds with paddy straw bedding. In such areas, semi-loose housing—with sand bedding on the concrete floor in the covered area during summers and straw bedding during winters, together with thatched roofing—provides effective buffer during the extreme climatic conditions to reduce the peak stress on the animals housed.

The basic principle of shelter management to minimize the heat load of animals is construction of farm building to reduce heat gain and promote heat loss from the structures of the animal house by radiation and conduction during summers. In addition, the use of water as a cooling agent has been reported as excellent technique for reducing heat stress (Lin et al., 1996; Frazzi et al., 1997). Sprinklers, evaporative cooling foggers and misters are very effective in evaporating the moisture and cooling the air surrounding the cow, but such proactive measures are beyond the means of smallholder livestock producers. Therefore, alternate cost effective ways of water usage are required for alleviating heat stress. For instance, water application on buffaloes for 15-20 minutes before milking increases the milk yield (Verma and Hussain, 1988). Also, wallowing in buffaloes was reported to be more effective than water showers for increasing milk yield in hot season (Gangwar, 1985; Chauhan, 2004). Management of village ponds is essential for providing clean water for the wallowing buffaloes. Further, low cost, renewable energy operated evaporative cooling systems need to be fabricated as important adaptive devices catering to the needs of rural India.

4.2 Nutritional Management

Reduction in voluntary feed intake in heat stressed dairy animals is the major reason for decrease in milk productivity. In such a situation, the practical approaches to increase the dry matter intake (DMI), which is the key to good performance, include more frequent feeding, improved forage quality, use of palatable feeds, good nutrient balance and greater nutrient (including energy) density. Feed intake declines with hot conditions and rations must be reformulated in an attempt to deliver an adequate quantity of nutrients for sustaining the productivity.

Water is the most important nutrient for the heat stressed dairy animals. Water is lost from the animal body via urine, respiration and sweat. The lactating animal loose additional water through milk as water constitutes 87% of milk. Body of adult animal normally contains 55- 65% of water and a loss of one-fifth of body water is considered to be fatal. Drinking water is the major source of water, and satisfies 80-90% of dairy animals total water needs. Inclusion of green fodders in the diet also helps in catering to the water requirement of the animals. Water consumption is variable, and depends on ambient temperature, DMI, milk yield, sodium intake, physiological stage, minerals present in water etc. In lactating dairy animals the water consumption may be 45-75 liters per day (lpd) per head, while in the dry animals it ranges from 25-40 lpd. Under heat stress, water intake could significantly increase by 120-200%. For *Bos indicus*, for example, water intake increases from about 3 kg per kg DM intake at 10 °C ambient temperature, to 5 kg at 30 °C, and to about 10 kg at 35 °C (NRC, 1981). This increased water intake helps to dissipate heat through the lungs (respiration) and by sweating. The drinking behavior of cows is interesting. Cows spend about six hours a day eating, but only five to ten minutes in drinking. They drink mainly after being milked and when fresh feed is offered. Since it is difficult to define how much water is adequate, it is crucial to supply abundant, clean and easily accessible drinking water to animals all the time.

Managing the feeding schedule of animals is another simple and effective adaptation option. The feeding behavior of animals changes when it is hot. Animals consume more feed during cooler evening hours (West, 1999). Thus, the quantity of feed and the feeding schedule should be adjusted to accommodate this behavior. Having fresh feed in the mangers after milking is a good way to encourage DMI. When the weather is very hot, at least 70% of the daily feed should be given fresh at night. More frequent feeding could keep feed fresher, and encourage cows to eat more frequently, thus stimulating DMI. Theoretically, more frequent feeding might decrease the diurnal fluctuations in metabolites and increase feed utilization efficiency in the rumen (Robinson, 1989). Commercial dairy producers usually believe that frequent feeding is crucial in achieving and maintaining high productivity. This practice could be introduced very easily in our country by smallholders to achieve maximum dry matter intake under heat stress. This practice may be even more important during hot weather, because feed is fermented faster after preparation when air temperatures are high.

The fall in the DMI during hot weather conditions affects the availability of adequate amounts of nutrients viz. energy, protein, and fats. Digestion and metabolism of feed create heat, and this heat production should be cut down as much as possible to provide relief to the animals exposed to environmental heat stress. Each kind of feed has its own heat increment (HI) value that is the value of energy expenditure associated with the digestion and assimilation of food. A diet with a higher nutrient density and low HI (higher energy conversion efficiency) for lactating animals under heat stress is desirable. This is achieved by inclusion of more or highly digestible nutrients rather poor quality roughages like straws.

The dairy rations during hot weather conditions should have low fiber content as there is greater heat production associated with metabolism of acetate compared with propionate. Feeding more concentrates at the expense of fibrous ingredients increases the energy density of rations, and should reduce HI (West, 1999). Also increasing the level of grain in animal ration would reduce the fiber content but a decrease in the fiber level has to be monitored carefully. In some experiments results have indicated that giving cows more grain in their feed leads to a lower rumen pH, especially in hot summer (Mishra et al., 1970), and sorting the feed to remove fiber could make the rumen pH even lower. The level of Acid Detergent Fiber (ADF) should be maintained at a minimum of 18-19%, or alternatively the Neutral Detergent Fiber (NDF) should be at least 25-28% of diet DM. Feeding very high-quality forage to lactating cows in hot summer is also recommended, because it reduces heat build-up and supplies necessary fiber content.

The addition of fat to the diets of lactating dairy animals is another practice that has the potential to reduce the heat increment due to the greater energy density and high energy conversion efficiency of high-fat diet. Although, the results of the research on the positive effects of dietary fat during hot weather are not robust (Skaar et al., 1989; Huber et al., 1994; Chan et al., 1997), biological principles argue in favor of fat supplementation under conditions of heat stress. Extension nutritionists still suggest fat supplements to give a final fat content of 6-7% of diet DM, especially for high milk producing animals. Sources of fat supplements include whole oilseed, crushed oil seeds and/or protected fat products.

The quantity and quality of protein in the diet needs to be considered when feed is being provided for heat-stressed animals as animals suffering from heat stress often have a negative nitrogen (N) balance, because of reduced feed intake. However, simply increasing the level of crude protein (CP) may increase energy requirements and cause problems of environmental pollution as excess dietary protein is converted into urea and excreted. Based on research, it was suggested that during heat stress, the level of crude protein (CP) in the diet should not exceed 18%, while the level of rumen degradable protein should not exceed 61% of CP or 100 grams of N/day (Huber et al., 1994). Cows fed diets with a low level of degradable protein had a higher percentage of milk fat and milk lactose, and a lower level of urea nitrogen in their blood.

Electrolyte minerals, sodium (Na) and potassium (K) are important in the maintenance of water balance, ion balance and the acid-base status of heat-stressed cows. The mineral requirements recommended by the National Research Council (NRC), 1989 do not seem high enough for cows suffering from heat stress. When heat-stressed cows sweat, they lose a considerable amount of K. Increasing the concentration of dietary K to 1.2% or more result in a 3-9% increase in milk yield, and also an increased DMI. Increasing the concentration of sodium in the diet from the NRC recommended level of 0.18% to 0.45% or more improved milk yield by 7-18% (Sanchez et al., 1994). If magnesium oxide (MgO) was added, thus increasing the Mg concentration from 0.25% to 0.44%, the milk yield of heat-stressed cows increased by 9.8% (Teh et al., 1985). In hot weather, the level of milk fat is usually lower. Supplementation with buffers such as sodium bicarbonate ($NaHCO_3$) and magnesium oxide (MgO) is common practice to provide these minerals which also help in maintaining the rumen pH.

Some feed additives were also available in terms of their ability to provide relief animals suffering from heat stress. Most research with lactating cows concerned with direct fed microbials or “probiotic” products deals with either *Aspergillus oryzae* (a mold classified as a fungus) or *Saccharomyces cervisiae* (a yeast). Both *A. oryzae* and *S. cervisiae* may influence the fermentation pattern and microbial population in the rumen (Yoon and Stern, 1996). Results indicated that three grams of *A. oryzae* supplementation had little effect on rectal temperature, respiration rate, or milk composition, but gave a 4% increase in milk yield (1 kg/day) (Huber et al., 1994). On the other hand, trials with niacin feed additive showed that under moderate to severe heat stress conditions, niacin at a rate of 12-36 grams a day lowered skin temperature by about 0.3 ^{o}C but it did not improve milk yield (DiCostanzo et al., 1997). In Indian conditions, however, feed additives for managing heat stress may not be economical for low producing animals but if supplemented in high producing animals positive results are expected.

4.3 Health Management

As brought out earlier, air temperature, relative humidity, intensity and duration of sunshine, precipitation etc. have important bearing on the occurrence of livestock diseases and spread of parasites. Successful control of disease requires timely and accurate diagnosis and adequate availability of veterinary medicines and vaccines. To counter the effect of climate change on the incidence of disease, the existing network of veterinary health support services will have to be strengthened in a big way, with particular emphasis on preventive health care services.

Presently, most of the government dispensaries and hospitals are stationary and are primarily engaged in providing curative health cover and breeding services. Only a meager 3.5% of the total staff engaged in livestock health institutions are taking care of disease investigation and control (Ahuja et al., 2003). The state machinery for providing preventive health care services is supported by about 250 disease diagnostic laboratories, 26 veterinary vaccine production units (seven in the private sector), one National Veterinary Biological Products Quality Control Centre and animal quarantine stations at the four metropolitan cities. Disease control programs and vaccinations are, however, sporadic, unsystematic and have limited coverage. Over 25 million vaccinations against FMD are carried out each year, as against the 420 million animals at risk and this does not confer adequate protection against the disease. FMD is a contagious disease and until more than 85% of the animal population in an area is vaccinated the herd immunity cannot be established (Chawla et al., 2004). In light of the fact that immunisation is one of the most economical means of preventing specific diseases, providing long-lasting immunity, the present approach of veterinary health management, needs to undergo a sea change. In general, vaccines offer a substantial benefit for comparatively low cost, a primary consideration for developing countries.

Apart from stepping up the capacities to cater to the infrastructure and pharmaceutical needs for health management, the trained human resources would also be required to meet the enhanced demand for veterinary services. The Tenth Plan Working Group on Animal Husbandry suggested that a minimum of 3,000 veterinarians will be required in the country annually in order to meet the growth rate of 10% by the year 2020. In addition, an input of 3,560 dairy graduates is required in order to sustain a growth rate of 10% in the sector. The current student intake of veterinary colleges may not be enough to fulfill this requirement and hence, an expansion is imperative.

Dealing with emerging challenges of climate change would also require new initiatives aimed at making veterinary services to smallholders more efficient through decision making and planning aids. An initiative in this direction has been proposed by IIT, Mumbai, for taking 'Technology to Masses' through utilization of ICT to provide efficient veterinary services to rural people and their cattle. The design ideas include creating a digitized history of the animals, a system for interaction between cattle owner, veterinary service center and doctor and automatic visit scheduling. Such initiatives need to be up-scaled with additional provision of weather based livestock disease advisory services.

4.4 Managing Common Property Resources

The poor livestock keepers depend heavily on common property resources for their survival. The land holding of these farmers is not sufficient even for crop cultivation. In the absence of CPR lands, they would be unable to maintain their ruminant livestock and shall lose the subsistence source of dairy income as well as face further degradation of their crop land due to deprivation of the only source of manure (dung) and draught power. Unfortunately, there has been rapid deterioration of CPRs on account of physical loss of resources due to infrastructure development, degradation of their physical productivity and re-assignment of usage and property rights. The brunt of developmental pressures may further fall disproportionately on the CPR, more so, as there are few organized efforts for the development of common lands and its sustainable management.

As the change in the status and productivity of common property resources, like pastures and grazing land, village ponds and rivulets etc. will directly influence the economy of the smallholders, particularly the climate change coping options related to nutrition and shelter; the key elements of an approach to regulate the use and enhance regeneration of CPR need to include: (1) introduction of technological investments and creation of economic incentives to conserve such resources while raising their productivity and (2) regulation of common resource use with the involvement of user groups and mobilization of a community strategy that complements state interventions with the essential participation of local people (Jodha, 1995). Available experiences of successful participatory natural resource management initiatives can offer useful lessons for replication.

4.5 Genetic Selection and Conservation

The genotype environment interactions have adapted the Zebu non-descript cattle of India to thermally stressful conditions by reducing the metabolic and heart rate and increasing the sweating capacity. However, as in the process of this adaptation, the low metabolism characters have been selected, it has resulted in low milk production potential of animals. High milk production requires high metabolic activity and more energy expenditure, reducing the capability to withstand high heat loads—a characteristic of *Bos taurus* cattle prevalent in temperate countries. Although the selection of animals in *Bos indicus*, the tropical cattle has been an adaptive one, the requirement of higher milk production led to their crossbreeding with exotic semen from *Bos taurus* cattle. One of the challenges associated with managing high producing cattle in a hot environment is that selection for increased performance is often in conflict with maintaining homeothermy. As genetic variation exists for traits important to thermoregulation, the adaptation challenge is to improve productivity traits while maintaining adaptive traits.

Unfortunately, although the developing countries like India are endowed with vast domestic animal diversity that have high adaptive potential to biotic and abiotic stresses, most of these animal genetic resources are still not characterized and the structured breeding programs are limited. Local breeds are often defined on the basis of subjective data and information obtained from local communities. Reliance on these criteria as the basis for classification for utilisation and/or conservation may be misleading. Hence, application of biotechnology and other advanced techniques for characterization of local breeds and subsequently building inventories, including spatial information, of breeds and valuable breeding stocks can be instrumental in the long run to exploit a genetic approach to heat tolerance while selecting for high milk yield potential. This would also be an adaptation response in the event of loss of local and rare breeds due to increased incidence of droughts, floods, or disease epidemics etc. resulting from climate change.

Besides, characterization of animal genetic resources, its conservation should be one of the priority livestock development activities for developing countries. Experience has indicated that in Indian conditions, "conservation through use" is insufficient due to widespread situation of indiscriminate cross-breeding. Hence, establishment of genebanks for local breeds and ex-situ especially, in vitro conservation needs to be considered as an important component of a broad-based strategy to conserve critical adaptive genes and genetic traits. The ex-situ approaches include cryopreservation of semen, ova and embryos for which the technology is sufficiently developed to be applied in developing countries. There is ardent requirement of financial support for implementing animal genetic resources conservation programs.

Further, development in genetic engineering, cryobiology, cell biology and embryology will provide techniques that may enhance our ability to preserve germplasm in vitro. Techniques such as transfer of DNA within and between species and the production of viable transgenic animals are far from practical application. However, biotechnology will certainly contribute newer and cheaper methods for preservation such as storage of catalogued DNA. At present, other than live animal and embryo preservation, the other techniques do not allow preservation of genomes in a form which can be reactivated in toto at a later stage, but they permit the preservation of individual genes or gene combinations for possible future regeneration (Kannaiyan, 2007).

4.6 Livestock Insurance

The increased risk resulting from climate change faced by the livestock farmers can also be mitigated to certain extent through management of climate perils using the instrument of insurance. In India, the livestock insurance programs are still in nascent stage with extremely low coverage of animals other than commercial poultry. For the dairy animals, the insurance policies only indemnify death due to disease and accident. In the changing circumstances, innovative insurance products will have to be designed aiming at: (a) livestock production insurance that would protect farmers from loss and business interruption due to illness or death as well as recovery of veterinary costs due to on-farm diseases; (b) net revenue insurance for protecting farmers against losses from the market place; and (c) catastrophe insurance, that would protect farmers against extreme price losses due to the emergence of a disease that correlates with rapid decreases in market prices.

The Index Based Livestock Insurance approach adopted in Mongolia to assist the herders in the management of the losses caused by weather induced calamity called *dzuds* can also provide useful learning experience for insuring the smallholders in India against potential threat of climate change to dairy production system.

4.7 Extension Strategy

One important prerequisite for farmers in adapting to the negative effects of climate change is to understand and know its impacts. Although many farmers already use strategies to cope with varying conditions, but as weather becomes less predictable, some of these strategies may no longer work or require additional information in order to remain of value. Hence, effective communication approaches are critical to help farmers adapt to climate change.

Electronic media like radio and television are very effective ways to reach farmers. The available information on climate change is, by and large, not aimed at a farming audience. The challenge for media is to ensure that their clientele understands climate change messages and finds them relevant. Media can also encourage communities to assess local problems, identify local solutions to climate change and establish collective action plans to reduce their vulnerability.

5. CONCLUDING REMARKS

As climate change poses formidable challenge to the development of livestock sector in India, this chapter discussed the vulnerability of dairy animals to climatic conditions and the coping mechanisms that could be instrumental in mitigating the negative effects of changing climate. The anticipated rise in temperature between 2.5 ^{o}C and 5 ^{o}C over the entire country, together with increased precipitation and occurrence of extreme events resulting from climate change is likely to adversely affect productive and reproductive performance of dairy animals by way of aggravated heat stress, susceptibility to diseases and feed and fodder shortages.

The animals employ physiological mechanisms to counter the heat stress. The adaptation to higher temperature is also complemented by the behavioral process, such as buffaloes prefer wallowing during summer to reduce thermal loads and maintain thermal equilibrium. While new knowledge about animal responses to adverse weather continues to be developed, there is a need for additional knowledge on managing livestock to reduce the impact of climatic changes. Management intervention is needed to ameliorate the constraints on production set by the climate, the physical environment and the health hazards in a region.

Responding to the challenge of climate change requires formulation of a wide range of adaptation options for the smallholder livestock producers, encompassing human intervention for physical modification of the environment, improvement in nutritional management practices, improved animal health technology, genetic selection for stress tolerant high yielding dairy breeds, market responses that are potentially effective adaptation measures to climate change, such as insurance schemes, income diversification opportunities, and institutional and policy changes. The on-farm decisions need to involve selection, design and management of production facilities, while the collective impacts would guide regional or national policy and determine responses to potential large-scale changes. Another critical requirement is the development of collaborative learning processes to support the adaptation of livestock systems to better cope with the impacts of climate change. Research cannot hope to contribute to improving adaptive capacity without a comprehensive understanding of the context in which decisions about adaptation are made and of the capacity of decision makers to change (Thorton et al., 2007). Farmers possess a wealth of indigenous knowledge for dealing with climate variability and risk that should be assessed for its efficacy and subsequently documented for wider dissemination. This exercise is to be done in conjunction with well-targeted capacity building efforts to help farmers deal with changes in their systems that go beyond what they have experienced in the past.

Despite the vital importance of the livestock sector in providing livelihood to the millions of people in India, unfortunately, the sector has by-passed the attention of the planners for reducing its vulnerability to climate change. The National Action Plan on Climate Change (GoI, 2008), which aims to provide the roadmap for the sustained development of various sectors in the future, is virtually silent about the strategies to adapt livestock production to climate change. Its vision for the National Mission for Sustainable Agriculture is essentially crop-centric with only lip-service to the livestock sector by including the use of biotechnology for the development of nutritional strategies to manage heat stress in dairy animals as one of the priority areas under the Mission. The research and development (R&D) efforts to fine-tune and upscale the adaptation measures discussed in this chapter would be instrumental in developing multi-pronged, long-term, integrated and inclusive strategies for insulating the livestock producers from the hazards associated with changing climate. The policy support from the Government through appropriate institutional mechanisms suited for effective delivery of various adaptation options is urgently required for achieving key goals in the context of climate change and livestock sector.

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