Mitigation of Climatic Change Effect on Sheep Farming Under Arid Environment

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Abstract

Livestock is the integral part of agricultural systems all over the world. However, in India, climate change has become a serious concern for ensuring nutritional security for the growing population. Small ruminants, especially pastoral farming, serve a major livelihood option and are embedded deep in the culture of resource-poor small and marginal farmers of arid and semiarid western India. The breeds of these arid and semiarid region are well adapted to the local climatic condition and have amalgamated themselves to very harsh climatic factors in the region. The local native animals of this region have their own adaptive mechanism of altering physiological, neuroendocrine, biochemical, cellular, and molecular process to encounter the stress; still, they need to endure stressful conditions due to high temperature, low feed, and water scarcity. All these constraints expose the sheep production into heat stress, nutritional stress, water stress, walking stress, and their combinations. All the stress factors affecting sheep production directly and indirectly and ultimately lead to compromised performance, lower efficiency, and increased mortality and affect the immune system. Giving the poor farmer's economic security, under changing climatic scenario, sheep production has to be sustainable by combating the detrimental effect of different mitigation strategies. In the present chapter, the mitigation strategies have been discussed which include genetic improvement, breeding management, grazing management, nutritional management, utilization of unconventional feed resources, antioxidant supplementation, water management, shelter management, and disease management. Basically, all these strategies are

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based on a physical modification of the environment, genetic modification, and improved nutritional management. To get optimum production under changing climatic scenario, holistic approach is needed as per the environmental conditions and available resources.

22.1 Introduction

In the twenty-first century, worldwide climate change is a critical challenge to the mankind as well as the animal kingdom. The developing countries like India are more vulnerable to this threat due to their dependence on natural resources and high poverty levels. High temperature hinders productive and reproductive performance, impairs metabolic health and metabolic status, and weakens immune response. A pertinent increase of drought may affect forage and crop production (Nordone et al. 2010). These situations will likely worsen further under the ensuing changing climatic scenario. Under such situation, sheep production may play a critical role for the development of sustainable and environmentally sound production system (Ben-Salem 2010).

Sheep husbandry is one of the sustainable livelihood options for the people living in arid and semiarid regions. But nature has been a little harsh toward these regions by providing less vegetative resources, climatic variability, and water scarcity. In India, the arid and semiarid region comprise almost 53.4% of the total land area. These regions cover mostly rangelands. Therefore, the poor landless small and marginal farmers of the region rear their livestock through a low-input pastoral system of management (Naqvi et al. 2013b). Nearly 21% of the sheep belong to arid and semiarid region, and they play an important role in the rural economy with its multifaceted utility of wool, meat, milk, skin, and manure. Out of 41 well-recognized breeds of India, 11 breeds survive/exist/sustain/belong to arid and semiarid region. The harsh climatic condition compels the breeds of these areas to make some behavioral, physiological, and morphological adjustment to adopt to the climatic variability. Therefore, the native breeds of these regions have become well adapted to scarce feed supply and shortage of drinking water and able to survive in extreme heat, can migrate long distances, and show resistance against tropical diseases. Nonetheless, the adaptation mechanism supports their survivability, but with a compromised production efficiency.

22.2 Impact of Climate Change on Sheep Production

The pronounced impacts of climate change on sheep production are apparent in breed composition, population and distribution, feed and fodder scarcity, shrinkage of grazing land, reproductive and productive disorders, spread of diseases, poor performances, consumer demand and market trend for wool and meat, etc. Some of the important attributable climate-driven changes are discussed here.

Table 22.1 Current changes in the sheep population in India and top five sheep-producing states

Year	Population (million)	State	Population (million)
1992	50.78	Andhra Pradesh	26.40 (40.5)
1997	57.49	Karnataka	9.6 (14.7)
2003	61.47	Rajasthan	9.1 (13.9)
2007	71.56	Tamil Nadu	4.8 (7.3)
2012	65.07	Jammu and Kashmir	3.4 (5.2)

Figures in parenthesis refer to percent increase in two decades (Source: Livestock Census 2012)

22.2.1 Sheep Population and Distribution

A reduction in the sheep population from 74 million in 2010 to 65 million in 2012 (Livestock Census 2012) raised an alarm on its future status. The reasons may be multifarious, an increasing demand for meat and higher slaughter rate to preference shift toward the rearing of other livestock species. The effect of climate change on the distribution of sheep population is visualized by the recent change in the sheep population from Rajasthan to Andhra Pradesh (Table 22.1). The sheep population in Rajasthan was 10.62 million in 1997, which declined to 10.05 million in 2003 livestock census with an overall reduction of 5.72%. On the other hand, the sheep population in Andhra Pradesh increased by 13.9%.

The frequent drought and famine situations and continuous declining of grazing resources, both in terms of quality and quantity, could be the reasons for the decline of sheep in Rajasthan during the period. In the present climate-changing scenario, migration becomes hard and harsh for the farmers. Flock size is declining sharply over the period; the average flock size was 100–120 in 1990, which has reduced to 70–80 in 2000 and 35–40 in 2008 in the semiarid region of Rajasthan (Shinde and Sejian 2013).

22.2.2 Breed Composition and Distribution

Farmers of arid and semiarid regions always prefer sheep breeds which can withstand thermal and nutritional stresses and able to walk long distances during migration. The evolution of indigenous sheep breeds in different agroecological niches through natural selection over the time period also supports these characteristic changes. 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 the migratory system (Shinde and Sejian 2013). Magra breed found in and around Bikaner, known as Bikaneri Chokla, produce excellent carpet wool with a fiber diameter of 32–35 μ and lustrous character. However, their population got reduced considerably with the intermixing of breeds during migration.

22.2.3 Grazing Land

In arid and semiarid regions of the country, 45–50% of the land is utilized for grazing purposes, and in extreme arid regions of Rajasthan, 90% of the land is utilized for grazing purposes. The area of common property resources (CPR) has declined by 26–63% during the last three decades. This CPR is also now in a state of dwindling and produce only 0.2–0.3 Mg ha^{-1} of dry fodder under normal rainfall, which reduced to 40–50% with changing climate due to decline and erratic distribution of rain (Sankhyan et al. 1999).

22.3 Multiple Stress Factors and Their Effect

22.3.1 Heat Stress

Heat stress is the foremost effect of climate change in the arid and semiarid region in sheep production. Heat stress can disrupt the physiology and productive performance of an animal. The increase in body temperature caused by heat stress has direct, adverse consequences on cellular function. Production losses in domestic animals are largely attributed to increase in maintenance requirement associated with sustaining a constant body temperature and altered feed intake (Indu et al. 2014). Heat stress also hampers the male and female reproduction. Heat stress affects estrus percent and duration, conception rate, lambing rate, and birth weight of lambs (Maurya et al. 2004). In addition, it influences plasma estradiol and progesterone concentration in Malpura ewes (Sejian et al. 2011). Further, a reduction in superovulatory response and embryo production occurred in Bharat Merino ewes (Naqvi et al. 2004) while it reduced the feed intake and body weight (Sejian et al. 2010a).

22.3.2 Nutritional Stress

Another potential stressor in this region is nutritional scarcity which is increasing due to the scarcity of good quality and quantity of fodder. Poor and marginal farmers of semiarid tropics depend a lot on livestock and agriculture for their livelihood. In extensive production system, the well-being of livestock entirely depends on the herbage. Livestock of this region mainly remained undernutrition during late spring and summer due to increased energy output for thermoregulation and concurrent reduction in energy intake (Sahoo et al. 2013). This can result in impairing reproduction and production efficiency of grazing animals (Ali 2008). Sheep and goat flocks migrate in search of feeding and grazing resources from one place to another and from the lower hills (800–900 m above MSL) up to the high alpine pastures (3600–4800 m above MSL) and back again as the climate determines the availability of fodder and forage (Sahoo 2013). But the magnitude of stress was severe when only 60% or less of their nutritional requirement are available (Sejian et al. 2014).

Thermal stress and feed scarcity are the major predisposing factors for the low productivity of ewes under hot semiarid environment. Moberg (2000) described a hypothetical scheme of how two stressors can summit together, and their total impact might be severe on biological functions. The combined thermal and nutritional stress had a severe impact on biological functions, though the native breeds possessed considerable adaptive mechanisms to overcome these stresses (Sejian et al. 2010b).

22.3.3 Water Stress

Water scarcity during summer is a serious problem in this region. Therefore, during this period, availability of good quality drinking water is reduced for all the species. Drinking water is often a limiting factor for livestock in grazing areas of the semiarid region (Sahoo et al. 2015a). Some breeds of small ruminants could survive up to 1 week with little or even no water in hot arid and semiarid regions (Nejad et al. 2014; Chedid et al. 2014), but water shortage affected animal's physiological homeostasis leading to loss of body weight, low reproductive performance, and a decreased resistance to diseases (Barbour et al. 2005). The feed intake, average daily gain, physiological responses, hematological parameters, and reproduction of ewes impaired during water stress (Kumar et al. 2016). Well-adapted Malpura ewes have the capacity to adjust their physiochemical response and reproduction comfortably up to 20% of water restriction during hot summer, and the impact increased with the magnitude of water restriction (Kumar et al. 2016).

22.3.4 Walking Stress

During the summer, another key constraint of arid and semiarid tropical environments is their low biomass productivity (Sahoo et al. 2015b). The availability of feed in the rangeland reduced substantially and most of the time, it is not available in the dry season. As biomass density (feed) per unit area remained very low, the sheep tries to increase the grazing time each day as well as disperse more widely. Therefore, other than thermal stress and feed scarcity, the animals need to walk long distances for grazing (Naqvi et al. 1991) and are exposed to exercise stress during walking in such an environment. These stresses lead to alterations in the process of homeostasis and metabolism. The changes in respiration rate, heart rate, rectal temperature, plasma cortisol, thyroxine, and triiodothyronine showed that native sheep have the capability to adapt to long-distance walking. The negative effect on growth performance shows that productive performances are compromised while trying to adapt to long-distance walking (Sejian et al. 2012b).

22.3.5 Multiple Stresses

Under field condition, most of the time, the above stresses, i.e., heat stress, nutritional stress, water stress, and walking stress, occur in combinations and simultaneously and causing multiple stress. Multiple stress affects body weight, respiration rate, pulse rate, rectal temperature, sweating rate, triiodothyronine, thyroxine, cortisol, hemoglobin, packed cell volume, glucose, and total protein (Sejian et al. 2013). Along with that, both conception and lambing rate also reduced significantly under multiple stress (Sejian et al. 2012a, b). Hence, selection of adapted animal breeds is very important for sustaining animal production under this challenging environment. The breeds of this region have developed adaptive capacity to survive in these adverse conditions.

22.4 Free Ranging and Metabolizable Energy Requirement

In free ranging, if the food availability is scarce, the animals are forced to travel to meet their energy requirements, and this extra energy drain can be an important contributor to the metabolizable energy (ME) need for maintenance (Sahoo 2013). Sheep have adapted well to environmental conditions prevailing in arid lands, being able to obtain an adequate diet even when forage is scarce. Anyhow, the energy requirements in open range may increase severalfold over values assessed for restrained animals due to walking stress in search of scarce feed resources in rugged and otherwise inaccessible terrain. According to NRC (1981), the energy requirement of goat increased 25% under grazing conditions due to increased muscular activity. The energy requirement increased 50% in semiarid rangeland pasture and in slightly hilly land due to higher muscular activity for less availability of biomass in these regions. The requirement of energy increased up to 75% in case of long-distance travel on sparsely vegetated grassland and/or mountainous transhumance pasture. Both the increased energy expenditure of eating and the energy expended in walking would account to this increased maintenance requirement. The heat production (HP) attained 401 kJ $kg^{-0.75}$ d^{-1} for restrained goats. The increase in HP for unrestrained over restrained goats was 43.1%, and daily distance traveled (say 2 km) accounted for 9% of the extra HP.

22.4.1 Sheep Diseases

Other than direct effect of climate change, sheep diseases and resistance are also affected by reduction in natural grazing land and increasing metabolic disorders. Poor-quality green grass due to vitamin A deficiency increases the incidence of corneal opacity and night blindness. The deficiency of vitamins A, D, and B_1 and minerals, viz., calcium, phosphorus, zinc, and copper, is not only prevailing unabated but also is 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 anemia, 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 would lead to economic losses to farmers (Singh et al. 2010). Under the traditional system, breeding of sheep is associated with acacia and khejri pods in arid and semiarid regions. The climate change and its effect on tree pods would adversely affect the reproduction in sheep and goats. A poor vegetation cover of CPR would provoke soil ingestion because of their close grazing habit, e.g., soil ingestion increased up to 39.1, 15.6, and 46.4% of dry matter intake in sheep during drought and famine conditions. Soil that accumulates in the rumen and reticulum impairs the digestion and production resulting in mortality under prolonged exposure (Shinde et al. 2005).

22.4.2 Marketing and Economics

The climate change is leading to shrinkage of grazing lands and scarcity of feed and fodder from grazing lands which are directly hampering production performance of sheep. As a consequence, farmers are being forced to sell their lambs early (3–4 months age weighing only 12–14 kg) instead of regular practice of selling lambs of 20–22 kg weight (9–12 months old) (Shinde and Sankhyan 2010). Earlier, flocks were managed completely on grazing resources. However, the grain supplementation to young stock has now become a common practice as a protection against the vagaries of nutritional stress. This along with climate change induced poor health and increased susceptibility to diseases which are adding to the cost of production (Shinde and Sejian 2013).

22.5 Mitigation Strategies

In changing climatic situation of arid and semiarid region, keeping in view the poor farmer's economic security, sheep production has to be sustainable by combating the deleterious effect of different stressors. Thermal variability challenges the animal's ability to maintain energy, thermal, water, and hormonal and mineral balance. Reducing stress on sheep requires multidisciplinary approaches that emphasize animal nutrition, housing, and animal health management. The effect of hot climate can alleviate through suitable management strategies like provision of shade, diminishing the ground reflection, suitable shelters, restriction of feeding during hotter parts of the day, postponement of shearing to cooler season, and control of mating so that late pregnancy occurs in comparatively cooler season (Naqvi et al. 2013b).

22.5.1 Genetic Improvement

The increasing demand for meat urges a serious need of sturdy, heat-tolerant, disease-resistant, and relatively adaptable breeds to the adverse conditions (Moran et al. 2006). In such situation, some of the indigenous breeds are able to cope better than the crossbred. The native sheep breed like Malpura, Chokla, Marwari, and Magra are well adopted in arid and semiarid region and can tolerate heat and nutritional stress. Disease- and parasite-resistant sheep breed need to propagate in this region as 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). Pattanwadi and Malpura sheep yield 1.2–1.4 and 0.6–0.7 liter of milk daily which can provide extra security and economic support in the dry regions. The crossbreeding of Awassi sheep that is well adapted to dry and hot conditions, with Pattanwadi or Malpura, to improve milk yield of native sheep appears to be a better option. Fat tail sheep breeds can withstand the harsh climate and can serve as a source of income for poor farmers (Shinde and Sejian 2013).

22.5.2 Breeding Management

In Rajasthan and Gujarat, the farmer used to tie the prepuce of rams with cotton threads to avoid matings during undesirable seasons. Most sheep breeding takes place in July–August, i.e., immediately after the onset of the monsoon and some of it in March–April, when stubble grazing and *Acacia* and *Prosopis* pods are available to the animals. Though 80–100% of animals exhibit estrus throughout the year, considering lambing percent and lamb survival and growth, breeding in March–April and August–September is preferable (Acharya 1982).

22.5.3 Grazing Management

The sheep mainly graze either on pastures, wasteland, fallow lands, or stall fed to meet their nutritional requirements as per their physiological state and levels of production. The climate variability is changing the pattern of land utilization, deforestation, degradation of pasture, and range lands, which ultimately are increasing the gap between availability and requirement of nutrients. In such condition, trees and shrubs provide green biomass of moderate to high digestibility and protein content when other feed reserves are scarce. There are several options for making effective use of shrubs and tree foliage. In many parts of the country, small ruminants are maintained on top feeds than conventional fodder resources. Sheep and goat browse on tree leaves. The tree leaves are also harvested, sun dried, and stored at proper stage; thereafter, they are supplemented during the lean summer months, at the time of feed scarcity to maintain the small ruminant production. Although lopping of standing trees in the forest is prohibited, removal of fallen tree leaves is allowed.

It is estimated that 300–350 million Mg dry fallen leaves and grass is available from the forests which has better CP value than the crop residues. Almost 43 million Mg of this resource, if processed, can be effectively used in livestock feeding. However, fallen tree leaves cannot maintain the sole feeding of sheep. Therefore, plantations of palatable trees like subabul (*Leucaena leucocephala*) can become a good alternative. Mainly locally available species should be preferred which produce leaf residues during lean period (Sahoo et al. 2013).

22.5.4 Nutritional Management During Migration

In Rajasthan, almost 0.5 million sheep are on permanent migration following established migratory routes and seasons (Acharya 1985). From western districts of Rajasthan, almost 1.0 million migrates for 6–9 months to the neighboring states. Most flocks begin migration between October and February and follow set migratory routes and return by May to June or before the onset of the monsoon. The sheep flocks are grazed on uncultivated land during the monsoon, and when the kharif crops are harvested, the animals are permitted to graze on crop stubbles. During later part of the year, beginning in September/October, most nonmigratory flocks graze on the harvested fields and reserve forests in their migratory tracts. During the extreme summer months, the flocks graze during the cooler hours of the day. About 60% of the flocks are penned in open fields away from the house; the rest are penned in temporary courtyards made out of thorny bushes or earth near the house (Naqvi et al. 2013b).

The sheep and goats fulfill their maintenance requirements from grazing during migration and thus considered to be not under stress (Sahoo 2013). However, nutrient requirements are higher during critical physiological stages, viz., last quarter of lactation and early part of lactation. In view of poor pasture quality and high stocking density of grazing lands, such animals remain underfed. Similarly, adequate nutrition of lambs/kids through their dam during pre-weaning phase is important. Healthy lambs of comparatively higher birth weight suckling from optimum fed ewes grow faster and attain finishing weights at an early age. Therefore, the supplementation of ewes/does on pasture is important for economic fat lamb production.

22.5.5 Utilizing Unconventional Feed Resources

The cactus species like prickly pear cactus (*Opuntia ficus-indica*) has been propagated successfully as an alternative to provide biomass and water to sheep during summer scarcity (CSWRI 2013–14). The approach is applicable elsewhere in dry arid region, where feed scarcity along with water scarcity is severe. Lopping of fodder trees like khejri (*Prosopis cineraria*), ardu (*Ailanthus* spp.), and neem (*Azadirachta indica*) serves as the best option during the harsh periods of the year.

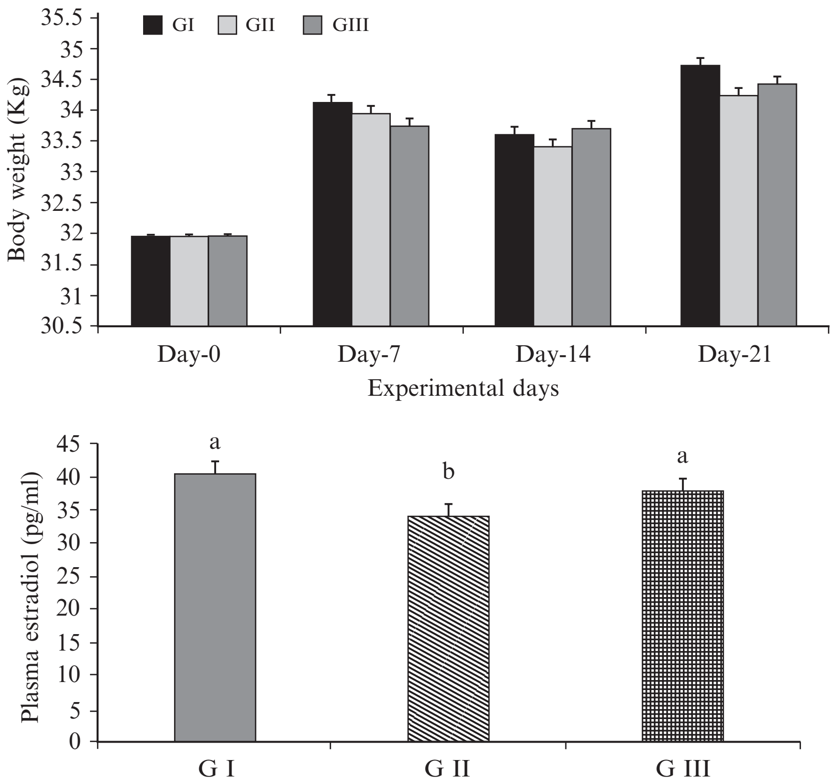

Fig. 22.1 Effect of antioxidant supplementation on body weight and plasma cortisol levels during summer (Source: Sejian et al. 2014) *GI*, control; *GII*, heat stress; *GIII*, heat stress + antioxidant supplementation

22.5.6 Antioxidant Supplementation

Heat stress stimulates excessive production of free radicals (Bernabucchi et al. 2002; Sivakumar et al. 2010). In such situation, the deficiency of dietary trace element affects physiological function and particularly on reproduction. The dietary and tissue balance of antioxidant nutrients is important in protecting tissues against free radical damage. Antioxidants such as vitamins C and E are free radical scavengers, which protect the body defense system against excessively produced free radicals during heat stress and stabilize the health status of the animal. Free radicals and reactive oxygen species play a number of significant and diverse roles in reproductive biology (Agarwal et al. 2006). Mineral mixture and antioxidant like zinc, cobalt, chromium, and selenium and vitamin E supplementation in the feed protected the ewes from adverse effects of heat stress (Fig. 22.1). The adverse effect of heat stress on the productive and reproductive efficiency of Malpura ewes (Tables 22.2 and 22.3) was alleviated by mineral mixture and antioxidant supplementation (Sejian et al. 2014).

Table 22.2 Effect of abiotic stresses on physiological, blood biochemical, hormonal, and reproductive responses of sheep

	Thermal, nutritional, and combined stress				Walking stress		Water stress		Multiple stress	
Parameters	Control	Thermal	Nutritional	Combined	Control	Stressed	Control	Stressed	Control	Stressed
Growth performance										
Initial body weight (kg)	33.8 ± 2.6	33.5 ± 1.9	34.7 ± 1.7	34.9 ± 1.5	27.4 ± 2.4	27.1 ± 2.43	38.8	38.9	30.9 ± 1.6	31.5 ± 1.1
Final body weight (kg)	39.7 ± 2.7^{a}	35.2 ± 1.5^{ab}	30.4 ± 1.5^{b}	30.0 ± 1.4^{b}	32.3 ± 0.6^{a}	30.1 ± 0.64^{ab}	38.5	37.6	32.6 ± 0.2^{a}	29.5 ± 0.5^{b}
ADG (g)	169.1 ± 0.01^{a}	47.7 ± 0.1^{b}	−122.6 ± 0.1^{c}	−138.0 ± 0.1^{c}	140.0 ± 1.5^{a}	86.0 ± 1.50^{b}	−7.4	−37.1	50.3 ± 1.01^{a}	−56.6 ± 1.4^{b}
Physiological response										
Respiration (breath min^{-1})	40.1 ± 2.4^{a}	130.8 ± 5.6^{b}	29.8 ± 1.2^{c}	107.5 ± 5.0^{b}	53.2 ± 1.3^{a}	69.3 ± 1.3^{b}	67.3 ± 2.6	62.9 ± 2.6	58.2	68.7
Pulse rate (beats min^{-1})	74.6 ± 2.8a^{b}	80.1 ± 2.5^{a}	67.5 ± 2.9^{b}	69.4 ± 3.6a^{b}	76.0 ± 2.8	79.8 ± 3.5	71.4 ± 1.3	68.6 ± 1.3	72.4	59.6
Rectal temperature (°F)	102.0 ± 0.1^{a}	103.3 ± 0.1^{b}	101.7 ± 0.2^{c}	102.9 ± 0.1^{d}	101.8 ± 0.1^{a}	102.6 ± 0.1^{b}	101.9 ± 0.1	101.8 ± 0.1	102.1	102.6
Blood biochemical										
Hb (g dl^{-1})	11.9 ± 0.4^{a}	9.5 ± 0.3^{c}	10.8 ± 0.3^{b}	8.6 ± 0.2^{d}	9.7 ± 0.1^{a}	11.0 ± 0.1^{b}	11.3 ± 0.5^{a}	12.3 ± 0.5^{b}	9.9 ± 0.1	10.9 ± 0.1
PCV (%)	41.3 ± 1.5^{a}	31.3 ± 1.6^{b}	35.8 ± 1.7^{b}	26.5 ± 2.1^{c}	34.2 ± 0.8^{a}	39.5 ± 0.8^{b}	41.6 ± 1.8^{a}	44.0 ± 1.8^{b}	30.4 ± 0.8	35.8 ± 0.8
Glucose (mg dl^{-1})	52.1 ± 2.4^{a}	47.8 ± 1.6^{ab}	44.2 ± 1.9^{b}	43.0 ± 2.5^{b}	56.9 ± 1.1^{a}	47.3 ± 1.1^{b}	51.2 ± 1.4^{a}	46.3 ± 1.4^{b}	45.4 ± 0.5	39.4 ± 0.5
Total protein (g dl^{-1})	8.9 ± 0.3^{a}	8.0 ± 0.4^{ab}	7.9 ± 0.3^{ab}	7.1 ± 0.3^{b}	7.7 ± 0.3	7.8 ± 0.3	–	–	7.3 ± 0.1	6.4 ± 0.1

(continued)

Table 22.2 (continued)

	Thermal, nutritional, and combined stress				Walking stress		Water stress		Multiple stress	
Total cholesterol (mg dl^{-1})	52.3 ± 1.9^{a}	43.0 ± 2.3^{b}	42.7 ± 2.2^{b}	35.6 ± 2.3^{c}	70.9 ± 5.1	67.8 ± 5.3	65.4 ± 1.6^{a}	55.5 ± 1.6^{b}	9.9 ± 0.1	10.9 ± 0.1
ACP (KA units)	2.1 ± 0.1^{a}	1.5 ± 0.1^{bc}	1.8 ± 0.1^{ab}	1.2 ± 0.2^{c}	6.6 ± 0.1	1.3 ± 0.1	–	–	–	–
ALP (KA units)	5.9 ± 0.3^{a}	5.1 ± 0.4^{b}	5.6 ± 0.3^{ab}	4.1 ± 0.3^{c}	7.8 ± 1.3	7.9 ± 1.3	–	–	–	–
Hormonal profile										
T_3 (nmol L^{-1})	1.7 ± 0.01^{a}	1.3 ± 0.0^{b}	1.4 ± 0.0^{b}	1.1 ± 0.01^{c}	2.3 ± 0.1^{a}	1.8 ± 0.1^{b}	–	–	2.4 ± 0.1	1.4 ± 0.1
T_4 (nmol L^{-1})	76.2 ± 4.2^{a}	58.9 ± 3.2^{b}	63.0 ± 3.6^{b}	46.0 ± 5.1^{c}	150.4 ± 6.3^{a}	135.7 ± 6.3^{b}	–	–	58.4 ± 0.1	24.4 ± 0.1
Cortisol (nmol L^{-1})	18.6 ± 1.3^{d}	77.0 ± 5.2^{a}	8.5 ± 1.1^{e}	46.4 ± 3.6^{b}	16.1 ± 1.1^{a}	28.1 ± 1.1^{b}	87.5 ± 5.9^{a}	69.3 ± 5.9^{b}	14.8 ± 1.1	31.0 ± 1.1
Insulin (microIU mL^{-1})	47.4 ± 2.9^{a}	39.8 ± 3.2^{ab}	35.2 ± 1.4^{bc}	26.4 ± 2.8^{c}	–	–			–	–
Estradiol (pg mL^{-1})	14.6 ± 1.0^{a}	12.1 ± 0.7^{b}	12.8 ± 0.9^{b}	10.0 ± 0.7^{c}	31.5 ± 10.0	29.4 ± 9.0	27.7 ± 2.3^{a}	19.2 ± 2.5^{b}	–	–
Progesterone (ng mL^{-1})	3.3 ± 0.6^{c}	4.5 ± 0.3^{ab}	4.0 ± 0.3^{bc}	5.2 ± 0.3^{a}	5.9 ± 2.8	5.7 ± 2.9	3.3 ± 1.7	3.6 ± 1.4	–	–

Reproductive performance										
Ewes in heat (%)	85.7^{a}	57.1^{b}	85.7^{a}	71.4^{ab}	–	–	100	85.7	66.67^{a}	41.7^{b}
Estrus duration (hr)	38.0 ± 2.4^{a}	23.4 ± 3.3^{b}	28.5 ± 5.7^{bc}	18.8 ± 3.8^{bd}	–	–	34.3 ± 6.0	28.0 ± 6.4	32^{a}	14.4^{b}
Estrus cycle length (days)	18.2 ± 0.3^{b}	20.3 ± 0.7^{ab}	18.0 ± 0.3^{b}	22.3 ± 1.7^{a}	–	–	17.0 ± 0.4	17.0 ± 0.5	18.2 ± 0.3^{b}	23.6 ± 1.5^{a}
Conception rate (%)	71.43^{a}	42.86^{ab}	57.14^{ab}	28.57^{b}	–	–	–	–	83.3^{a}	50^{b}
Lambing rate (%)	71.43^{a}	42.86^{ab}	57.14^{ab}	28.57^{b}	–	–	–	–	83.3^{a}	50^{b}

Source: Sejian et al. (2010a, b; 2011; 2012a, b; 2013); Kumar et al. (2016)

Thermal stress, by keeping ewes in climatic chamber at 40 °C and 55% RH for 6 h/day between 1000 and 1600 h; *nutritional stress*, by providing restricted diet, i.e., 30% intake of control; *combined stress*, by inducing both thermal and nutritional stress; *walking stress*, by complling ewes to walk 14 km in two spans between 0900 and 1500 h; *water stress*, by providing restricted water, i.e., 40% intake of control; *multiple stress*, by inducing thermal, nutritional, and walking stress at a time

Table 22.3 Effect of mineral antioxidant supplementation on reproductive performance of Malpura ewes

Parameters	Control	Heat stress	Heat stress + antioxidant supplementation
Estrus (%)	85.71	85.71	100
Duration (h)	34.29 ± 6.10	24.86 ± 5.77	36.86 ± 2.42
Length (days)	14.00 ± 0.01	14.33 ± 0.31	14.29 ± 0.18

Source: Sejian et al. (2014)

22.5.7 Water Management

Water scarcity during summer is a serious problem in this region. Water management of the sheep in the desert area is costly affair. During peak summer, literally no groundwater is available in the areas falling under Thar Desert and even the adjoining the same. Watering sheep in nearby ponds is essential for their good health, and for this, watering twice a week is sufficient to sustain health and productivity of sheep. Magra and Marwari breeds are genetically adapted to the desert conditions (Mittal and Ghosh 1983) and are able to produce and reproduce normally even with prolonged periods of drinking naturally occurring saline waters (TSS up to 3500 mg l^{-1}). The native sheep breeds have also the capability to overcome water shortage of about 40% for a month with little effect on their physiology and rejuvenation (Table 22.4; De et al. 2015b). Watershed management is a very effective strategy for long-term supply of water in the areas prone to drought. Integrated watershed management (IWM) provides a framework to integrate natural resource management with community livelihoods in a sustainable way. Several approaches can be initiated starting from desert rainwater harvesting for saving more water and its utilization. Development of watershed will not only help to fertilize the region but also for better management and upkeep of the livestock and sheep in particular (Naqvi et al. 2017).

22.5.8 Shelter Management

The sheep keepers of arid and semi-arid region generally construct different types of structure within their limited resources which are mostly primitive to semi-migratory type. In the southern and the northeastern part of Rajasthan, the flocks are kept in mud hut only in the night and the rest of them in an open field under grazing condition. These huts are mostly attached to the outer side of the owner's house. Roofs are commonly thatched with long rough grass. In the northern and western part of Rajasthan, the flocks are mostly migratory and are kept in open fields during the night. They usually flock back to their native village after 2 days of grazing for drinking water (De et al. 2013).

Table 22.4 Effect of rehydration on water-restricted Malpura ewes

	Body weight (kg)		FI (DMI g $W^{-0.75}$ d)		Hemoglobin (g%)		Packed cell volume (%)		Glucose (mg dL^{-1})		Cortisol (nmol L^{-1})	
Stage of watering	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2	G1	G2
Ad libitum	38.8	38.8	57.5^{xy}	54.7^{xy}	12.5	12.95	38.7	34.9^{y}	50.0^{a}	45.3^{b}	21.3^{y}	22.3^{y}
Restriction	38.4	37.5	54.1^{y}	51.5^{y}	11.8^{b}	14.8^{a}	41.1	47.3^{x}	49.4	45.9	55.4^{ax}	34.7^{bx}
Rehydration	38.8	38.9	62.6^{x}	60.4^{x}	12.1	14.1	32.7	35.9^{y}	49.2	47.4	29.3^{y}	20.2^{y}

G1, 20% water restricted; G2, 40% water restriction; Source: De et al. (2015b)

Table 22.5 Meteorological data of different housing during winter

Weather parameters	Control	Bamboo dome	Thermocol insulated
Maximum temperature	8.5 ± 0.7[c]	14.6 ± 0.5[a]	11.8 ± 0.6[b]
Minimum temperature	25.0 ± 0.3[a]	23.9 ± 0.4[ab]	22.6 ± 0.4[b]
Relative humidity (%)	59.2 ± 4.5	66.4 ± 2.0	56.4 ± 3.7
Temperature–humidity index[2]	12.5 ± 0.9[b]	16.1 ± 0.6[a]	14.0 ± 1.0[ab]
Wind velocity (m s^{-1})	5.58 ± 0.4	5.58 ± 0.4	5.58 ± 0.4

Source De et al. (2015a)

a,b, c values within a row with different superscripts differ significantly at $P<0.05$

The traditional sheep housing depends on the local customs and availability of materials. The sheep houses are mostly constructed in one corner of the main family house, an overhang attached to the roof of the house of open yard with no roof or at the basement under the family house or a separate house of thatched roofs. But mostly the traditional sheds are insufficient in drainage and ventilation. It is generally recommended that smallholder producers who keep a few animals should construct a shed attached to their main house using locally available inexpensive materials to reduce the cost of construction. Generally, thatched roof houses are often sufficient. New knowledge about the animal response to the environment continues to be developed to reduce the effect of climate change (De et al. 2014). Keeping this in view, different models of sheds have been tried. A bamboo dome is one of such sheds, where lambs are kept to protect from severe cold during the night (Table 22.5). Generally, lambs are kept inside the dome in the shed that maintains higher minimum temperature at night and provides comfortable microclimate (De et al. 2015a). Cold- and heat-protected sheds have also been tried to protect the weaner or grower lambs from winter as well as summer. In this special type of shed, the floor is usually at lower level than the outside, and its roof is prepared from thermocol-insulated PV sheet. These types of shed maintain lower maximum temperature and higher minimum temperature than asbestos-roofed shed (De et al. 2015a). Yagya-type shed is also constructed to protect animals during extreme summer. It has pagoda-style roof which provides better ventilation. The wall is double walled with a hollow space in the middle, which is filled up with sand and the sand remains moist by continuous water drip. This innovative strategy protects the animal from direct hot wind as well as provide extra evaporative cooling that keep the microclimate inside the shed comfortable (De et al. 2017). Another option is preparing a mat of locally available dry grasses at the open side wall and sprinkling water three to four times in a day on that mat to provide evaporative cooling. Similarly, canopy curtain may be used in the open side of the wall to provide protection in the chilling cold nights. Increased roof height building with ridge ventilation is constructed to protect from direct solar radiation as well as better ventilation during the summer months.

22.5.9 Disease Management

Sheep in the arid region are relatively less susceptible to diseases due to less humidity that is an impediment for the pathogen development. Most mortalities occur due to liver-fluke infestation, while other causes include enterotoxaemia, anthrax, and foot-and-mouth disease. Sheep pox also results in serious mortality, although it usually becomes epidemic once in 3–4 years. So far health care has been given little attention, and the sick animals are generally treated using indigenous medicines. Animals infested with gastrointestinal parasites, though not a major menace during dry periods, must be treated after 1 week of onset of monsoon and thereafter on case-to-case basis. Nutritional stress also leads to chronic worm problems and thus nutritional supplementation is necessary (Naqvi et al. 2013a). However, considering the overall poor facilities for prevention and control of sheep diseases, a comprehensive plan (e.g., health, disaster reduction) needs to be developed to prevent proliferation of diseases with climate change. In endemic regions, vaccination can be done as a protective measure. By combining improved empirical data and refined models with a broad view of the production system, robust projection of disease risk can be developed (Swarnkar and Singh 2013).

22.6 Conclusion

In India, a major portion of the rural poor community depends greatly on small ruminants for their survival. Like other agricultural systems, small ruminant production system is also likely to be affected directly or indirectly by climate change. This would impact the performance and profitability in sheep production system by lowering feed intake and nutrient utilization and production. Although sheep husbandry, itself, is a climate-smart agriculture, still there is a scope to make it better and sustainable under the pressure of climate change and increasing demand. For this purpose, the present science and technology has to concentrate more on thematic issues related to climatic adaptation, dissemination of new understanding in rangeland ecology, and holistic understanding of pastoral resource management. The issues need to be addressed are early warning system, multiple stress research, simulation model, water availability, exploitation of genetic potential of native breeds, suitable breeding program, and nutritional intervention. However, the present existing condition concentrates on reduction of the magnitude of climate change in the long term, i.e., mitigation and adaptation. In this process, the local livestock farmers should have a key role in determining what adaptation and mitigation strategies existing husbandry system will support to make the production sustainable in the changing climate scenario. Furthermore, integration of new technologies into the research and proper transfer of those into the field offers many opportunities in the development of climate-smart sheep production system.

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