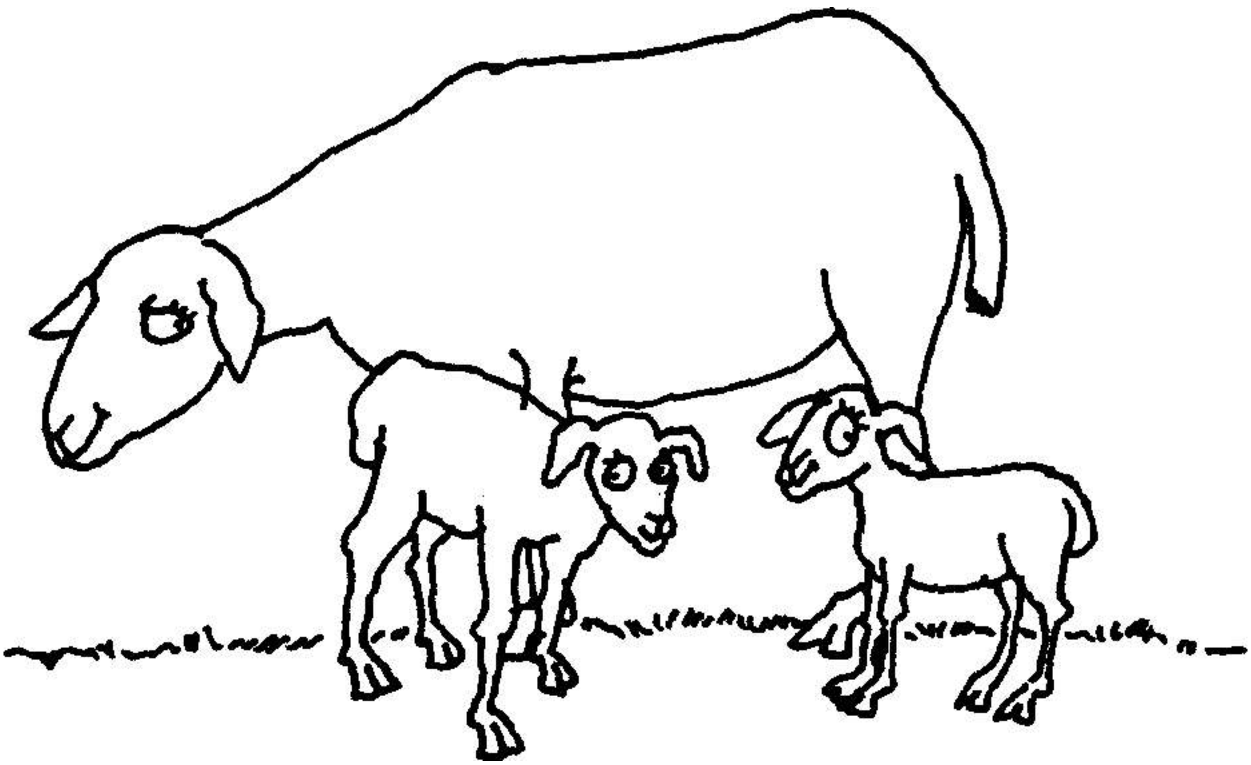
CLIMATE RESILIENT SMALL RUMINANT PRODUCTION



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CLIMATE RESILIENT AGRICULTURE (NICRA)

CLIMATE RESILIENT SMALL RUMINANT PRODUCTION

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PREFACE

The prospect of animal productivity and its share to food security and national GDP, although is on an upward swing in recent years, the impending problems that have been identified and needs urgent attention includes safeguarding the environment and ensuring acceptable level of animal productivity in the prevailing scenario of land and water scarcity, and ensuing climate change. Besides there are important issues involving the propagation of animal production systems suitable for small holders as mode of livelihood security? In the hindsight, the responsibilities bestow up on us to answer the questions like i) how can livestock keepers take advantage of the increasing demand for livestock products, where this is feasible, and ii)how can the livestock assets of the poor be protected in the face of changing and increasingly variable climates? Nevertheless, given the complexity of livestock and crop-livestock systems, a mix of technological, policy and institutional innovations will inevitably be required.

In this backdrop, the workshop on “Climate Resilient Shelter and Stress Management in Small Ruminants in Hot Arid and Semi-Arid Regions of India” on 02-05-2013 at Central Sheep and Wool Research Institute, Avikanagar, one of the partner (Sponsored Research Grant) in NICRA provided the impetus to come out with this compilation in the form of a book entitled, **“Climate Resilient Small Ruminant Production”** for the reach of elite and concerned readers. It assumes colossal significance in a way that it provides an opportunity to make an objective appraisal and eventual strategies to make it more resilient in the present-day scenario. Additionally, it would also throw open windows to brain-storm, and to discover tangible solution to tribulations already-identified as well as any unforeseeable ones.

The authors are thankful to all the contributors who have come forward to share their findings, knowledge and ideologies through this publication for the benefit of livestock production in general and small ruminant productivity in particular. We take this opportunity to thank National Coordinator, NICRA, Director, CSWRI and ICAR, New Delhi in providing all support for bringing out this publication for researchers and academicians working in this field. While every care was taken to publish the information in totality, there might have been some omission or commission while editing the manuscripts; we take that responsibility solely on us and promise to improve upon it in future publication to match the set requirements.

Authors

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NATIONAL INITIATIVE ON CLIMATE RESILIENT AGRICULTURE (NICRA): AN OVERVIEW

Climate change has become an important area of concern for India to ensure food and nutritional security for the growing population. Its impact is global, but countries like India are more vulnerable in view of the high population depending on agriculture. In India, significant negative impacts have been implied with medium-term (2010-2039) climate change, predicted to reduce yields by 4.5 to 9 percent, depending on the magnitude and distribution of warming. Since agriculture makes up roughly 16 percent of India's GDP, a 4.5 to 9% negative impact on production implies a cost of climate change to be roughly up to 1.5 percent of GDP per year. The Government of India has accorded high priority on research and development to cope with climate change in agriculture sector. The Prime Minister's National Action Plan on climate change has identified Agriculture as one of the eight national missions. Thus, the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture has launched a major Project entitled, National Initiative on Climate Resilient Agriculture (NICRA) during 2010-11 with an outlay of Rs.350 crores for the XI Plan (to be contimued in the XII plan) with the following objectives:

- To enhance the resilience of Indian agriculture covering crops, livestock and fisheries to climatic variability and climate change through development and application of improved production and risk management technologies;
- To demonstrate site specific technology packages on farmers' fields for adapting to current climate risks;
- To enhance the capacity building of scientists and other stakeholders in climate resilient agricultural research and its application.

Key Features

- Critical assessment of different crops/zones in the country for vulnerability to climatic stresses and extreme events, in particular, intra seasonal variability of rainfall
- Installation of the state-of-the-art equipment like flux towers for measurement of green house gases in large field areas to understand the impact of management practices and contribute data on emissions as national responsibility.
- Rapid and large scale screening of crop germplasm including wild relatives for drought and heat tolerance through phenomics platforms for quick identification of promising lines and early development and release of heat/drought tolerant varieties.
- Comprehensive field evaluation of new and emerging approaches of paddy cultivation like aerobic rice and SRI for their contribution to reduce the GHG emissions and water saving.

- Special attention to livestock and fishery sectors including aquaculture which have not received enough attention in climate change research in the past. In particular, the documentation of adaptive traits in indigenous breeds is the most useful step.
- Thorough understanding of crop-pest/pathogen relationship and emergence of new biotypes due to climate change.
- Simultaneous up-scaling of the outputs both through KVKs and the National Mission on Sustainable Agriculture for wider adoption by the farmers

Possible output

- Selection of promising crop genotypes and livestock breeds with greater tolerance to climatic stress.
- Existing best bet practices for climate resilience demonstrated in 100 vulnerable districts.
- Infrastructure at key research institutes for climatic change research strengthened.
- Adequately trained scientific man power to take up climate change research in the country and empowered farmers to cope with climate variability.

Final outcome: Enhanced resilience of agricultural production in vulnerable regions of the country.

Project components

Both short term and long terms outputs are expected from the project in terms of new and improved varieties of crops, livestock breeds, management practices that help in adaptation and mitigation and inputs for policy making to mainstream climate resilient agriculture in the developmental planning. The overall expected outcome is enhanced resilience of agricultural production to climate variability in vulnerable regions. The project is comprised of four components.

1. Strategic research on adaptation and mitigation
2. Technology demonstration on farmers' fields to cope with current climate variability
3. Sponsored and competitive research grants to fill critical research gaps
4. Capacity building of different stake holders

Strategic Research

The strategic research has been planned at leading research institutes of ICAR in a network mode in the area of 'Natural Resource Management', 'Crops', 'Pests and Disease Dynamics', 'Livestock', 'Fisheries' and 'Energy Efficiency'. To begin with, the project is focusing on crops like wheat, rice, maize, pigeon pea, groundnut, tomato, mango and banana; cattle, buffalo and small ruminants among livestock and both marine and freshwater fish species of economic importance. The major research themes are:

- Vulnerability assessment of major production zones
- Linking weather based agro-advisories to contingency planning

- Assessing the impacts and evolving varieties tolerant to key climatic stresses (drought, heat, frost, flooding, etc.) in major food and horticulture crops
- Continuous monitoring of greenhouse gases in open field conditions in major production systems
- Evolving adaptation and mitigation strategies through enhancing water and nutrient use efficiency and conservation agriculture
- Studying changes in pest dynamics, pest/pathogen-crop relationships and emergence of new pests and pathogens under changing climate
- Adaptation strategies in livestock through nutritional and environmental manipulations
- Harnessing the beneficial effects of temperature in inland and marine fisheries through better understanding of the spawning behaviour.

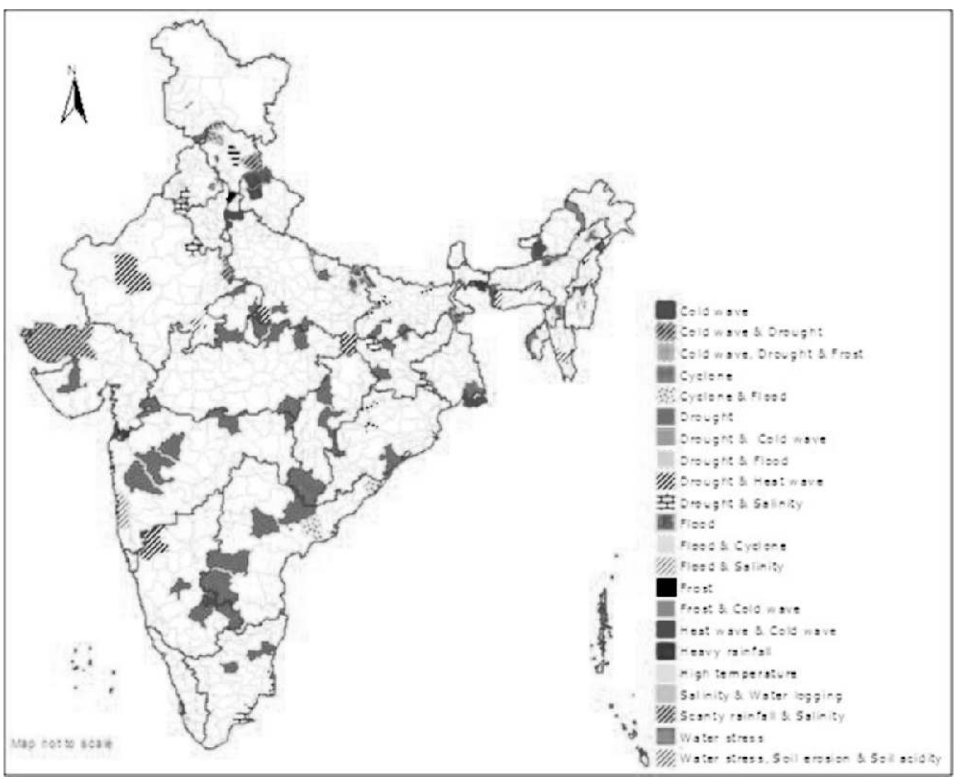
The strategic research is being carried out involving 21 Institutes of the Indian Council of Agricultural Research out of which seven are core institutes where state of the art research infrastructure and equipments will be installed for climate change research on irrigated crops, rainfed crops, horticulture, livestock, fisheries and energy efficiency. ICAR Research Complex-NEH at Shillong is addressing all issues related to North-East. A detailed assessment on vulnerability of different agro-climatic zones of the country is also planned. The key activities along with institutional and commodity wise responsibilities are described in the following table.

Activity	Institution
Vulnerability assessment of major food crop production zones to climate variability.	CRIDA (major rainfed crop zones) IARI (with focus on irrigated crops - rice, wheat, chickpea)
Weather based Agro-advisories, contingency plans and identification of best-bet management practices	CRIDA through network of AICRPDA and AICRPAM centres
Evaluation of major food and horticultural crops for tolerance to climatic stresses and genetic enhancement of tolerance	CRIDA, IIPR (rainfed crops: maize/ sorghum, pigeonpea and blackgram) IARI (irrigated crops: rice, wheat, chickpea) NRCPB (thermo tolerant wheat; prospecting of genes for thermo tolerance from microbial & plant resources) CRRI (evaluation of key rice germplasm for tolerance to drought and submergence) DRR (heat tolerance and nitrogen use efficiency in rice) ICAR-NEH (Identification of temperature tolerant rice and maize varieties for north-east)

	IIHR, IIVR, ICAR-RCER Ranchi centre (tomato, banana, mango)
Monitoring of GHG emissions through flux towers.	CRRI (onitoring of GHG emissions in rice based production systems)
Adaptation and mitigation through enhanced water productivity, nutrient use efficiency, conservation agriculture and agro-forestry systems	CRIDA & DWM (water productivity in rainfed and irrigated crops, carbon sequestration, water harvesting potential and ground water recharge in relation to rainfall variability PDFSR (assessment of mitigation potential through farming system approach) CRRI (mitigation potential of improved management practices and products in rice cultivation) NRCAF & CRIDA (quantification of carbon sequestration potential in selected agroforestry systems) ICAR-NEH (SWM practices for enhancing climatic resilience) CIAE (engineering interventions for conservation agriculture and precision farming)
Pest and disease dynamics, changes in croppest/pathogen relationships, changed profile of insect pests and emergence of new bio types due to climate change	DRR & NCIPM (initial model on pest dynamics of rice -BPH) CRIDA & NCIPM (pest and disease dynamics of pigeonpea, groundnut and forewarning system) IIHR & NCIPM (relationships between high temperature and pest and disease on tomato and mango)
Understanding the unique traits in indigenous livestock which make them resilient to climate change and development of database	IVRI (livestock diseases resistance traits) ICAR-NEH (pig and poultry)
Adaptation strategies in livestock to thermal stress through nutritional and environmental manipulations	NDRI (cattle and buffalo)
Assessment of spawning behaviour of major fish species in marine and inland environments with a view to harness the beneficial effects of temperature	CMFRI (marine fish) CIFRI (Inland fish)
Impacts on aquaculture and mitigation options	CIBA, Chennai

The research was initiated during 2011-12 in all the above themes. The major emphasis during the year was on building state of art research infrastructure like high throughput phenotyping platforms, free air temperature elevation systems in open fields, environmental growth chambers with CO_2 and temperature controls and special caloric metric system to study livestock response to heat stress. These are some of the unique facilities being set up for the first time in Asia. In all the target crops like rice, wheat, maize, pigeonpea, tomato and mango, core sets of genetic resources were assembled and field phenotyped at different institutions with a view to identify sources of tolerance to climatic stresses and related genes and traits. For the first time, all the germplasm of wheat with NBPGR has been multiplied for field phenotyping and currently under evaluation. Country wide studies have been initiated to understand the impact of temperature on flowering behaviour in mango. A nationwide pest surveillance and monitoring system has been put in place for all the target crops for major pests and diseases wherein real time incidence is being monitored along with weather parameters to build pest warning models. Methods for measurement of green house gas emissions in the marine ecosystem have been standardized. Carbon sequestration potential through agro forestry systems across the country is being quantified. Monitoring of experiments on conservation agriculture in different production systems is initiated to assess the adaptation and mitigation potential of CA practices. The vulnerability of all the rural districts in the country (about 540) is being quantified in terms of exposure, sensitivity and adaptive capacity in order to prepare a vulnerability atlas.

Technology demonstration



The technology demonstration component deals with demonstrating proven technologies for adaptation of crop and livestock production systems to climate variability. This component is implemented in selected vulnerable districts of the country through location specific interventions by Krishi Vigyan Kendras in a participatory mode. The project is implemented in 100 districts (see map) involving over one lakh farm families across the country. These districts are selected based on the following criteria besides the strength of the KVKs:

- Drought proneness based on 30 years rainfall data (Source: IMD)
- Cyclone proneness based on frequency as recorded by IMD / State Disaster Management agencies.
- Flood proneness based on IMD data and NDMA maps.
- Vulnerability to heat wave and cold wave based on IMD grid data on temperatures.
- Actual incidence of floods and droughts as recorded by AICRPAM centers

The interventions in the village panchayats are finalized following a participatory approach through the Village Climate Risk Management Committee (VCRMC), after the PRA to assess the climate related problems in the village and baseline survey. The program was launched formally in all the villages by involving the state line department functionaries and leaders of the panchayats to ensure local ownership of the project from the beginning and convergence of related schemes currently in operation in the panchayat. In each village, the interventions are made in the following four modules:

Module I (Natural resources): This module consists of interventions related to in-situ moisture conservation, water harvesting, supplemental irrigation, improved drainage in flood prone areas, conservation tillage where appropriate, artificial ground water recharge and water saving irrigation methods.

Module II (Crop production): This module consists of introducing drought/temperature/flood tolerant varieties, advancement of planting dates of rabi crops in areas with terminal heat stress, water saving paddy cultivation methods (SRI, aerobic, direct seeding), frost management in horticulture through trash burning, community nurseries for delayed monsoon, custom hiring centres for timely planting, location specific intercropping systems with high sustainable yield index.

Module III (Livestock and Fisheries): Use of community lands for fodder production during droughts/floods, improved fodder/feed storage methods, preventive vaccination, improved shelters for reducing heat stress in livestock , management of fish ponds/tanks during water scarcity and excess water, etc.

Module IV (Institutional interventions): This module consist of institutional interventions either by strengthening the existing ones or initiating new ones relating to seed bank, fodder bank, commodity groups, custom hiring centre, collective marketing, introduction of weather index based insurance and climate literacy through a village level weather station.

Sponsored and competitive grants

One of the key components of the National Initiative is sponsored/competitive grants. An amount of 25.00 crores is earmarked through sponsored/competitive grant component for 2010-12, out of which 10% is earmarked for North East. Research proposals addressing critical gaps of national importance not covered in the main project will be funded under this component inviting proposals from identified institutions or through an open invitation on competitive basis from institutions/individuals both within and outside National Agricultural Research System (NARS). Under this component, critical researchable issues like impact on plant pollinators, fisheries in esturian habitats, hail storm management, hill and mountain eco-system, small ruminants and socio economic aspects of climate change etc. are provided research grants. The priority areas are given below:

- Adaptation strategies including carbon sequestration for climate resilient agriculture in arid, hill and mountain, coastal and Island ecosystems
- Germplasm collection and characterization from climate hot spots
- Impact of climate change on pollinators
- Nutrient management and physiological adaptations for enhanced tolerance to climate variability and change Methane mitigation strategies in livestock through metagenomic approach
- Socio economic impact assessment of climate variability and Change
- Fisheries and aquaculture related aspects with focus on climate variability
- Management of extreme weather events including hailstorms etc

Capacity building

Since climate change is an emerging area of science, capacity building of young scientists on simulation modeling, high through put phenotyping, greenhouse gasses measurement, etc. is being taken up through training programs organized in India and sponsoring scientists abroad. Simultaneously, more than 100 training programs have been organized across the country covering 50000 farmers to create awareness on climate change and variability.

Future Plans

The project will continue in XII Plan with further expansion of the technology demonstration to 200 districts and also include crops like maize, sugarcane, cotton and temperate fruits which are weather sensitive and have significant role in the national economy/exports. A dedicated web portal will be developed as one-stop information on all aspects of climate change and agriculture in India.

LIVESTOCK PRODUCTION UNDER ENSUING CLIMATE CHANGE SCENARIO: RESILIENCE VERSUS PERFORMANCE

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Introduction

The livestock sector accounts for 40% of the world's agriculture Gross Domestic Product (GDP). It employs 1.3 billion people, and creates livelihoods for one billion of the world's population living in poverty. Climate change is seen as a major threat to the survival of many species, ecosystems and the sustainability of livestock production systems in many parts of the world. Global demand for livestock products is expected to double during the first half of this century, as a result of the growing human population, and its growing affluence. Over the same period, we expect big changes in the climate globally. The dramatic expansion of crop production for biofuels is already impacting on the resources available globally for food production, and hence on food supply and cost. Food security remains one of the highest priority issues in developing countries, and livestock production has a key role in many of these countries. However, food security is re-emerging as an important issue in many developed countries that had previously regarded it as 'solved'. These interconnected issues are creating immense pressure on the planet's resources. We need high quality animal science to help meet rising demand for livestock products in an environmentally and socially responsible way.

The inter-relationship between climate change and the livestock sector is important to explore for a number of reasons. First of all, the livestock sector has recently been blamed for contributing more to global climate change than the automobile industry (FAO 2006). At the same time, the sector is booming due to a surging global demand, which is closely linked to both economic growth and urbanization: two factors which are in turn linked to climate change. Thirdly, livestock play a critical role in the livelihoods of many of the world's poorest people, acting as a source of both credit and savings in rural areas that are remote from financial services, providing food and cash income for the urban as well as the rural poor, and for many people offering a route out of poverty. A fourth point to consider is that some major livestock systems are credited with providing environmental services, including promoting rangeland health (and total biomass) and thereby helping to capture atmospheric carbon and mitigate climate change. The contradictions between these points highlight the inconsistencies in how different groups of people view the livestock sector as well as the great diversity within the livestock sector.

The relationship between the livestock sector and climate change is likely to greatly influence the overall nature of the approach to adaptation within the livestock sector. The sector has been much maligned since the publication of 'Livestock's Long Shadow' by FAO in 2006 and the allegation that the industry contributes more to climate change than the automobile industry does. However, the real relationship between livestock and climate change is much more complex and the environmental services of extensive livestock systems have generally been overlooked. Such services could become crucial to adaptation in the sector in future. Livestock play a critical role in rural poverty reduction; therefore, livestock development is vital for development in India. Development in all sectors will be increasingly scrutinized for its 'clean' credentials and it is desirable that livestock development can be carried out without significantly contributing further to climate change. Nevertheless, livestock are important to the adaptation strategies of poor people on a continent that is a major victim of, and a minor contributor to, climate change. This chapter in short provides an overview of how livestock contributes to climate change in addition to getting impacted by the same. Further, the chapter will address in detail the various adaptation strategies available to mitigate climate change impact on livestock production and measures to be taken to curtail green house gas (GHG) emission. Lastly this chapter will discuss the various steps to be taken to increase the resilience of livestock production systems and livestock dependent livelihoods to climate change.

Climate change and its consequences on livestock economy

Global climate change is expected to alter temperature, precipitation, atmospheric carbon dioxide levels, and water availability in ways that will affect the productivity of crop and livestock systems (Hatfield, et al. 2008). For livestock systems, climate change could affect the costs and returns of production by altering the thermal environment of animals thereby affecting animal health, reproduction, and the efficiency by which livestock convert feed into retained products (especially meat and milk). Climatic changes could increase thermal stress for animals and thereby reduce animal production and profitability by lowering feed efficiency, milk production, and reproduction rates (St-Pierre and Schnitkey, 2003).

Climate changes, could impact the economic viability of livestock production systems worldwide. Surrounding environmental conditions directly affect mechanisms and rates of heat gain or loss by all animals (NRC 1981). Environmental stress reduces the productivity and health of livestock resulting in significant economic losses. Heat stress affects animal performance and productivity of dairy cows in all phases of production. The outcomes include decreased growth, reduced reproduction, increased susceptibility to diseases, and ultimately delayed initiation of lactation. Heat stress also negatively affects reproductive function (Amundson et al. 2006). Normal estrus activity and fertility are disrupted in livestock during summer months. Economic losses are incurred by the livestock industries because farm animals are generally raised in locations and/or seasons where temperature conditions go beyond their thermal comfort zone. The livelihood of the rural poor in developing countries depends critically on local natural resource-based activities such as crop and livestock production. As a result of negative weather impact on livestock rearing, the poor shepherds/farmers whose principal livelihood security depends on these animal performances is directly on stake. Housing and management technologies are available through which climatic impacts on livestock can be reduced, but the rational use of such technologies is crucial for the survival and profitability of the livestock enterprise (Gaughan et al. 2002).

Climate Change and concept of multiple stresses

In the present changing climate scenario, there are numerous stresses other than the heat stress which constrain the livestock and have severe consequences on their production. The projected climate change (CC) seriously hampers the pasture availability especially during the period of frequent drought in summer. Thus, livestock suffer from drastic nutrition deficiency. Both the quantity and the quality of the available pastures are affected during extreme environmental conditions. Further, with the changing climate, animals have to walk a long distances in search of pastures. This locomotory activity also put the livestock species under enormous stress. The majority of domesticated ruminants are raised solely or partially in semi-extensive or extensive production systems in which most nutrients are derived from grazed forage. Grazing is associated with daily activities considerably different than for confined animals, such as time spent eating and distances travelled. These activities result in greater energy expenditure than in confinement, which can limit energy available for maintenance and production. The grazing animals in the tropical areas usually have access to poor quality food available at lower densities per unit area, and to counter such hardship, animals increase their grazing time and disperse widely. Hence it's not only the heat stress that need to be counteracted but the nutrition and walking stress are also of great concern. Though the animals live in a complex world, researchers most often study the influence of only one stress factor at a time. Comprehensive, balanced, and multifactorial experiments are technically difficult to manage, analyze and interpret. When exposed to one stress at a time, animals can effectively counter it based on their stored body reserves and without altering the productive functions. However, if they are exposed to more than one stress at a time, the summated effects of the different stressors might prove detrimental to these animals. Such a response is attributed to animal's inability to cope with the combined effects of different stressors simultaneously. In such a case, the animal's body reserves are not sufficient to effectively counter multiple environmental stressors. As a result their adaptive capabilities are hampered and the animals struggle to maintain normal homeothermy. Moberg (2000) hypothesized that when animals are exposed to only one stress, they may not require the diversion of biological resources needed for other functions. If, however, two of these stressors occur simultaneously, the total cost may have a severe impact on other biological functions. Thus, normal basal functions are drastically affected which jeopardizes production.

Climate change impact on livestock production and reproduction

Impact on growth

It is known that sheep that are exposed to high ambient temperatures, augments the efforts to dissipate body heat, resulting in the increase of respiration rate, body temperature and consumption of water and a decline in feed intake (Marai et al., 2007). This finding of reduced feed intake after thermal exposure was in agreement to the findings of Pereira et al. (2008). They reported that the rate of feed intake by sheep tended to decrease after the heat exposure. Further, Padua et al. (1997) reported that apart from feed intake, feed conversion also significantly decreased under hot condition in climatic chamber as compared to shelter during spring. Marai et al. (2007) had postulated a reason for this reduced feed intake in sheep after thermal exposure. They explained that exposure of the animal to a high environmental temperature, stimulates the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite centre in the hypothalamus and thereby causing a decrease in feed intake. The decrease in feed intake could be due to the adaptive mechanism of sheep to produce less body heat. The water intake of combined stress group was significantly higher as compared to *ad libitum* fed groups. This shows that the high water intake which is utilized to combat heat stress may be indicating that restricted fed animals are under more stress (Minka and Ayo, 2009). Further, it is an established fact in small ruminants that lack of food and particularly the potassium content, impedes the sodium uptake from the reticulum-rumen causing hyponatraemia and hypo-osmolality (Holtenius and Dahlborn, 1990). The average body weight of thermal, nutritional, combined and multiple stresses groups significantly decreased as compared to control group (Table 1). Growth, the increase in the live body mass or cell multiplication, is controlled genetically and environmentally (Marai et al., 2007). Habeeb et al. (1992) reported that elevated ambient temperature is considered to be one of the environmental factors influencing average daily gain. Similar findings of impaired body weight and growth rate following exposure to elevated temperatures were reported by Marai et al. (1991) and Ismail et al. (1995). The reason for the effects of elevated ambient temperature on growth reduction could be due to decrease in anabolic activity and the increase in tissue catabolism (Marai et al., 1999). They attributed this increase in tissue catabolism due to increase in catecholamines and glucocorticoids after exposure to heat stress in sheep.

Table 1. Effects of climate change on Livestock

Parameters	Climate Change Impact
Water	Change in quantity and timing of precipitation
Feed	▪ Land use and systems changes ▪ Changes in the primary productivity of crops, forage and rangeland ▪ Changes in species composition ▪ Quality of plant material
Biodiversity (genetics and breeding)	▪ Loss of genetic and cultural diversity ▪ Both livestock and crops Change in ecosystem function and resilience
Livestock health	▪ Change in pattern and range of vector-borne disease and helminth infections ▪ Loss of disease resistant livestock breeds ▪ Change in pattern of human disease, including malaria, Schistosomiasis, and filariasis ▪ Increase in heat-related mortality and morbidity

Source: Calvosa et al. (2010)

Impact on Reproduction

Multiple stresses showed highly significant influence on estrus duration and estrus cycle length (Table 1). This could be related to the high plasma progesterone concentration in multiple stressed ewes. Presumably, therefore, the longer estrus cycles were due to a slower rate of follicular maturation after CL regression. This statement was supported by the finding of Stewart and Oldham (1986), who reported that nutritional effect on ovulation rate seems to be more due to mechanisms confined to final stages of folliculogenesis rather than change in secretion of GnRH, LH and FSH. There are evidences proving the influence of nutrition on folliculogenesis and ovulation rate (Kiyma et al., 2004; Scaramuzzi et al., 2006). Another hypothesis put forth by Downing et al., (1995) states that ovarian responses are influenced by availability of nutrients. Nutrient deficiency potentially acts on the reproductive process and affects estrus behavior and ovulation rate. Nutritional influences on reproduction may be linked through variations in the IGF-1 system (Roberts et al., 2001). Acute nutrient restriction to the point of decreasing IGF-1 secretion may affect the ability of developing follicles to respond to FSH through a reduction in FSH receptor expression (Kiyma et al., 2004).

Combined stress had relatively more detrimental effect on the conception rate (Table 1). The probable reason for this could be reduced sex steroid receptor and altered sex steroids concentration. This view is supported by the fact that there is evidence for inhibitory effect of undernutrition on the number of uterine sex steroid receptors which will inturn affect conception rate (Sosa et al., 2006). It has been established that sheep embryo is most susceptible to maternal heat stress (Thwaites, 1971). In addition, Lawson and Cahill, (1983) postulated that variations in the physiological range of peripheral progesterone concentration due to management factors such as nutrition may induce asynchrony between the embryo and uterus resulting in failure of pregnancy to be established. Lambing rate also showed results similar to conception rate in combined stress group. The probable reason for low conception rate in combined stress group could be the insufficient progesterone concentration to maintain pregnancy as the thermal and nutritional stress were withdrawn after mating at the end of the experimental period. Higher level of nutrition has been found to be associated with lower circulating progesterone concentrations in ewes (O'Callaghan et al., 2000). Ample evidence supports that undernutrition of ewes before and after mating increases embryonic mortality which in turn reduces the lambing rate (Abecia et al., 2006).

Plasma estrogen and progesterone showed reverse trend in individual, combined as well as multiple stresses groups (Table 1). The effect of thermal stress is more severe than nutritional stress on plasma estradiol 17-β level (Sejian et al., 2011a). It is generally accepted that nutrition modulates reproductive endocrine function in many species including sheep. Kiyma et al., (2004) reported that serum concentrations of estradiol were lower in undernourished ewes. Decreased concentration of estrogen may result from diminished ovarian follicular development caused by suppressed peripheral concentration of gonadotrophins (Gougeon, 1996). The level of nutrition and peripheral progesterone concentrations are inversely related (Parr, 1992) in ewes. This inverse relationship between level of feed intake and plasma progesterone concentration was attributed to difference in metabolic clearance rate of progesterone (Parr et al., 1993). This view was further strengthened by the finding of Abecia et al. (2006) which states that difference in the rate of clearance rather than differences in secretion levels can explain the apparent inverse relationship between nutrition and peripheral progesterone concentrations in ewes. The increased plasma progesterone concentration in undernourished ewes in these studies might be due to the limited extravascular pool in such animals with low body fat content (Lamond et al., 1972).

Table 2: Effect of thermal, nutritional, combined and multiple stresses on growth and reproductive parameters of Malpura ewes

Parameters	Control	Thermal stress	Nutritional stress	Combined stresses	Multiple stresses
Initial body weight	33.752.56^{a}	33.521.85^{a}	34.681.70^{a}	34.871.46^{a}	32.63± 0.98^{a}
Final body weight	39.672.65^{a}	35.191.46^{ab}	30.391.50^{b}	30.041.35^{b}	29.55±1.22^{b}
ADG	169.140.01^{a}	47.710.07^{b}	122.570.06^{c}	-138.000.07^{c}	88.000.17^{c}
Ewes in heat (%)	85.71^{a}	57.14^{b}	85.71^{a}	71.43^{ab}	41.7^{c}
Estrus duration (hrs)	38.002.41^{a}	23.403.34^{b}	28.505.68^{bc}	18.753.75^{bd}	14.42.78^{c}
Estrus cycle length (days)	18.170.31^{b}	20.280.74^{ab}	18.00 0.27^{b}	22.251.67^{a}	23.561.45^{a}
Conception rate (%)	71.43^{a}	42.86^{ab}	57.14^{ab}	28.57^{b}	-
Lambing rate (%)	71.43^{a}	42.86^{ab}	57.14^{ab}	28.57^{b}	-
Estradiol (pg/mL)	14.580.96^{a}	12.060.73^{b}	12.800.91^{b}	10.040.74^{c}	7.190.23^{d}
Progesterone (ng/mL)	3.310.56^{c}	4.480.32^{ab}	3.980.26^{bc}	5.190.27^{a}	7.340.28^{d}

Combined stresses-thermal and nutritional stress; Multiple stresses- thermal, nutritional and walking stress. Means and SEM within a row having different superscripts differ significantly ($P<0.05$). (Source: Sejian et al., 2011a)

Significance of improving the adaptive and resilience capacity of livestock to climate change

Changes in rainfall amounts and seasonal patterns are already being experienced in many parts of the world, including Indian sub continent, creating problems for vulnerable farmers and other land users in securing their livelihoods, and increasing the risks they face. The frequency and intensity of extreme climatic events such as heat waves and erratic heavy rainfall, as well as the long term chronic effects of higher temperatures are set to increase. The effects of these climatic changes will become even more pronounced in the future, particularly in Sub-Saharan Africa where livelihoods and ecosystems are highly sensitive to changes in climate. For this reason, effective strategies and plans for adaptation to both climate change and climate variability are of central importance to India, to ensure that continued development in vulnerable areas is resilient to the impacts of climate change.

The insight that climate change will affect agricultural production in developing countries in particular has resulted in support to increase the adaptive capacity among vulnerable populations. Livestock also has potential to strengthen resilience to climate change, as livestock production systems tend to be more resilient than crop based systems. This chapter also discusses a number of innovative social, technical and management interventions that might be considered to increase the resilience of livestock production systems to climate change. However, substantial controversy exists about the short term and long term effectiveness of a number of them. This will require more in depth analyses over the coming years.

Strengthening resilience in the livestock sector relies on building the adaptive capacity of livestock keepers and it is necessary to take an ambitious approach to address the fundamental determinants of capacity. Four dimensions of adaptive capacity are:

- The ability to make informed assessment of imminent threats
- The ability to make to make an informed choice, from a range of options, about the best response measure
- Being capable of deploying the preferred option (skills, money, infrastructure)
- Being free to implement this option (policy, governance, rights)

Inherent resilient adaptive capacity of livestock to cope with climate change

Resilience is about maintaining diversity in genetic resources and in approaches. A diversity of farming techniques/practices allows farmers to cope with differences in local environments and the seasonality that is a part of life. A diversity of productive assets is crucial to farmers having many seed varieties and breeds of animals, each adapted to different conditions, ensured their survival. The traits of inherent resilient and adaptive capacity are: long legs, Short hair coat, higher sweating rate, large surface area, body conformation, higher capacity for maintenance of heat balance, lower metabolic rate and higher feed efficiency, higher tolerance to dehydration and adipose tissue depots and capacity to alter the hormone and biochemical profiles to adapt to a particular environment.

Adaptation Strategies to improve livestock production under the changing climate scenario

Table 3 describes the various adaptation strategies for livestock sector to counter the impact of climate change. Effective adaptation to climate variability and climate change is dependent on access to climate information for the coming seasons and years, to enable communities make decisions for now and the future. Flexible planning in the face of a continuously changing climate a key element of adaptive capacity needs to be informed by climate forecasts and the effects of uncertainties and risks on different vulnerable groups and socio-economic sectors, so as to identify a range of response options. Scenario development of how livelihoods and sectors would be affected by probable climate futures contributes to making livelihoods more climate resilient, and can be a first step towards mitigating the effects of climate related disasters on communities. In general, there two sets of adaptation strategies general and innovative strategies. The various strategies belonging to these two groups are listed below:

General Adaptation Strategies for livestock sector

- *Breeding locally adapted livestock species*
- *Diversifying livestock types*
- *Adopting livestock production as an adaptation strategy*
- *Resource management practices*
- *Feed production technologies*

- *Pastoral livestock mobility*
- *Diversification of livelihood activities*
- *Understanding the constraints to adaptation*

Innovative adaptation within the livestock sector

- *Social innovation*
- *Technological innovations*
- *Management innovations*
- *Developing niche markets to preserve indigenous breeds*
- *Information technology*
- *New energy supplies*
- *Climate forecasting capacity*
- *Developing financial services*
- *Developing community adaptation strategies*

Table 3. Livestock adaptation strategies under ensuing climate change scenario

Parameters for livestock adaptation	Respective livestock adaptation strategies
Production adjustments	i) Change in quantity and timing of precipitation
Breeding strategies	i) Identifying and strengthening local breeds that have adapted to local climatic stress and feed sources ii) Improving local genetics through cross-breeding with heat and disease-tolerant breeds
Market Responses	i) For example, promotion of interregional trade and credit scheme
Institutional and policy changes	i) Removing or introducing subsidies, insurance systems ii) Income diversification practices iii) Livestock early warning systems
Science and technology development	i) Understanding of the impacts of climate change on livestock ii) Developing new breeds and genetic types iii) Improving animal health iv) Enhancing soil and water manage
Capacity building for livestock keepers	i) Understanding and awareness of climate change ii) Training in agro-ecological technologies and practices
Livestock management systems	i) Provision of shade and water to reduce heat stress from increased temperature ii) Reduction of livestock numbers in some cases iii) Changes in livestock/herd composition iv) Improved management of water resources

Improving the resilience for livestock production under ensuing climate change scenario

Strengthening the assessment of climate change threats

- *Improved forecasting and warning*
- *Building awareness of climate change and its consequences*

Enabling informed choice of adaptation strategy

- *Raise awareness of the value of different livestock breeds*
- *Raise awareness of the value of different management strategies*
- *Build capacity for integrated land use planning*
- *Build knowledge on fodder production and conservation*
- *Strengthen herd health and reduce mortality*
- *Strengthen understanding of the carbon cycle in livestock systems*

Strengthening capabilities to act

- *Developing skills in the livestock sector*
- *Developing resources in the livestock sector*
- *Developing infrastructure*

Creating an enabling environment for adaptation

- *Policy engagement*
- *Strengthening markets*
- *Organizations*
- *Land and resource tenure*
- *Transhumance*
- *Strengthening women livestock keepers' rights*
- *Pastoral codes and ministries*

Specific recommendations for livestock research and development

- Strengthen forecasting capacities in the livestock sector
- Promote breed development that is relevant to local environmental conditions
- Strengthen understanding of appropriate pasture management that accommodates climatic flux
- Increase participatory research into the roles of women in the livestock sector
- Develop financial products that are adapted to the production cycle of rural livestock enterprises
- Strengthen access to appropriate veterinary services, including Community Animal Health Workers
- Further develop relevant fodder production and conservation technologies

- Strengthen understanding of the shifting relationship between the crop and livestock sectors
- Identify ecologically and socially sound options for improving water availability
- Strengthen natural resource tenure and governance
- Explore the options and benefits for mitigation strategies in the livestock sector

Conclusion and future perspectives

Livestock systems in developing countries are characterized by rapid change, driven by factors such as population growth, increases in the demand for livestock products as incomes rise, and urbanization. Climate change is adding to the considerable development challenges posed by these drivers of change. Climate change is seen as a major threat to the survival of many species, ecosystems and the sustainability of livestock production systems in many parts of the world. Livestock production is thought to be adversely affected by detrimental effects of extreme climatic conditions. Consequently, adaptation and mitigation of detrimental effects of extreme climates have played a major role in combating the climatic impact in livestock production. Infact, the animals can adapt to the hot climate, nevertheless the response mechanisms are helpful for survival but are detrimental to performance. Hence formulating mitigation strategies incorporating all requirements of livestock is the hour of need to optimize productivity in livestock farms. This chapter also elaborates on different adaptive strategies that need to be given due consideration to prevent huge economical losses incurred due to climate change impact on livestock productivity. Further, this chapter details the issues of less-than-perfect information on climate impacts and vulnerabilities, and need for better informed decisions on "resilient adaptation" by merging adaptation, mitigation and prevention strategies. It offers new perspectives for policy-makers, institutions, societies and individuals on improved ways of identifying most at-risk communities and "best practices" of coping with current climate variability and extreme climate events.

Responding to the challenges of global warming necessitate a paradigm shift in the practice of agriculture and in the role of livestock within the farming system. Science and technology are lacking in thematic issues, including those related to climatic adaptation, dissemination of new understandings in rangeland ecology, and a holistic understanding of pastoral resource management. The key thematic issues on environment stress and livestock production includes: early warning system, multiple stress research, simultaneously, simulation models, water experiments, exploitation of genetic potential of native breeds, suitable breeding programme and nutritional intervention research. Livestock farmers should have key roles in determining what adaptation and mitigation strategies they support if these have to sustain livestock production in changing climate. The integration of new technologies into the research and technology transfer systems potentially offers many opportunities to further the development of CC adaptation strategies.

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STRATEGIES FOR SUSTAINING SMALL RUMINANT PRODUCTION IN ARID AND SEMI-ARID REGIONS

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Introduction

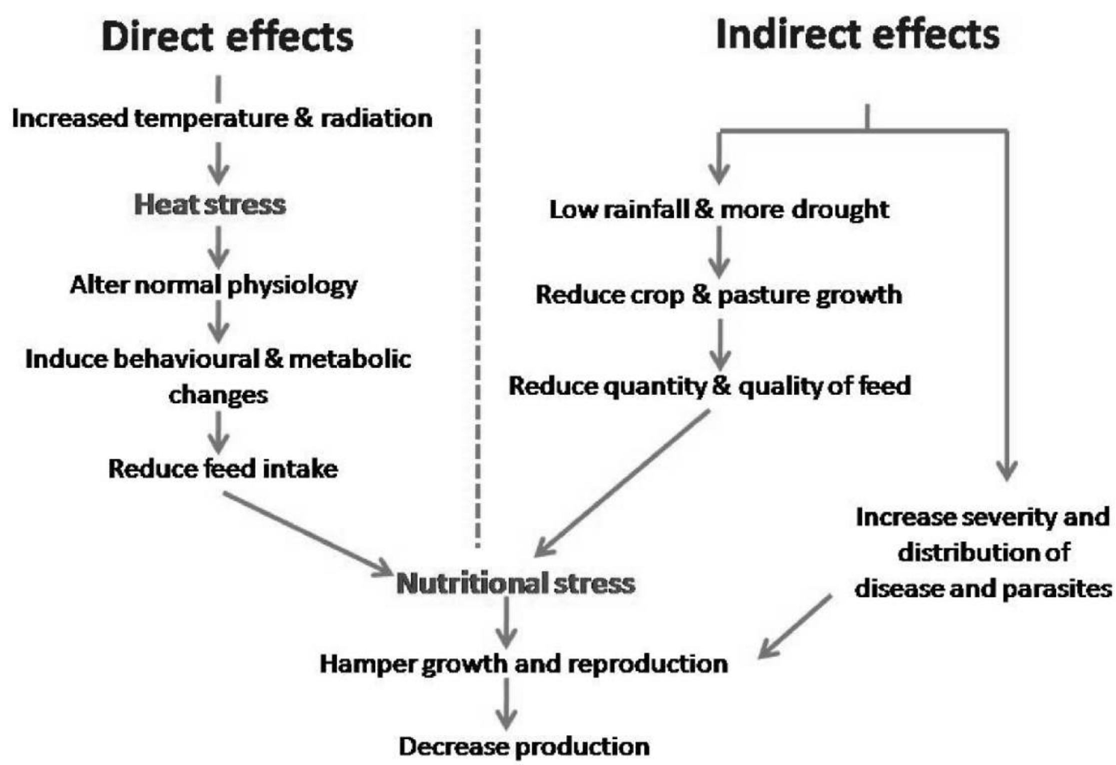
While climate change is a global phenomenon, its negative impacts are more severely felt by poor people in developing countries who rely heavily on the natural resource base for their livelihoods. Moreover, rural poor communities rely greatly for their survival on agriculture and livestock that are amongst the most climate-sensitive economic sectors. Among the livestock species, small ruminants are more vulnerable to climate change as they are reared by poor, unprivileged landless/ marginal farmers under extensive system of production. Animals which are more hardy and adapted to harsh climate condition may thrive well while others may either shift to more suitable region or suffer stressful environment. Adverse climate condition is known to influence more severely to non-adapted and high producing sheep and goats. For example the production performance and survivability of Bharat Merino sheep i.e., Crossbred (75% exotic inheritance), was unsatisfactory at Avikanagar (semi-arid tropical area) but their shifting to Mannavanur (sub-temperate location) resulted in marked increase in production and health performance (growth, reproduction and survivability) (Naqvi and Sejian, 2011). The IPCC summarized research on the potential impacts of climate change for livestock and listed four possible effects: (1) changes in livestock feed grain availability and price; (2) direct effects of climate on animal health, growth, and reproduction; (3) impacts on pasture and forage crops; and (4) changes in distribution of disease and parasites.

The extreme climatic conditions will impose various stresses on animals which will adversely affect their production and reproduction. The important environmental stresses include i) heat stress due to direct effects of high temperature and solar radiation on animals, and ii) nutritional stress due to the negative effect of lower rainfall and more droughts on crops and on pasture growth, reducing quantity and quality of feed. It is expected that the livestock systems based on grazing (extensive production system) and the mixed farming systems (Semi-intensive production system) will be more affected by climate change than an industrialized system (Intensive system). This will be due to the negative effect of lower rainfall and more droughts on crops and on pasture growth and of the direct effects of high temperature and solar radiation on animals (Fig. 1). The most important aspect of the temperature effects is heat stress, which is caused by high ambient temperature and aggravated by high relative humidity.

Effect of heat stress

Under stressful conditions the physiological and cellular aspects of body function are disrupted by either the effect of stresses (like increase in body temperature caused by heat stress) or by the physiological adaptations engaged by the animal to reduce these effects. It is known that animal that are exposed to high ambient temperatures, augments the efforts to dissipate body heat, resulting in the increase of respiration rate, body temperature and consumption of water and a decline in feed intake (Marai et al., 2007; Pereira et al., 2008) which result in poor growth performance (Rowlinson, 2008). Heat stress stimulates the peripheral thermal receptors to transmit suppressive nerve impulses to the appetite centre in the hypothalamus and thereby causing a decrease in feed intake (Marai et al., 2007). The decrease in feed intake could be due to the adaptive mechanism of sheep to produce less body heat. Further, it is an established fact in small ruminants that lack of food and particularly the potassium content, impedes the sodium uptake from the reticulum-rumen causing hyponatraemia and hypo-osmolality (Holtenius and Dahlborn, 1990). The reason for the effects of elevated ambient temperature on growth reduction could be due to decrease in anabolic activity and the increase in tissue catabolism through increase in catecholamines and glucocorticoids (Marai et al., 1999). Reproductive processes in the male and female animal are very sensitive to disruption by hyperthermia with the most pronounced consequences being reduced quantity and quality of sperm production in males and decreased fertility in females.

Fig. 1. Effects of climatic change on livestock productivity (Source: Naqvi and Sejian, 2011)



Under the changing climatic scenario, the concept of multiple stresses emerges as a potential threat to small ruminant production. Hence research needs to be prioritized to tackle multiple stresses simultaneously. Generally when animals are exposed to one stress at a time, they can effectively counter them based on their stored body reserves without altering the normal body functions. However, if they are exposed to more than one stress at a time, the summated effects of the different stressors might prove detrimental to these animals. This is because of their inability to cope with the combined effects of different stressors simultaneously. In such a case, the animal's body reserves are not sufficient to effectively counter such environmental extremes. As a result their adaptive capability are hampered and the animals struggle to maintain normal homeothermy.

The series of studies conducted in our laboratory clearly established the effect of heat stress on sheep production and reproduction (Maurya et al., 2004; Sejian et al., 2011a). In female, heat stress significantly affected estrus%, estrus duration, conception rate, lambing rate and birth weight of lambs (Maurya et al., 2004). In addition, heat stress also significantly influenced plasma estradiol and progesterone concentration in Malpura ewes (Sejian et al., 2011a). Further, Naqvi et al. (2004) also reported significant reduction in superovulatory response and embryo production in Bharat Merino ewes after exposing them to heat stress. The effect of various stresses [thermal, nutritional, combined (thermal + nutritional) and multiple (thermal + nutritional + walking) stresses on blood biochemical and endocrine parameters of Malpura ewes are depicted in table 1.

In addition to high temperature and deficient nutrition, water scarcity is another important limiting factor to small ruminants during summer season in semi-arid tropical environment under changing climatic scenario. Water is considered as an essential nutrient and is involved in every metabolic function of the body. Considering its importance in sheep productivity we have conducted a study to examine the effect of water restriction on physiological responses, blood metabolites and growth of Malpura sheep. The results of this study indicate that despite of significant effects of water restriction on physiological response, blood biochemical and feed intake, Malpura ewes have capability to adapt and can tolerate up to 50% water restriction as well as alternate day water restriction without affecting the growth of animals during summer season under semi-arid tropical environmental conditions.

Table 1. Effect of thermal and associated stresses on physiological and reproductive parameters in Malpura sheep.

Parameters	Control	Thermal stress	Nutritional stress	Combined stresses	Multiple stresses
Hb (g/dl)	11.910.35^{a}	9.480.26^{c}	10.750.32^{b}	8.590.17^{d}	10.910.12^{b}
PCV (%)	41.31.46^{a}	31.31.64^{b}	35.81.73^{b}	26.52.05^{c}	35.80.75^{b}
Glucose (mg/dl)	52.12.43^{a}	47.81.61^{ab}	44.21.91^{b}	43.02.52^{b}	39.40.53^{c}
Total Protein (g/dl)	8.880.33^{a}	7.950.41^{ab}	7.910.26^{ab}	7.080.33^{b}	6.370.08^{c}
Total Cholesterol (mg/dl)	52.31.86^{a}	43.02.29^{b}	42.62.21^{b}	35.62.33^{c}	30.61.78^{d}
ACP (KA Units)	2.140.12^{a}	1.480.14^{bc}	1.780.09^{ab}	1.160.18^{c}	-
ALP (KA Units)	5.890.25^{a}	5.100.37^{b}	5.570.25^{ab}	4.100.33^{c}	-
T_3 (nmol/L)	1.710.01^{a}	1.330.00^{b}	1.420.00^{b}	1.140.01^{c}	1.390.05^{b}
T_4 (nmol/L)	76.24.17^{a}	58.93.22^{b}	63.03.64^{b}	45.95.14^{c}	24.40.10^{d}
Cortisol (nmol/L)	18.631.30^{d}	76.985.18^{a}	8.501.06^{e}	46.443.64^{b}	31.031.08^{c}
Insulin (MicroIU/mL)	47.42.92^{a}	39.83.20^{ab}	35.11.39^{bc}	26.42.84^{c}	-

Means (±SE) in a row having different superscripts differ significantly ($P<0.05$) (Source: Sejian et al., 2010a, b; Sejian et al., 2011c)

Sustainability of small ruminant production

The small ruminant production system is affected by climate change and at the same time itself contribute to climate change. So for sustainable small ruminant production there is need to adopt strategies (i) to reduce the magnitude of climate change in the long term i.e. mitigation and (ii) to reduce the effect of climate change on livestock i.e. adaptation. However, neither mitigation nor adaptation alone can counter all climate change effects. Thus, it will be necessary to focus on both mitigation, to reduce the level of emission of GHG contributing to global warming, and on adaptation, to support local communities in dealing with the effects.

Mitigation strategies: The livestock production system contributes to global climate change directly through the production of GHG emissions and indirectly through the destruction of biodiversity, the degradation of land, and water and air pollution. Livestock contribute directly (i.e. as methane and nitrous oxide (N_2O)) to about 9% of global anthropogenic GHG emissions (Gill et al., 2010). There are three main sources of GHG emissions in the livestock production system: the enteric fermentation of animals, manure (waste products) and production of feed and forage (field use) (Dourmad et al., 2008). Reducing the increase of GHG emissions from livestock production should therefore be a top priority, because it could curb warming fairly rapidly (Sejian et al., 2010a). Methane has relatively short life (10-12 years) in the atmosphere as compared to other GHGs, for example CO_2 has 120 years and therefore strategies to reduce the methane in atmosphere offer effective and practical means to slow global warming (Turnbull and Charme, 2001). Decreased emission rate of only 10% will stabilize methane concentration in atmosphere at present level (Lelieveld et al., 1993). Several options have been considered for mitigating methane production and emitting in atmosphere by the livestock (Joblin, 2001). All approaches points towards either reduction of methane production per animals or reduction per unit of animal product (Johnson et al., 2002). Generally the methane mitigation strategies can be grouped under three broader headings viz., managemental (Ulyatt and Lassey, 2001; DeRamus et al., 2003), nutritional (Yan et al., 2000; Lovett et al., 2005) and advanced biotechnological strategies (Sejian et al., 2010a). Various mitigation strategies for reducing enteric methane production from ruminant livestock are:

- Improved genetic selection to produce low methane producing animals
- Reducing livestock population by culling non-producing and low-producing animals and by maintaining a dynamic high producing animals for meeting the future demand
- Improved nutrition by providing high quality feed and strategic supplementation of essential nutrients
- Improving grassland management and maximizing green biomass availability through three-tier silvipasture system
- Introducing high-producing animals to reduce per unit methane emission
- Development of complete feed to increase nutrient utilization and to reduce losses through fermentation/emission
- Diet modification and dietary manipulation to reduce methane, viz. oil, ionophore (e.g. monensin), phytochemicals (tannins, saponins, essential oil) supplementation
- Rumen ecological manuevouring to reduce methane production (e.g. acetogenesis, propionate synthesis)
- Defaunation and rumen microbial intervention
- Reducing the manufacture of livestock products
- Employing advance technology like immunization
- Recombinant technology for reducing methane production (introducing novel microbes)
- Ensuring proper health care through upgraded veterinary therapeutic and preventative practices

Adaptation strategies: While new knowledge about animal responses to the environment continues to be developed, managing animal to reduce the impact of climate remains a challenge. As discussed earlier, heat stress can compromise the production and reproduction by decreasing expression of estrus behavior, altering follicular development, compromising oocyte competence, and inhibiting embryonic development. While preventing effects of heat stress can be difficult, several strategies exist to improve production of livestock during heat stress. Among these strategies are changing animal housing to reduce the magnitude of heat stress (physical protection), utilization of animals with increased resistance to heat stress (Genetic development), and manipulation of physiological and cellular function to overcome deleterious consequences of heat stress.

Physical protection

Physical protection with artificial or natural shade presently offers the most immediate and cost-effective approach for sustainable small ruminant production. Evaporative cooling also can be effective. Various shade management systems have been evaluated extensively and generally result in improved feed intake and productivity. In more temperate regions with only episodic thermal stress, they may not be cost-effective. Innovative low-cost 'YANGYA' type shed which facilitates heat dissipation and maintains relatively lower temperature at the ground level can be constructed for rest during grazing in semi-arid and arid regions. Introduction of silvi-pasture system or implantation of fodder trees in grazing area can be a successful integrated-farming type approach that provides feed as well as shelter during summer. To protect the lambs from extremely low temperature at night during winter a 'Dome' type easy to carry shed made of bamboo can be provided which may be useful for migratory sheep flocks. For sedentary sheep flocks a house protected against direct wind-flow (cold wave) with thermocol-insulated roofing can also be a very good strategy to conserve day temperature to provide warmth at night.

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Bedded barn facilities appear to be useful for buffering animal against the adverse effects of the environment under hot and cold conditions even though 2 to 4ºC higher temperature, as well as THI level is maintained within the barn when compared to outside conditions, possibly by the decreased air flow through the building. The use of bedded barns does not reduce heat stress, as measured by the THI but act as a shade to decrease the solar heat load on the animal. Some of the following temporary but objective measures to resist thermal stress can also be adopted at farm level.

- Providing cooling for a limited number of days during maximum sensitivity of the embryo to heat stress can moderately improve pregnancy rates as the embryos are most sensitive to heat stress early in pregnancy (Ealy et al, 1993; Edwards and Hansen, 1997). Failure of limited cooling to increase pregnancy rate more dramatically is probably a reflection of heat stress on follicular or oocyte function before cooling was initiated or later in pregnancy after cooling had been terminated.

- Sprinkling animal in the morning is more effective than sprinkling in the afternoon. Sprinkling of pen surfaces may be as much or more beneficial than sprinkling the animal.
- Minimal handling of animal is recommended for promoting animal comfort: In handling studies, moving animal through working facilities requires an expenditure of energy causing an elevation of average body temperature between 0.5 and 1.0 °C (.9 and 1.8 °F), depending on the ambient conditions.
- It is recommended to start cooling strategies prior to animal showing signs of heat stress (panting).

Development of heat resistant breeds

There are clear genetic differences in resistance to heat stress, with tropically-adapted breeds experiencing lower body temperatures during heat stress than non-adapted breeds. Even in non-adapted breeds, it is probably possible to perform genetic selection for resistance to heat stress. There are also specific genes that could be selected which confer increased thermoregulatory ability. It may be possible to identify genes that control cellular resistance to elevated temperature. The superior fertility of tropically-adapted breeds during heat stress is a function in large part of the enhanced ability of animals from these breeds to regulate body temperature in response to heat stress. However, certain tropically-adapted breeds are also more resistant to elevated temperature at the cellular level. Identification of the genes responsible for enhanced cellular resistance to heat shock may allow these genes to be transferred into thermally-sensitive breeds through conventional or transgenic breeding techniques to produce an animal whose oocytes and embryos have increased resistance to elevated temperature.

Genetic selection for major physiological defence mechanisms against rising body temperatures, such as reduced feed intake and metabolic rate and increased peripheral blood flow with concomitant reduction in flow in alimentary tract tissues, offers little potential advantage. Selection for high producing animals, which also are less sensitive to thermal stress under existing natural conditions, would not seem plausible physiologically. Adequate experimentation has not been carried out to obtain precise estimates of heritability for physiological indexes such as efficiency of heat loss, rectal temperatures, respiration rates and sweating rates; likewise estimates of genetic correlation of these traits with most production responses are scant. Heritability estimates obtained from small data sets have large sampling errors. For example, to obtain heritability estimates with narrow confidence limits, e.g., .02 to .04, approximately 500 families of 5 to 10 individuals each are required.

Manipulation of physiological and cellular function

Nutritional management: In summer feeding studies, restricting feed intake to 85% of ad libitum lowers body temperature approximately 0.5 °C (0.9 °F), even after the period of feed restriction ended. Development of new nutritional technologies (e.g., protected-fat feeding) under thermoneutral conditions may offer particular advantages to intensively managed animals in warmer environments as well. In intensive management systems where harvested feedstuffs may be fed, reductions in feed intake may be recovered partially by increasing metabolizable energy (ME) and nutrient densities of diets. Because ME requirements for maintenance increase by 10 to 30% at 30 to 40 ^{0}C vs 18 to 20 ^{0}C, increasing ME intake (by increasing the concentrate to roughage ratio) would leave more ME for reproductive functions (NRC, 1981).

Requirements for specific nutrients appear to differ during thermal stress compared to thermoneutral conditions. There is need to establish prediction equations for requirements of all nutrients fed to livestock in different reproductive states at varying degrees of thermal stress. Other logical and relatively simple nutritional management strategies should be instituted on a broader basis. For example, increasing the number of feedings per day may entice animals to take more meals and keep feed fresher, thus increasing total daily consumption. Scheduling feeding strategically with, or right after, other routine events could result in increased daily consumption. As part of a shade management system, placement of feed and water so that they are always in the shade is paramount. If feed and water are provided in an unshaded area, animals must either sacrifice some benefits provided by the structure to eat and drink, or go without nourishment until cooler periods of the day. Either of these obviously would reduce benefits of the shade on production. It has been noticed that in shade management system, with access to shade and also an adjoining unshaded dirt lot, animals will stay in shade during the hot part of the day but will rest in the unroofed dirt lot at night.

Inclusion of specific nutraceuticals in the diet to improve reproductive function offers an exciting new dimension to small ruminant production. It has been observed that mineral mixture and antioxidant supplementation protected the ewes from the adverse effects of heat stress on feed and water intake, respiration rate and rectal temperature, Hb, packed cell volume, plasma glucose, total protein and endocrine responses (Sejian et al., 2013). Additionally, there is reduced plasma cortisol level, the principal stress relieving hormone. This could be a short-term and low-cost catalytic micro-nutrient supplementation to check production decline and maintain body condition during heat stress. Strategic supplementation of fatty acids accordingly to physiological stage can selectively benefit immune function, maximize production and improve reproductive responses. Supplementary feeding of lupin grain for 14 days and the 'ram effect' can be combined as a strategy for increasing ovulation rate in sheep. Feeding 500 g lupins/head/day for 14 days commencing 12 days after the introduction of vasectomised rams, increase the number of ovulations from 126 to 146 per 100 ewes exposed to rams. This increase is reflected in an improvement in fecundity (lambs born per ewe lambing) but not fertility (ewes lambing per ewe mated to rams). Net reproductive performance (the product of fertility, fecundity and lamb survival) is increased by 11 lambs weaned per 100 ewes exposed to rams due to lupin supplementation at mating (Nottle et al., 1997).

Feeding of cactus (Fig. 1) could also be a useful strategy to dual benefit the animal with a source of feed as well as water. It has been demonstrated that feeding of Opuntia (prickly pear cactus; *Opuntia ficus-*

indica(L.) Mill.) to sheep helps to reduce considerably drinking water consumption and supplemented dry matter and nutrients with similar digestibility during scarcity (Sirohi et al., 1997; Misra et al., 2006). In this line, feeding of Kantela (*Blepharis sindica*), Azola (*Anabaena azollae*) etc may also hold promise to provide feed as well as water to animals during summer feed scarcity, particularly in semi-arid and arid regions of the country.

Intervention through reproductive technologies: Infertility in the male caused by heat stress can be eliminated through the utilization of artificial insemination (AI) with semen collected and frozen from males in cool environments. In females, the situation is more complicated embryo transfer (ET) represents a method analogous to AI in that embryos can be collected from non stressed cows and transferred to heat-stressed recipients (Rutledge 2001). One important attribute of the embryo is that it becomes more resistant to heat stress as pregnancy advances, probably caused by the increased resistance of embryos to cellular disruption caused by elevated temperature. ET can be an effective fertility-enhancing strategy for the heat-stressed animal because most of the effects of heat stress to reduce fertility occur before the blastocyst stage of development when embryos are typically transferred. It may also be possible to remove damaged follicles from the ovary by transvaginal aspiration to hasten the recovery period after heat stress.

Estrus induction techniques offer the opportunity to induce fertile estrus in non-cyclic animals, to increase fertility. Different treatments have been utilized to induce estrus, such as prostaglandin, gonadorelin and progestagen. Better results have been obtained using PRID plus PMSG and prostaglandin. Improved estrus detection and fixed time AI can be used for overcoming the reduced expression of estrus in heat-stressed animals. Little research has been conducted to determine their efficacy under heat stress conditions. Improvements in the synchronization procedure itself, including inclusion of pre-synchronization treatments and selection of animals based on body condition score and improvements in culture systems and freezing systems to improve the freezability of in vitro produced embryos should make timed embryo transfer of in vitro produced embryos a useful tool for enhancing fertility under changing climatic scenario.

Use of antioxidants: The use of antioxidants to improve fertility during heat stress is predicated on the idea that free radicals contribute to embryonic mortality. Culture at elevated temperature has been reported to increase free radical production in embryos at Days 0 and 2 relative to insemination (Sakatani et al, 2004). However, experiments using antioxidants to block effects of elevated culture temperature on development of bovine embryos have been largely unsuccessful (Ealy et al, 1995; Paula-Lopes et al, 2003). In the cow, as well, most antioxidant treatments to improve fertility of heat-stressed cows have not been effective. Among the treatments used has been administration of vitamin E at breeding (Ealy et al, 1994), multiple injections of vitamin E and selenium before and after calving (Paula-Lopes et al, 2003) and administration of β-carotene at Days 6, 3 and 0 relative to insemination (Arechiga et al, 1998 a). One explanation for negative results with antioxidants is that the choice of antioxidant or the dosing regimen was inappropriate to block free-radical damage induced by heat stress. There is one study reporting beneficial effects of antioxidant feeding on reproductive function of lactating cows during heat stress (Arechiga et al, 1998 b). Cows that received supplemental β-carotene (400 mg/day) for at least 90 days beginning at 15 days postpartum were more likely to be pregnant at 120 days postpartum (35%) than cows not receiving supplemental β-carotene (21%). There was also a non-significant tendency for inseminations required to achieve pregnancy to be lower for cows receiving supplemental β-carotene.

Intervention at somatotropininsulin-like growth factor-1 axis: Among its many actions, insulin-like growth factor-1 (IGF-1) can protect cells from various forms of stress including elevated temperature. In particular, administration of IGF-1 to bovine embryos produced in vitro reduced the magnitude of effects of elevated temperature on inhibition of development and apoptosis (Jousan and Hansen, 2004; 2007). Probably the easiest way to increase IGF-1 concentrations in animals is to administer bovine somatotropin (bST). Such a treatment can affect cellular thermotolerance because lymphocytes collected from heifers treated with bST were less affected by elevated culture temperature than lymphocytes from control heifers (Elvinger et al, 1991). A recent study evaluated the effect of bST treatment during summer on fertility of lactating cows (Jousan et al, 2007). An injection regiment of slow-release bST every 14 days was initiated at 7 days before OvSynch was initiated for first insemination postpartum. Treatment with bST caused an increase in milk yield and a slight increase in body temperature that probably reflects in large part the increased milk yield. There was, however, no effect of bST on first service or second service pregnancy rate. One possibility is that the elevation in body temperature may have counteracted any fertility-promoting effect of bST. If so, short-term administration of bST to avoid actions promoting increased body temperature may prove effective at increasing fertility. However, Sakatani et al (2004) indicated that treatment of cows with bST can increase pregnancy rates of cows bred via timed AI, increase the survivability of embryos recovered from donors, and increase the pregnancy rate of recipients treated with bST.

ET offers the opportunity to expose embryos directly to IGF-1. Transfer of in vitro produced embryos that were cultured with IGF-1 into heat stressed, lactating recipients resulted in increased pregnancy and calving rates as compared to transfer of in vitro produced embryos cultured without IGF-1 (Block and Hansen, 2007; Block et al, 2003). The action of IGF-1 to enhance post-transfer survival of embryos is dependent upon heat stress because no beneficial effect of IGF-1 on embryonic survival was observed when recipients were not heat stressed (Block and Hansen, 2007). Possible mechanisms responsible for effects of IGF-1 on embryonic survival are discussed by Block (Block, 2007).

Pharmacological control of body temperature: There has been little interest in animals in identifying methods to pharmacologically regulate body temperature during heat stress. There are reports that feeding culture extracts of the fungus Aspergillus oryzae (Huber et al, 1994) and supplemental niacin (Spain and Spiers, 1997) can decrease body temperatures of heat-stressed cows. In sedentary sheep, treatment with indomethacin lowered the rise in body temperature accompanying heat stress (Sakurada and Hales, 1998), presumably because indomethacin blocks prostaglandin-mediated actions of gastrointestinal endotoxins released during heat stress on hypothalamic thermoregulatory centers. Interestingly, physically fit sheep experienced lower degrees of hyperthermia following heat stress (ascribed to increased blood perfusion of the gastrointestinal tract due to increased cardiovascular output) than sedentary sheep and indomethacin did not affect body temperature in these sheep (Sakurada and Hales, 1998).

Conclusion

Evidence from the IPCC is now overwhelmingly convincing that climate change is real, that it will become worse, and that the poorest and most vulnerable people will be the worst affected. Rural poor communities rely greatly for their survival on agriculture and livestock keeping particularly small ruminants that are amongst the most climate-sensitive economic sectors. The small ruminant production system is affected by climate change and at the same time itself contribute to climate change. So for sustainable small ruminant production there is need to adopt strategies (i) to reduce the magnitude of climate change in the long term i.e. mitigation and (ii) to reduce the effect of climate change on small ruminants i.e. adaptation. However, neither mitigation nor adaptation alone can counter all climate change impacts. Thus, it will be necessary to focus on both mitigation, to reduce the level of emission of GHG contributing to global warming, and on adaptation, to support local communities in dealing with the impacts. The important adaptation strategies include physical protection, genetic development of heat resistant breeds and manipulation of physiological and cellular functions of animals. Whereas application of managemental, nutritional and advanced biotechnological strategies are the options for mitigation of climate change impact on livestock.

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FEEDS AND FEEDING OF SMALL RUMINANTS DURING CLIMATE-CHALLENGE SCARCITY

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Introduction

Livestock in general and small ruminants (sheep and goat) in particular play an important role in rural economy of India where small, marginal and landless farmers are the main beneficiaries. The sheep and goats either graze on pastures, wastelands, fallow lands etc. or stall fed to meet their nutrient requirements for various physiological state as well as level of production. While the majority of these small ruminants are maintained on the roughage based diet, the lactating goats and advance pregnant ewes and does are supplemented with traces of concentrates up to 500 g per head per day depending upon the level of production. In view of the climate change, changing land utilization pattern, deforestation, degradation of pastures and rangeland, the gap between availability and requirement of nutrients is increasing. Further, the already scarce feed resources are also being diverted for other purposes. Therefore, under the prevailing circumstances, exploration and evaluation of new feed resources and their efficient utilization should be continual process to overcome with problem of feed scarcity. Newer feed resources- under or unutilized non-conventional feeds including agro-industrial by-products and livestock waste have great role to play by providing useful nutrients to already under nourished livestock population. Importance of these feed resources has been realized for the last four decades and lot of work has been done since then. The feeding value, level of incorporation in a particular livestock species and presence or absence of incriminating factor in a newer feed resource are the main criteria for its effective use in sheep and goat ration. Various aspects of utilizing the newer feeds during climate change scarcity are being discussed in detail as under.

Top feed resources

Trees and shrubs provide green biomass of moderate to high digestibility and protein content when other feed reserves are scarce and low in nitrogen. There are several commonly available options for making effective use of shrub and tree foliage in tropics. In some regions of the country probably more animals are maintained on top feeds than the conventional fodder resources. The trees and shrubs of different agro-climatic zones having significance in small ruminant feeding are detailed in Top Feed Resources edited by Manohar Singh (1983). The tree leaves are best utilized in browsing by sheep and goats. Additionally, in arid and semi-arid regions of the country tree leaves are harvested and sun dried at appropriate stage and stored, for use as supplements in addition to grazing during lean summer months when scarcity of feeds becomes a problem for maintaining the small ruminants. However, browsing by the animals on the bushes or freshly lopped trees is nutritionally advantageous as well as economical.

The dry matter content of the top feed ranges from 20 to 40 per cent with 10 to 15 per cent CP on DM basis whereas higher CP value (20 to 23 %) has been found in Subabul (*Leucaena leucocephala*) leaves. The cultivation of Subabul as a palatable, high-protein browse or cut- and- carry feed component, often used with crop residues or native grasses as the basal roughage. Mainly locally available species are used for cultivation. The ether extract fraction of top feeds is high with low crude fibre content whereas the fibre fraction gets complex and lignified at maturity with concomitant decrease in CP content. The calcium content is generally 2 to 3 times higher than the conventional fodders with low phosphorus content resulting in wide Ca to P ratio. Higher Ca content of top feeds has little advantage without P supplementation. It is important to note that the palatability, digestibility and nutritive value of the tree leaves also decreases with advancing maturity.

Lopping of standing trees in forest is prohibited. However, the forest department does not object the removal of dry fallen leaves from the surface. It is estimated that 300 to 350 million MT dry fallen leaves and grass is available from the forest with nutrient content particularly CP value better than the crop residues like paddy and wheat straws. About 43 million MT of this resource, if processed, can be effectively used in livestock feeding. The ground tree leaves can be incorporated in various feed formulation at appropriate levels for maintenance of sheep and even for growth providing ADG of 180 to 200 g (Karim, 1995). Under farmers' flock (Chaturvedi et al., 2000), providing supplement in the form of concentrate @ 1% of the body weight to weaner lambs grazing on community rangeland is beneficial because the additional profit in terms of per Rupee spent was Rs. 1.74. The biomass yield of the community rangeland is low which is not sufficient to meet the nutrient requirement of ewes during late gestation and early lactation. However, concentrate supplementation @ 1% of body weight to ewes besides grazing during late quarter of pregnancy and/or early part of lactation improves their production performance and growth rate of their lambs (Chaturvedi et al., 2001; 2003; 2008; 2010).

Fallen tree leaves however cannot maintain sheep on sole feeding owing to their low palatability and nutritive value. However, the major constraint in its utilization is the collection of the material since free grazing is objected by the forest officers as the process will hamper natural regeneration of forest cover. Further small ruminants, particularly goats have been blamed for degradation of forest cover due to their bipedal stance whereas it is realized that higher stocking density with cattle will have similar consequences.

Prickly pear cactus [Opuntia ficus-indica (L.) Mill.], an excellent natural bio-mass is a fast growing xerophytes draught resistant plant and well adopted to arid and hot environment. Dry matter yield from opuntia may exceed 2000 kg/hectare on uncultivated wastelands. Prickly pear cactus (Opuntia) is rich in energy and water and poor in protein, has been used in livestock feeding in North America since 19th century (NRC, 1976). It has been used as a drought feed and as forage for cattle feeding. In most of the instances it is still used as emergency feed during drought and scarcity. However, the genus appears in great genetic diversity as it is widely used in human (fruits and green vegetables) and animal diets (fodder) in Mexico. The plant is extremely variable in nutritional value depending upon species, variety, and age of the plant, sampling season and plant parts. However, in general Opuntia is high in moisture (85%) and IVDMD (75%) and can be used as source of sustenance during climate change scarcity or drought feeding.

The chemical composition (% DM basis) of Opuntia species having dry matter 12.0, crude protein 10.5, neutral detergent fibre 57.2, acid detergent fibre 25.9, acid detergent lignin 2.4 and gross energy (Mcal/kg) 3.9, categorized it as a good source of moisture (water) and biomass in arid/semi-arid ecology. Research findings on practical Opuntia feeding are:

- Sheep offered Opuntia species in combination with Cenchrus hay had low feed intake, apparent digestibility of DM, CP and energy, nutritive value, plane of nutrition and N balance.
- Laxative effect of cactus can be improved by use of lime as additive to control acidosis if fed ad lib or as sole feed.
- Its low DCP content can be compensated with 50 g groundnut meal supplementation in a way that the values were similar to cenchrus plus 200 g concentrate supplemented diet (Misra et al. 2006).
- Excretion of purine derivatives and microbial N as well as microbial protein supply was poor in sheep on opuntia diets. Opuntia feeding increased ruminal pH but decreased TVFA and fractional VFA.
- Supplemented groundnut meal improved ruminal N and NH_3-N, whereas impaired microbial N supply needs further research to optimize P and other nutrient additives for better animal performance.
- The opuntia diets could be advantageous, when appropriate N supply is emphasized, as sheep may have similar digestion than those on common diets and may reduce considerably drinking water consumption.
- 1.0 kg Opuntia (prickly pear cactus) feeding in adult sheep compensated mild water restriction, say 1 litre without any significant effect on feed intake.
- Study on water balance also shows adaptive conservation of water and N in response to water restriction and feeding of moderate N containing prickly pear cactus could serve as potential gut filler and also, by ensuring nutrient supply during summer feed scarce.

Arid and semi-arid ecology of our country is vulnerable for natural calamities. Thus Opuntia can be successfully fed to sheep during feed scarcity meeting water and nutrient requirement.

Vilayati babul (Prosopis juliflora), a leguminous plant well adapted to semi arid and arid ecology having multifaceted utility yielding 17 to 140 kg pods having high CP and energy value can replace 30% of concentrate in ruminant feeding.

However, dried green leaves of P. juliflora are not palatable to rams feeding even at a very low level, i.e. 100-150 g per head per day and it also affects feed and nutrient intake and utilization (Chaturvedi and Sahoo, 2012).

Babul (Acacia nilotica) pods at the rate 150 g/day with ad libitum cenchrus hay could maintain the pregnant ewes in positive N balance. Ground Siris (*Albezia lebbeck*) pods can replace 20 to 40 per cent concentrate for adult sheep. Similarly, cotton straw, cotton seed hulls, groundnut hulls, sunflower straw, sunflower heads, sugarcane bagasse, saw dust, wood pulp waste, forest dry grass and leaves have been used in small ruminant feeding at appropriate level of incorporation.

Agroindustrial by-products

Fibrous agro-industrial by-products are usually regarded as being of limited nutritional value and low to very low digestibility, supporting low intake by the animal (Egan, 1989). The products of digestion are considered to be poorly balanced for all productive purposed. Sufficient guidelines are being developed on the use of supplements or combination of feeds to enhance animal performance on these basal roughages. Supplements are needed that improve the pattern of rumen fermentation. The extent to which supplements result in improved efficiency of overall feed use depends on changes in the rates of fermentation of fibrous carbohydrates, synthesis of microbial protein, degradation of dietary protein and outflow of particulate matter from the rumen. The tactics in supplying supplements are all related to timing, so as to best modify these rates, which both determine and are determined by the level of intake.

At present large number of non-conventional/agro-industrial by-products, have been tested for their nutritive value, are being used in compound feed industry up to 30-35 per cent in ruminant mash. Incriminating or anti-nutritional factors present in these feeds reduce their nutritive value and may affect production and reproduction adversely if recommended levels are exceeded. Therefore, suitable treatments are given for removal of anti-nutritional factors from these foodstuffs before their use in the feed. Protease inhibitors, goitrogenic substances and tannins are most common incriminating factors present in these new feed materials. Tannin combines with the protein and consequently forms protein-tannin complex which is resistant to microbial attack in rumen. Many of the biological effects are attributed to this nature of tannin. It is reported that there are certain non-rumen microbes like Aspergillus niger having capacity to degrade pure tannic acid. Successful technology to introduce such microbes in rumen will make small ruminants capable of utilizing tannin rich feeds efficiently.

Large quantity of other agro-industrial by products viz. banana leaves, pineapple waste, maize cobs, groundnut hulls, cashew bran, neem seed cake and karanja cakes are used as non-conventional feed resources in livestock feeding. Large quantity of sugar cane bagasse is becoming available from sugar industries. Steam treatment of sugarcane bagasse with or without addition of molasses and urea has been proved encouraging in terms of increasing feed intake and digestibility. Since the farmers engaged in sheep and goat raising belong to weaker sections of the society, this group of foodstuffs have real importance in meeting their requirements. Mustard straw (MS), a by- product of widely cultivated mustard crop in semi-arid and arid regions of the country, is usually burnt or left in the field to decay naturally without serving any practical purpose rather adding to environmental pollution. The MS as such is not accepted by the animals due to its hard consistency and high glucosinolate content. Urea treatment of MS followed by ensiling changes its physical nature and improves digestibility as well as utilization by the sheep (Misra et al., 1995; Mishra et al., 1996). The MS as such or urea treated alone cannot maintain the sheep whereas in combination with 200 g concentrate can sustain them during scarcity. However, under farmers' level concentrate feeding is not feasible due to his poor socioeconomic status. Therefore, maintenance of sheep on all roughage diet utilizing urea treated MS in combination with tree leaves in 25:75 ratio will be viable alternative (Misra et al., 2000).

Waste from the breweries (antibiotics, enzymes, and beverages like wine, beer and distilled spirits). The primary waste from antibiotic industry is spent mycelia (ratio of waste to antibiotic production is about 2.5: 1) is very rich in protein and may find place in livestock feeding.

Aquatic plants

Some of the common aquatic plants, viz*. Myriophyllum, Ceratophyllum, Pontamogeton, Nymphaea, Hydrilla, Salvinia, Ipomoea quatica, Ceratopteris sp., Nelumbium speciosum* and *Eichhornia crassipes*, are found in the lakes of India and other South and Southeast Asian countries. Water hyacinth (*Eichhornia crassipes*), a prolifically growing weed of terrestrial as well as running water is reported to have 9.2 % DCP and 45.7 % TDN in hay and 4.64 % DCP and 40.3 % TDN in silage. The leaves of Lotus (*Nelumbium speciosum*) are eaten by the cattle and buffalo. Several species of Ramdana (*Nymphaea sp*.) with varying shades of flower may be seen in waterlogged areas. India with vast sea line has great potential for the production of large quantities of seaweeds. The algae (55 % DM digestibility) are very rich in CP (30- 70 % with >70 % digestibility), ether extract (6 - 8 %) and low in crude fibre (5- 8 %).

Animal waste

There is a good scope for increasing nutritive value of agro-industrial by-products, animal waste and fibrous crop residues by following new feeding system wherein these ingredients are blended into complete feeds. It helps in developing the low cost feed, ensures better roughage-concentrate ratio, avoids refusal of unpalatable portion of plant residues, and improves utilization of NPN compounds, enables use of locally available ingredients and by increasing bulk density to facilitate economic transport. Complete feeds containing 35 and 15 per cent wheat straw and hay, respectively supported 450 g daily growth rate in crossbred calves. The vegetable waste is available amply in and around big cities. Good silage can be prepared out of market vegetable waste up to level of 70 per cent mixed with paddy straw and added with molasses and urea up to 10 and 5.3 per cent, respectively. Cattle and buffalo waste from animal production system is generally a mixture of dung, urine and feed refusal which vary in chemical composition. Slaughter of animal for human consumption leads production of large quantity of rumen content and blood. Intensive growth of poultry has led to production of large quantity of Poultry waste/dropping. Poultry droppings alone contribute to 1.3 million tonnes of DM excretion annually. Poultry waste can be processed to destroy pathogens by heating at 150oC for 20 minutes at thickness of 0-6 mm. Deep stacking is the most popular method used to process poultry waste. Nitrogen utilization and performance of the animal have been reported similar for ensiled and deep stacked litter. Poultry excreta and poultry litter contain more nitrogen and ash but less fibre than waste from cattle and pigs.

The animal waste, if properly processed, could supply energy equivalent to about 4.3 million tonnes of cereals or protein equivalent to 4.2 million tons of oil seed meal in our country. Most of the research on recycling has been undertaken with poultry, Swine and cattle waste. These wastes are ranked as feeds for ruminants in the order of excreta of young poultry, deep litter of young poultry, hog faeces, excrements of layers, hog and layer dung solids and excrements of cattle. Nutrient content and digestibility of such waste depends upon age of the animal, animal diet, type of animal, condition under which the animals are kept, methods used to separate the solid and liquid components of animal waste, storage, handling, processing and other factors. Animal wastes are high in fibre and NPN compounds and therefore it has potential for using in ruminants feeds. In recent years, the problem of animal/poultry waste disposal has increased due to limited availability of land, increased disposal cost and increased public awareness about environmental pollution. Reutilisation of such waste in livestock feeding system provides solution for such problems.

In order to exploit the genetic potential, poultry wastes are fed in conjunction with good quality cereal grains, protein supplements and other nutrients. Large quantity of undigested protein gets excreted in faecal matter of the birds in undigested form. These droppings of poultry contain CP up to 20-30 percent out of which about 2/3rd is present in the form of NPN, mainly as uric acid, which can be utilized by ruminants effectively. Uric acid from poultry waste is utilized more effectively by ruminants than urea, mainly because of slower rate of its degradation in comparison to urea. In addition, it is also high in Ca and P. Availability of this waste from poultry industry has increased recently due to steady rise in poultry farming. Therefore, the significance of recycling of the nutrients from poultry dropping has increased in cattle feed.

Depending on the rearing system, two types of waste from poultry farm are available. One is known as poultry litter which is available under deep litter system of rearing. This contains bedding litter material, bird excreta, wasted feed, feathers etc. Other type is poultry waste of caged layer birds which is collected under cages and consist mainly excreta of the birds, wasted feed and feathers. Poultry litter can be fed either after drying or after ensiling. Broiler litter is usually high in protein. Poultry excreta can be used as protein supplement for ruminants, provided rich source of readily available carbohydrate is added to the diet to ensure effective utilization of NPN by rumen microbes. No effect on milk yield and composition was observed when diet containing poultry litter up to 36 per cent was fed to cross-bred cows. The level of replacement of concentrate with dried poultry litter (DPL) above 40 per cent is uneconomical in growing cross-bred calves. Harmful effect on health of sheep fed with ration containing broiler litter having high levels of copper is copper toxicity. However, with withdrawal period of five days after feeding of ration containing poultry waste, such problem was not observed in cattle.

Waste like rumen content is available in larger quantities from animal slaughter houses. About 4000-5000 tones of CP could be obtained annually from rumen content of animals slaughtered in India (Rao and Fontenot, 1987). This waste consists of nutrients of partially digested material which is consumed by the animal before slaughter, digestive juices and bacteria. Chemical composition of rumen content varies with the type of the diet of animal before slaughter and time interval between feeding and slaughter. High moisture content of rumen content in combination with low moisture roughages is helpful in ensiling the feed which increases the palatability and destroys harmful pathogens. It is good substitute for roughages and its nutritive value can be improved by adding urea as a source of nitrogen. The digestibility is improved significantly by adding 10 per cent molasses. The slaughterhouse by-product like rumen content is a potential source of nutrients for ruminants and can be successfully recycled as an animal feed after ensiling. It was further reported that ensiling the rumen content for 21 days with paddy/ sorghum straw along with urea and blood (2:1) and molasses produced good silage which improved growth performance of crossbred calves significantly. The slaughter house waste like rumen content and blood in the ratio of 2:1 can be included in the diet of growing crossbred calves up to the level of 40 per cent, if ensiled with paddy straw along with molasses (10%) for 21 days without affecting the performance. Daily growth rate of 435 g has been obtained in crossbred calves fed with ensiled complete feed incorporating fibrous crop residues like sorghum straw up to 50% and rumen content up to 25 per cent without affecting growth. Thus, the digestive tract contents of slaughtered livestock can successfully be recycled as animal feed which will reduce the cost of production and will ameliorate the environmental pollution problem as well.

Incriminating factors in non-conventional feeds

The toxic factors can be classified into three broad groups viz. the substances limiting digestion and metabolism of proteins, reducing solubility and utilization of minerals, increasing requirement of certain vitamins and hormones. The toxic factors having significance in small ruminant feeding are ricin, saponins, tannins, phytate and oxalate, glucosinolates, gossypol, mimosine, cyanogens and certain mycotoxins. Various treatments such as water soaking and washing, urea and alkali treatment, supplementation of chemical compounds have been developed for annulment of these factors. However in view of socio-economic status of farmers these methods have little significance hence their traditional method of dilution is of practical use. The use of unconventional agro-industrial byproducts with toxic/anti-nutritive factors in animal feeding should be restricted to dilute its detrimental effects (Table 1).

Use of unconventional agro-industrial byproducts in animal feeding

Byproduct	Availability (mT)	Toxic factor	Detoxification value	Nutritive	Level of inclusion
Kapok (silk cotton) seed meal	_	Cyclopropenoid acid, fibre & tannins	Lysine & Methionine supplementation	20% CP, 1.30 Mcal ME/kg	10%, may be fed to ruminants
Kosum cake	0.30	HCN (Cyanogenic glucoside)	_	15% DCP, 79% TDN	(35% in conc. mix.)
Linseed (flax) meal	0.57	Linamarin, Linatin	_	34% CP, 1.60 Mcal ME/kg	Toxic to poultry, if pyridoxine is not supplemented
Mango seed kernel	1.00	Tannins	--	6% DCP, 50% TDN	Milch cows (10 % in conc. mix.)
Niger seed cake	0.10	--	--	32% CP, 49% TDN	(50 % in conc. mix.)
Palm kernel meal	1.97	High fibre	--	20% CP, 1.90Mcal ME/kg	Commonly fed to ruminants
Panewar seed	0.03	Crysophanic acid, Tannins	Fresh water washing/boiling	16% DCP, 66% TDN	15% in conc. mix.
Safflower meal	1.49	Oxalates, Phytate in hull fraction	_	40% CP, 2 Mcal ME/kg	15% with lysine & mineral supplementation
Spent Annato seeds	0.30	Tannic acid	_	8% DCP, 67% TDN	20% in conc. mix.
Sunflower meal	3.28	Chlorogenic acid, Tannins	Supplementing with Methyl donors (Methionine, Choline)	36% CP, 2.10 Mcal ME/kg	15-20% of protein concentrates
Rubber seed cake	0.15	HCN	Roasting, Toasting, Water soaking	18% DCP, 54% TDN	25 % in conc. mix.
Tamarind seed	8.70	Tannins	--	1.3%DCP, 67% TDN	starter diet (up to 25 %)

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EXTREME CLIMATIC VARIABLES AFFECTING MALE REPRODUCTION IN SHEEP

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Introduction

Animals live in complex environment in which they are constantly confronted with short and long term changes due to a wide range of factors such as temperature, humidity, radiation, and wind, commonly called climatic variables. Extremes in climatic variables alter energy transfer between the animal and its environment and have adverse affect on reproductive performance of farm animals. Fertility of farm animals is affected by high ambient temperature, excess humidity, severe cold and lesser access to drinking water. Heat stress due to high ambient temperature accompanied with excess humidity during summer months causes infertility in most of the farm species. It becomes more important to know how these extreme climatic variables affect fertility of farm animals specially under changing climatic scenario. Inter-Governmental Panel on Climate Change (IPCC) has shown that the earth temperature has been increased 0.74 ^{0}C between 1906 and 2005 due to increase in anthropogenic emissions of green house gases (GHG). By the end of this century, temperature increase is likely to be 1.8-4.0 ^{0}C (Aggarwal, 2008). For Indian region the IPCC has projected 0.5-1.2 ^{0}C rise in temperature by 2020, 0.88-3.16 ^{0}C by 2050 and 1.56-5.44 ^{0}C by 2080 depending on the scenario of future development. Similar trend with varying magnitude has been shown by Indian Meteorology Department and the Indian Institute of tropical Meteorology, Pune. It is projected that by the end of 21st century the mean annual temperature of India will increase by 3-6 ^{0}C (Aggarwal, 2008). Moreover, the IPCC report estimates a confidence level of 90% that there will be more frequent warm spells, heat waves and heavy rainfall and a confidence level of 66% that there will be an increase in drought, tropical cyclones and extreme high tides. The magnitude of the events will vary depending on the geographic zones of the World.

It is expected that the extensive and semi-intensive animal production system will be more affected. Sheep is one of the important livestock species reared under extensive production system in almost all parts of the world by marginal and landless farmers. The impact of climate change will be due to the negative effect of lower rainfall and more droughts on crops and on pasture growth and due to the direct effects of high temperature and solar radiation on animals. The most important aspect of the temperature effects is heat stress (HS), which is caused by high ambient temperature and aggravated by high relative humidity. The temperature-Humidity Index (THI) is a widely used tool to assess the impact of heat stress on livestock. In order to maintain body function in steady state, homeotherms are required to maintain body temperature within narrow range. Deviation from the set level of body temperature under stressful hot environment, leads to interference with physiological events and consequently negatively impacts animal reproduction. The maintenance of homeotherms is dependent upon the energy flow from animal to environment and viceversa. Effective ambient temperature (EAT) is a major environmental factor controlling the energy flow. Due to the fact that various factors influence the EAT viz. dry bulb temperature, wet bulb temperature, humidity, wind speed, heat radiation, contact surfaces etc., no satisfactory measures have been developed so far to quantify EAT and hence ambient temperature is the most commonly used indicator. Sheep possess thick insulating boundary on the body and only about 10% of solar radiation received by fleeced sheep, reaches to the skin. The exogenous (solar) heat load of the shorn sheep standing in sun may be about 5-6 times greater than its internal heat production (resting metabolic heat). Animals can adapt to the hot climate, nevertheless the response mechanisms are helpful for survival but are detrimental to productive and reproductive performance. Reproduction is basically a 'luxurious phenomenon' and appropriate when the animal is in just right homeostasis. In case of severe stress, reproduction is typically the first physiological event to let go by the body. Reproductive processes in the male animal are very sensitive to disruption by hyperthermia with the most pronounced consequences being reduced quantity and quality of sperm production and decreased fertility. Under heat stress the physiological and cellular aspects of reproductive function are disrupted by either the increase in body temperature caused by heat stress or by the physiological adaptations engaged by the animal to reduce hyperthermia. The studies conducted in our laboratory clearly established the effect of HS on male sheep reproduction. What are the effects of HS on male reproduction and how HS affects male reproduction is discussed in this chapter with particular reference to sheep.

Effect on Scrotal and testicular morphology

Scrotal circumference and testicular consistency, tone, size and weight, are excellent indicators of sperm production capacity and spermatogenic functions. HS reduces these testicular measurements due to the degeneration of the germinal epithelium and partial atrophy in semniferous tubules. Mikelsen et al. (1981) recorded lowest scrotal circumference values during summer and the highest in autumn in rams. However, Hafez et al. (1955) reported that testes size of farm animals not affected by seasonal changes. In two different studies conducted on Malpura rams in our laboratory clearly showed that HS significantly affected the sexual behavior, scrotal and testicular measurements.

Effect on spermatogenesis

The testes of most mammalian species are located extra abdominally in the scrotum and function at a temperature that is a few degrees lower than normal body temperature. In addition, there is an intricate thermoregulatory system in the testis involving countercurrent exchange of heat from warm blood entering the testis and cool blood draining from the testis through an arterio-venous plexus called the pampiniform plexus. The degree of cooling is further controlled by two muscles: the tunica dartos in the scrotum that regulates scrotal surface area and the cremaster muscle that controls the position of the scrotum relative to the body. The lower intra-testicular temperature is necessary for spermatogenesis and any disruption to thermoregulatory system of testis may cause problems with spermatogenesis. It can be observed when a local heat source is applied to the testis, the scrotum is insulated, the testes are internalized (i.e. cryptorchidism induced) or body temperature is raised because of fever or hot environment (Setchell 1998). However, It has been reported that under tropical environments, rams appear to be able to breed throughout the year, and their spermatogenesis is not seriously affected by the environmental conditions. (Mittal and Ghosh, 1979; Galil and Galil, 1982; Ibrahim, 1997; Kumar et al., 2012).

Exposure of testis to high temperature impairs spermatogenesis by elimination of spermatogonial germ cells in the seminiferous tubules and degeneration of sertoli and leydig cells. The heat damage in the testes is thought to be due to hypoxia causing oxidative stress and consequently germ cell apoptosis and DNA strand breaks (Perez-Crespo et al. 2008; Paul et al. 2008, 2009) mainly in pachytene spermatocytes and round spermatids (Lue et al. 2002). Spermatogonia are relatively resistant to heat compared to spermatocytes and spermatids, because of the fact that the number of spermatogonia remains unchanged and the morphological characteristics are less sensitive to heat exposure (Yin et al. 1997; Lue et al. 2000). Additionally, the testis is able to be repopulated with germ cells following a relative brief or mild temperature exposure (Lue et al. 1999, Yin et al. 1997). Spermatogenic defects of HS are associated with decreased cytoplasmatic HSP60 immunoreactivity in spermatogonia (Werner et al. 1997). This decreased cytoplasmic HSP60 may negatively affect the mitotic proliferation of spermatogonia because of the fact that HSP60 is necessary for normal functioning of mitochondria. Normal spermatogonia proliferation continues to be drastically reduced for weeks even after the end of the heat treatment. The effects of heat on the spermatogonia seem to be dependent on the method, temperature, duration of heat application and the livestock species.

Effect on seminal attributes

In the ram, sexual activity is subject to seasonal variations, the intensity of which varies from breed to breed. These variations can affect all components of reproductive function, particularly the quality of semen and its fertilizing ability (Colas, 1983). HS has a negative effect on semen attributes, such as semen volume, sperm concentration, sperm motility, sperm viability, sperm morphology and acrosome integrity. The seasonal infertility may be due, at least in part, to a combination of these parameters. Semen characteristics are not immediately affected by changes in testicular temperature because damaged spermatogenic cells do not enter ejaculates for some time after HS. When semen quality is reduced by high ambient temperature, several weeks in the thermoneutral environment are needed before semen quality returns to normal. Infertility in the male caused by heat stress can be eliminated through the utilization of artificial insemination with semen collected and frozen from males in cool environments.

Effect on sperm capacitation and fertilization

A satisfactory level of rams' fertility may be retained throughout the whole year, but in many instances, fertility is depressed when mating occurs during the hot months of the year (Hafez 1987). A high percentage of rams could be sterile during the summer time, especially under conditions of high humidity. Conception failure in ewes mated to heat-stressed ram was related to a failure to fertilize than to embryonic mortality (Curtis 1983) Fertility of the rams is related to several phenomena: the ability to mate, sexual desire, sperm production and viability and fertilizing capacity of ejaculated sperm, which are influenced by elevated ambient temperature.

The seasonal infertility may be due to early occurrence of the acrosome reaction in response to stimulus, possibly resulting from a decrease in acrosomal stabilizing proteins in the seminal plasma during summer (Murase et. al. 2007). These changes may be modulated by heat/humidity stress and/or photoperiod-regulated testosterone. There are a number of reports in the literature that suggest males exposed to HS can produce sperm which do not produce normal offspring in unexposed females. Sperm produced by mice which had been exposed to a hot environment, bind to ova normally but are less able to fertilize *in vivo* and *in vitro*, even when motile sperm are selected by a swim-up procedure, and many of the resultant embryos do not develop normally.

Effect on testosterone concentration

Testes testosterone content fell from 1.1 to 0.4 µg/gm and spermatic vein plasma content from 8.2 to 1.9µg/dl, when rams were exposed for 14 days to an average environmental temperature of 30°C (Curtis 1983). The lowest serum testosterone level was recorded during hot environmental conditions in Ossimi rams (El-Darawany 1999). Exposure of the intact rat to increased environmental temperatures is accompanied by decreased capacity of the testes to synthesize testosterone and consequently reduced serum testosterone concentration (Chap and Bedrack 1983). However, in developing ram lambs, direct exposure to high ambient temperature has no significant effect on testosterone production during non-breeding season (Rasooli et al. 2010). Short daylight stimulates the secretion of testosterone, FSH and LH in rams, while long daylight inhibits their secretion. Rams sexual activities peak occurs during the autumn breeding season and coincides with a sharp rise in plasma testosterone level. Then it declines in late winter, spring and summer (Jainuden and Hafez 1987). In two different studies conducted on Malpura rams in our laboratory clearly established significant reduction on plasma testosterone concentration in Malpura rams after exposing them to heat stress.

Effect on heat shock protein genes

It is widely accepted that changes in gene expression and in the activity of expressed proteins are an integral part of the cellular response to HS. Although the HSPs are perhaps the best-studied examples of genes whose expression is affected by heat shock, it has become apparent in recent years that HS also leads to induction of a substantial number of genes not traditionally considered to be HSPs. The cellular response to HS characteristically includes an increase in thermotolerance (i.e., the ability to survive subsequent to more severe heat stresses) that is temporarily associated with increased expression of HSPs. Heat-induced changes in gene expression occur both during hyperthermia as well as after return to normothermia.

HSPs were originally identified as proteins whose expression was markedly increased by heat shock (Lindquist 1986). Several HSPs are expressed even in unstressed cells and play important functions in normal cell physiology. The intensity and duration of the heat stimulus needed to HSP expression vary considerably from tissue to tissue. A typical *in vitro* exposure involves heating mammalian cells to 4245°C for 2060 min and then reverting to normothermic temperatures (37°C). Induction of HSP expression typically starts within minutes after the initiation of HS, with peak expression occurring up to several hours later. Importantly, several experiments have found that, during the period of hyperthermia and shortly thereafter, HSPs become the predominant proteins synthesized by cells (Lindquist 1986). Interestingly, most HSP genes lack introns (Lindquist 1986), which may facilitate their rapid expression and which may also help explain how they can be expressed in the presence of stressors (such as heat) that can interfere with RNA splicing.

Heat shock factors (HSFs) are transcription factors that regulate HSP expression through interaction with a specific DNA sequence in the promoter [the heat shock element (HSE)]. The HSE is a stretch of DNA, located in the promoter region of susceptible genes containing multiple sequential copies (adjacent and inverse) of the consensus pentanucleotide sequence 5′-nGAAn-3′ (Morimoto 1998) and has been found in both HSPs and in a number of other genes. Three HSFs have been identified in mammalian systems: HSF-1, HSF-2, and HSF-4 (Morimoto 1998). HSF-1 (Morimoto 1998) and HSF-2 (Mathew et al. 2001) are involved in the acute response to heat shock. HSF-2 also has a major function in controlling expression of genes important for embryonic development and maintenance of sperm production (Wang et al. 2003).

Before heat-induced activation, HSF-1 exists as a monomer localized to the cytoplasm. The initial stimulus for activation of HSF-1 appears to take place after exposure of hydrophobic domains of denatured proteins to HS. HSPs preferentially bind to denatured proteins, and hence activation of HSF-1 may occur as a result of competitive release of this transcription factor from HSPs when the concentration of denatured cytoplasmic proteins increases as a result of heat shock (Morimoto 1998). After activation by HS, HSF-1 is found primarily in the nucleus in trimeric form, concentrated (in human cell lines) in granules (Sarge et al. 1993). It is this activated, trimeric form of HSF-1 that binds to the HSE and is involved in increased HSP gene transcription during HS (Sarge et al. 1993). Evidence has also indicated that HS induces tagging of HSF-1 with SUMO-1, a ubiquitin-like protein that is used by the cell to mark proteins for transport into different cellular compartments and to alter their activities (Hong et al. 2001). Importantly, in these experiments, HSF-1, *in vitro*, was incapable of binding DNA unless it had first acquired a SUMO-1 tag at lysine 298. In addition to positive regulation of the HSE through HSF-1, evidence also exists for negative regulation of this promoter element in mice by means of a constitutively expressed protein known as the HSE binding factor (HSE-BF) (Liu et al. 1993; Kim et al. 1995). Thus, in addition to a phosphorylation state, the ability of HSF-1 to activate transcription may also be modulated by regulatory processes that affect the binding of HSE-BF to the HSE.

Probable mechanism of stress affecting reproduction

The different possible mechanisms by which stress affects male reproduction are given below and depicted in figure 1.

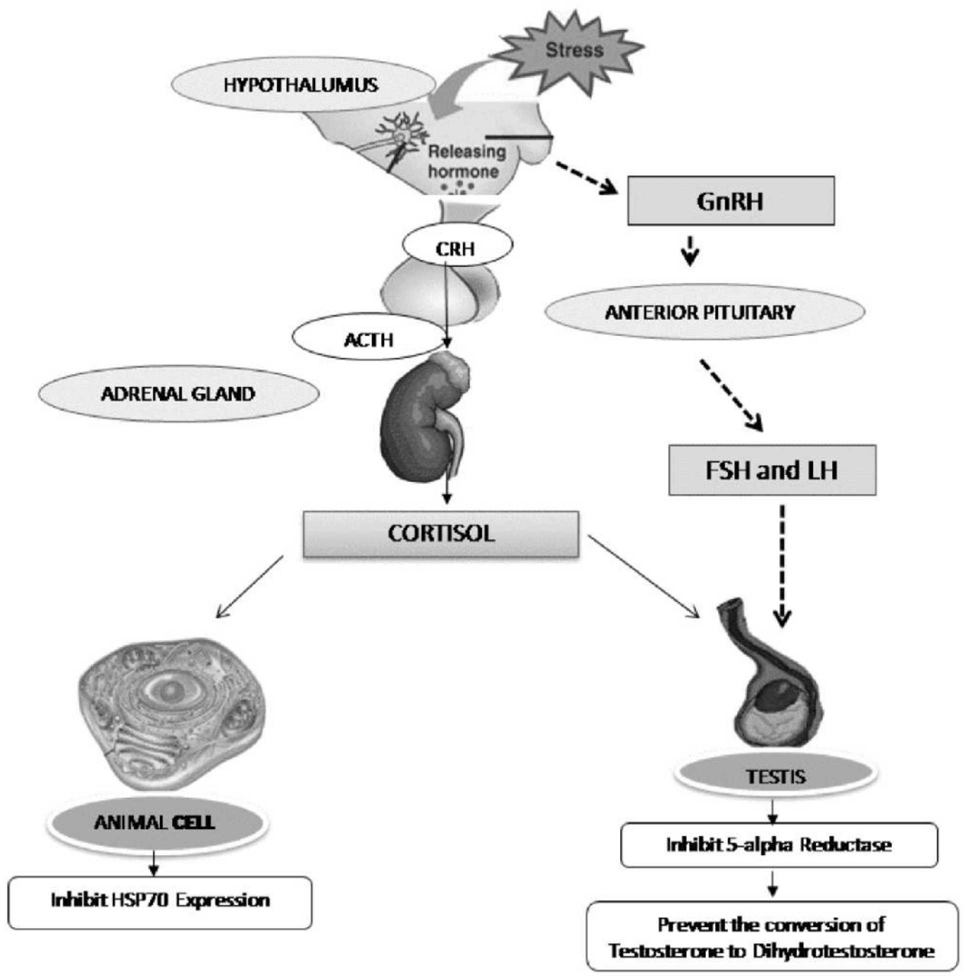

Fig 1. Different mechanisms with which HS affects male reproduction in livestock
CRH- Corticotrophin releasing hormone; ACTH- Adrenocorticotropic hormone, GnRH- Gonadotrophin releasing hormone; FSH- Follicle stimulating hormone; LH- Leutinizing hormone

- Body systems activated by HS are considered to influence reproduction by altering the activities of the hypothalamus, pituitary gland or gonads. Activation of stress pathways may directly affect the activity of Gonadotropin-releasing hormone (GnRH) neurons within the hypothalamus or higher neural centres which intern affects the synthesis or secretion of GnRH into the hypophysial portal blood. It is also possible that HS directly influences the responsiveness of gonadotroph cells in the anterior pituitary gland via the actions of GnRH.

- A further potential action of HS is to alter the feedback actions of sex steroids in the hypothalamus or pituitary and inhibin in the anterior pituitary gland. Glucocorticoids are capable of enhancing the negative feedback effects of estradiol and reducing the stimulation of GnRH receptor expression by estrogen. Glucocorticoids may also exert direct inhibitory effects on gonadal steroid secretion and sensitivity of target tissues to sex steroids.
- HS prevents the basic cell function by causing improper folding of proteins. To cope with this, expressions of HSPs like HSP70 are stimulated/upregulated. The basic function of HSPs is to help in 'proper folding' of proteins so that the three dimensional structure of the protein is not compromised and thus maintaining its normal function. Further, the cell diverts its entire transcriptional and translational machinery to synthesize proteins that are required for maintaining 'house-keeping functions' like cellular respiration, ATP synthesis, excretion of protons (H^+ ions) at the expense of other functions of the cell, e.g. testosterone production. To combat stress, the Adrenocorticotropic hormone (ACTH) - Cortisol axis is activated and cortisol and other glucocorticoids are produced to enhance stress tolerance.
- In male animals, stress adversely affects spermatogenesis perhaps by inhibiting the proliferation of spermatocytes. At cellular level, testosterone is converted into dihydrotestosterone (bioactive form of testosterone) by 5alpha reductase and stress may adversely affect the expression of this enzyme.

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EFFECT OF CLIMATE CHANGE ON LIVESTOCK DISEASES

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Introduction

While climate change is a global phenomenon, its negative impacts are more severely felt by poor people in developing countries who rely heavily on the natural resource base for their livelihoods. Rural poor communities rely greatly for their survival on agriculture and livestock keeping that are amongst the most climate-sensitive economic sectors. India has a geographic disadvantage as it is already in the warmer part of the world. Nearly two thirds of the Indian population is rural mostly living in harsh climatic regions of mountains, deserts and river deltas, which are more susceptible to climate change. Owing to anthropogenic activities, there is widespread scientific agreement that the world's climate is warming at a faster rate than ever before, with concomitant changes in precipitation, flooding, winds and the frequency of extreme events such as El Nino. Innumerable studies have demonstrated links between infectious animal diseases and climate, and it is unthinkable that a significant change in climate during this century will not impact significantly on at least some of them. In the health/disease process there is a constant fluctuation between the health situation and the disease occurrence, where the change from one to the other is determined by a change in the balance between the three elements that comprise the ecological triad: the agent, the host and the environment. Although the environment surrounding the animal health system is constantly changing, the system is not immune to such changes. The emergence and re-emergence of vector-borne diseases in many regions of the planet provides a clear example of the link between climate change and effects on the human/animal health interface. With more frequent extreme events, there could be an increase in climate-related deaths and diseases. The damage to the animal health profile will not necessarily come from a specific biological agent; it may be driven by multiple environmental factors that cause what are known as "production diseases". How should we react to predicted changes in animal diseases ascribed to climate change? The answer depends on the animal populations and human communities affected, whether the disease changes in incidence or spatiotemporal distribution and, of course, on the direction of change. It also depends on the relative impact of the disease. If climate change is predicted to affect only diseases of relatively minor impact, then our concerns should be tempered.

Effects of climate change on livestock diseases

Many important animal diseases are affected directly or indirectly by weather and climate. These links may be spatial, with climate affecting distribution, temporal with weather affecting the timing of an outbreak, or relate to the intensity of an outbreak. Several processes have been proposed by which climate change might affect infectious diseases. These processes range from the clear and quantifiable to the imprecise and hypothetical. They may affect pathogens/parasites directly or indirectly, the hosts, the vectors, epidemiological dynamics or the natural environment. Only some of these processes can be expected to apply to any single infectious disease.

Direct effect: It will include, for example, higher temperatures and changing rainfall patterns, which could translate into the increased spread of existing vector-borne diseases and parasites, accompanied by the emergence and circulation of new diseases. In some areas, climate change could also generate new transmission models. There will be an increase in the incidence of disease, which, in turn, would reduce animal productivity and possibly increase livestock mortality. Vector-borne diseases could be affected by: (i) the expansion of vector populations into cooler areas (tick-borne diseases in higher altitude areas) or into more temperate zones (eg bluetongue disease) and (ii) changes in rainfall pattern during wetter years, which could also lead to expanding vector populations and large-scale outbreaks of disease. Temperature and humidity variations could have a significant effect on helminth infections. Heat-related mortality and morbidity could also increase.

Indirect effect: These will be brought about by, for example, changes in feed resources linked to the carrying capacity of rangelands, the buffering abilities of ecosystems, intensified desertification processes, increased scarcity of water resources, decreased grain production. Other indirect effects will be linked to the expected shortage of feed arising from the increasingly competitive demands of food, feed and fuel production, and land use systems.

Effects on pathogens: Higher temperatures resulting from climate change may increase the rate of development of certain pathogens or parasites that have one or more life cycle stages outside their animal host. This may shorten generation times and, possibly, increase the total number of generations per year, leading to higher pathogen/parasite population sizes. Conversely, some pathogens are sensitive to high temperatures and their survival may decrease with climate warming. Lengthening of the warm season may increase or decrease the number of cycles of infection possible within one year for warm- or cold-associated diseases respectively. Arthropod vectors tend to require warm weather so the infection season of arthropod-borne diseases may extend. Some pathogens/parasites and many vectors experience significant mortality during cold winter conditions; warmer winters may increase the likelihood of successful overwintering. Pathogens and parasites that are sensitive to moist or dry conditions may be affected by changes to precipitation, soil moisture and the frequency of floods. Changes to winds could affect the spread of certain pathogens and vectors.

Effects on hosts: Mammalian cellular immunity can be suppressed following heightened exposure to ultraviolet B (UV-B) radiation - an expected outcome of stratospheric ozone depletion In particular, there is depression of the number of T helper 1 lymphocytes, the cells involved in the immune response to intracellular pathogens like viruses, rickettsia (such as *Cowdria* and *Anaplasma*) and some bacteria, such as *Brucella.* Furthermore, increased UV-B exposure may diminish the host's response to certain vaccinations. Diurnal animals that live outdoors may be less susceptible to heightened UV-B exposure.

A second host-related effect is genetic resistance to disease. Many animals have evolved a level of genetic resistance to some of the diseases to which they are commonly exposed. It seems unlikely that climate change will directly affect genetic or immunologic resistance to disease in livestock. However, significant shifts in disease distributions driven by climate change pose a greater threat than simply that of the exposure of new populations. Naïve populations may, in some cases, be particularly susceptible to the new diseases facing them.

Certain diseases show a phenomenon called "endemic stability". This occurs when the disease is less severe in younger than older individuals, when the infection is common or endemic and when there is lifelong immunity after infection. Under these conditions most infected individuals are young, and experience relatively mild disease. Counter-intuitively, as endemically stable infections become rarer, a higher proportion of cases are in older individuals (it takes longer, on average, to acquire infection) and the number of cases of severe disease rises. Certain tick-borne diseases of livestock, such as anaplasmosis, babesiosis and cowdriosis, show a degree of endemic stability. If climate change drives such diseases to new areas, non-immune individuals of all ages in these regions will be newly exposed, and outbreaks of severe disease could follow.

Effects on vectors: Biting midges, brachyceran flies (e.g. tabanids, muscids, myiasis flies, hippoboscids), ticks and mosquitoes all dominate as vectors of livestock disease. There are several processes by which climate change might affect disease vectors. First, temperature and moisture frequently impose limits on their distribution. Often, low temperatures are limiting because of high winter mortality and a relatively slow rate of population recovery during warmer seasons. By contrast, high temperatures are limiting because they involve excessive moisture loss. Therefore, cooler regions which were previously too cold for certain vectors may begin to allow them to flourish with climate change. Warmer regions could become even warmer and yet remain permissive for vectors if there is also increased precipitation or humidity. Conversely, these regions may become less conducive to vectors if moisture levels remain unchanged or decrease, with concomitant increase in moisture stress. For any specific vector, however, the true outcome of climate change will be significantly more complex than that outlined above. Even with a decrease in future moisture levels, some vectors, such as certain species of mosquito, could become more abundant, at least in the vicinity of people and livestock, if the response to warming is more water-storage and, thereby, the creation of new breeding sites. Equally, some vectors may be relatively insensitive to direct effects of climate change, such as muscids which breed in organic matter or debris, and myiasis flies which breed in hosts' skin. Changes to temperature and moisture will also lead to increases or decreases in the abundance of many disease vectors.

The feeding frequency of arthropod vectors may also increase with rises in temperature. Many vectors must feed twice on suitable hosts before transmission is possible - once to acquire the infection and once to transmit it. At the warmer temperature, the vector is more likely to take the two feeds on suitable hosts that are required for successful transmission. Transovially - infectable vectors need feed only once for successful transmission. Nevertheless, a higher feeding frequency may increase the number of feeds taken and thereby increase the likelihood of transmission. Lastly, there may be important effects of climate change on vector dispersal, particularly if there is a change in wind patterns. Wind movements have been associated with the spread of epidemics of many *Culicoides* and mosquito borne diseases.

Effects on epidemiology: Climate change may alter transmission rates between hosts by affecting the survival of the pathogen/parasite or the intermediate vector, but also by other, indirect, forces that may be hard to predict with accuracy. Climate change may be one of the forces that lead to changes in future patterns of international trade, local animal transportation and farm size - all of which may affect the chances of an infected animal coming into contact with a susceptible one. For example, a series of droughts resulted in pastoral communities moving their animals to graze in areas normally reserved for wildlife. This resulted in severe diseases in livestock. Climate change is bound to have further impacts on heat-related mortality and morbidity and on the incidence of climate-sensitive infectious diseases and these may be considerable. Climate variability impacts on food production and nutrition can affect susceptibility to diseases.

Factors influenced by climate change that could affect livestock diseases:

Molecular biology of the pathogen: Microbial pathogens mutate and respond to opportunities arising from change, high evolutionary rate of RNA viruses, amino acid substitutions leading to adaptation to a new efficient vector.

Biology of the vector (Snail, biting midges, ticks, mosquitoes, rodents etc): Expansion of the traditional vector, changes in vector abundance, vector/pathogen interaction, vector activity and survival of the pathogen in a vector population. Warmer winters might allow year-round development of *Oestrus ovis* and warmer, wetter conditions favour snail intermediate host.

Farming practice and land use: Effect of climate change on farming practice and land use is uncertain and affects nature and intensity of livestock farming and respond to extreme weather events. The increased occurrence of weather extremes favours faecal-oral pathogens like botulism, anthrax. An increase in grass growing season will increase outdoor time for livestock, decrease animal to animal contacts and decrease transmission of diseases between livestock but may increase transmission of diseases between wildlife and livestock. The increase in farming intensity will enhance adoption of housing facilities for feed and water as well as to protect livestock from heat stress. In another situation of increased flooding, there will be rise in livestock transportation. Under both situations there will be increased contact among animals with increase probability for transmission of diseases.

Climate and animal diseases

The effects of climate change on animal or non-vector borne disease has received comparatively little attention. Indeed, certain directly transmitted, food/waterborne and aerosol-transmitted diseases are also affected. A common feature of non-vector borne diseases affected by climate is that the pathogen or parasite spends a period of time outside of the host, subject to environmental influence. The diseases transmitted directly between animals in close contact (tuberculosis, brucellosis, CCPP, FMD, coccidiosis, rabies, rinderpest, salmonellosis and scrapie) have few reported associations with climate. Additionally, climate appears to be more frequently associated with the seasonal occurrence of non-vector borne animal diseases than their spatial distribution. By contrast, the associations of vector borne diseases with climate are equally apparent in time and space - a reflection of the strong influence of climate on both the spatial and temporal distributions of the intermediate vectors.

Foot and mouth disease (FMD): It is a highly contagious, viral disease of cloven-footed animals. Usually mode of transmission is contact between infected and susceptible animals or contact with contaminated animal products. However, it can also spread on the wind. The survival of the virus is low at relative humidity below 60% and wind-borne spread is favoured by the humid, cold weather.

Peste des petits ruminants (PPR): It is an acute, contagious, viral disease of small ruminants and transmitted mostly by aerosol droplets between animals in close contact. The appearance of clinical PPR is often associated with the onset of the rainy season or dry cold periods.

Blue tongue (BT): It is a viral disease of ruminants spread by biting midges. The study on integration of climate data into a disease transmission model showed suggests that climate was influencing the increase in outbreaks. Vector distributions are largely dependent on environmental variables such as temperature, moisture and wind. BT can be transported over hundreds of kilometres of sea by winds carrying virus-infected *Culicoides* vectors. If rainfall is low then increases in temperature will lead to a decrease in risk of BT outbreaks, and if rainfall increases, higher temperatures will lead to an increase in risk.

Pasteurellosis: *Pasteurella multocida* survive well outside the host in moist environments. It is associated with areas of high humidity and occurs during rainy seasons.

Anthrax: An acute infectious disease of most warm-blooded animals with worldwide distribution. *Bacillus anthracis* forms spores able to remain infective for 10-20 years in pasture. Temperature, relative humidity and soil moisture all affect the successful germination of anthrax spores, while heavy rainfall may stir up dormant spores. Outbreaks are often associated with alternating heavy rainfall and drought, and high temperatures.

Haemonchosis: It can cause significant economic loss in terms of reduced productivity. Survival of the eggs and larvae, until they are ingested by another animal, depends on temperature and moisture, under appropriate conditions of warmth and moderate humidity, the larvae can survive for weeks or months.

Fascioliosis: The disease is a particular problem where environmental conditions favour the intermediate host, lymnaeid snails. These conditions include low lying wet pasture, areas subject to periodic flooding, and temporary or permanent bodies of water.

Approaches for predicting the disease pattern with climate change

Correlative approach: Predictive models of species distribution, for both epidemiology and conservation, are often based on correlative ecological niche models. These models are based on Hutchinson's ecological niche theory where the current geographic distribution is used to infer the environmental requirements of a species. The current, past or future distribution of that species is then predicted based on these requirements. Insights into the biology of parasite dynamics should be used to systematically build the foundations of these models, and the most proximal environmental predictors should be chosen based on known ecological and physiological theory.

To date, correlative predictive models of helminthiasis have focussed on *F. hepatica* due to the close relationship between weather and fasciolosis outbreaks and the worldwide importance of fasciolosis as a zoonosis. There are a number of factors that made correlative modelling the preferred approach for determining diseases risk. Firstly, the existence of long term prevalence data facilitated the development of a statistical model Secondly, despite their complex life cycle, the distribution of pathogen is driven by simple proximal drivers - temperature, humidity, rainfall and water availability. Thirdly, their dispersal by wild hosts and speed of colonisation of new regions makes them ubiquitous where livestock are present across their fundamental niche. There are a number of disadvantages to applying this approach to climate change predictions. A prominent bottleneck to the development of correlative models is the lack of current or past parasite distribution data. The data used to train these models is usually opportunistic, passive surveillance data. Climate parameters are used according to which measurements and predictions are available, rather than those that are most pertinent to disease transmission. In order to build reliable models, purpose-driven active surveillance data is needed. As climate affects long term, large scale trends, these data must be collected over appropriate scales to observe these trends, rather than the patchy distribution visible at finer scales, which is likely to be a consequence of non-climatic factors. Despite their limitations, correlative models can still provide a first indication of how climate will influence helminth distribution, and identify where limited resources and targeted surveillance should be focused. Reliability of correlative models will ultimately be governed by the quality of data used for model training and validation, the statistical methods employed, the ecological and physiological knowledge on which inclusion of proximal variables is based, and discrepancies between the realized and fundamental niche.

Mechanistic approach: Mechanistic models are based on detailed knowledge of the physiology of the species and attempt to replicate the underlying mechanisms that drive the species' response to environmental variables. Given sufficient understanding of the parasites physiology, these models can be employed to predict changes in prevalence. However these models have not been used to assess the impacts of climate change on helminth transmission.

One element of mechanistic modelling that makes it well adapted in a changing climate is that it is less prone to extrapolation problems than correlative models. The mechanistic approach does not rely on relationships between climate variables that may cease to exist under future climate change, making them less prone to breaking down when tested outside current observation limits. Extrapolated predictions for novel climates may prove to be unreliable if the response curves are not fully determined, hence empirical data on survival and development under conditions beyond a parasite's current climatic ranges are required. The severity of helminth infections is often dependent on intensity, rather than prevalence. The economic and welfare implications of outbreaks would be difficult to evaluate using a correlative approach, as data availability typically constrains these models to only look at prevalence. If data on adult worm burden are available they are often based on indirect measures such as faecal egg count. It is more feasible to include models of adult worm burden within a mechanistic framework. Although mechanistic models can predict changing intensity, the relationship between helminth burden and host production losses is non-linear; a doubling of infection intensity does not lead to a doubling of production loss. A deeper understanding of the relationship between parasite burdens and potential production losses is still required.

The survival of larvae on pasture is largely driven by climate, but helminth population dynamics are governed by density dependent process and it is vital that these processes are incorporated (e.g., host acquired immunity), as more larvae on pasture do not necessarily translate to higher parasite burden in the livestock. Models that do not take the overdispersed parasite distribution into account are likely to overestimate burden. Future changes in grazing season, stocking density, host behaviour and host resistance may affect the aggregation of parasites at the suprapopulation level. Models that incorporate the changing distribution of the suprapopulation would also allow identification of scenarios where individuals within a flock are at risk from heavy infections, thus addressing economic and welfare concerns. Recent empirical work on how livestock parasites respond to changing climatic variables should facilitate their development and parameterisation. For example, the correlation between the timing, distribution and quantity of rainfall and *H. contortus* development have been investigated and threshold rates of precipitation and evaporation required for survival of *H. contortus* larvae to the infective stage have been determined. These studies demonstrate that there are quantitative data on the effects of climatic variables on physiological processes, which can be used to parameterise mechanistic models. In addition to altered temperature and precipitation, changes in UV reaching the extra-mammalian stages will also vary with changing climate (due to e.g., varying cloud cover, changes in seasonality of infection). Larval mortality rates on pasture increased by up to 100 times due to exposure to UVA light equivalent to the maximum levels expected for a summers day. Mechanistic models provide a powerful tool in predicting the influence of climate change on helminth risk. They are comparatively robust under spatio-temporal extrapolation and can be developed to answer complex questions.

Predicted effects of climate changes on parasites: The effect of rainfall and temperature variation on predicted effects of parasites is summarized in table 1.

Table 1. Predicted effects of climate changes on parasites

Parasites	Rainfall		Temperature	
	Increase	**Decrease**	**Increase**	**Decrease**
GI Nematodes	Increased release of larvae during summer Decreased risk due to flooding during winter/ spring	Decrease risk due to drought conditions in summer Increased risk due to longer winter / spring	Rapid larval development, increased generation intervals and increased disease risk in summer	Slower larval development in summer Increased larval survival in winter / spring

			Decreased larval survival in winter / spring	
Lungworms	Increased larval survival and release, greater survival of intermediate hosts in all seasons	Decreased risk due to low numbers of larvae and lower transmission levels in summer	Decreased survival of larvae and intermediate hosts in hot dry summers Increased mollusc activity in winter	Slower larval development in summer
Tapeworms	Reduce risk in summer due to heavy rainfall	Hot and dry summers reduce risk	Increased risk due to increased numbers of oribatid mite in summer but hot and dry summers reduce risk	Reduced mite activity and transmission in summer
Fluke	Increased risk of transmission, creation of snail habitats and greater snail survivability in all seasons; greater risk in subsequent year	Decreased risk of transmission, loss of snail habitats and reduced snail survivability, reduced risk in subsequent year	Increased mollusc activity and survival, greater risk in spring	Cold winters decrease survivability of snail populations; less risk in spring
Coccidiosis	Wet weather may precipitate stress and disease	Decreased oocyst development, decrease risk	Increased oocyst development, increase risk	Cold weather may precipitate stress and disease
Mites, Lice, Keds	Increases risk of disease and spread in winter		Decrease in survivability of pathogens	
Flies	increased diarrhoea and odours and risk of strike	Dry fleece less attractant, reduced risk	Increased risk due to extended fly season	Reduced fly season and risk
Ticks	Increase in humidity and bio-habitats, increase and spread of ticks	Decrease in humidity, reduced tick activity and survival through desiccation	Hot dry conditions reduce activity and survival	Reduced risk of establishment

Bioclimatographs and epidemiology of Haemonchus contortus in India a study at CSWRI, Avikanagar

Over the years due to change in climate, grazing resources, rearing practices and intensive use of drugs, there is dramatic change in parasite prevalence, intensity and biology. In view of challenges in management of worms *vis-a-vis* anthelmintic resistance, now it is general consensus among researchers to shift prime target from adult parasite in host to exogenous stages in environment with the main aim to break life cycle of parasite. The interaction between climate and biology of parasite in the form of bioclimatographs and simulation forecasting systems strengthen our tool box in combating the menace caused by gastrointestinal parasites.

Weather, climate and supra-population of parasites: The role of weather and climate in the distribution and prevalence of nematodes are different. Weather is a composition of atmospheric conditions like temperature, barometric pressure, precipitation, humidity, wind direction and velocity, sun light, sunshine hours, cloud cover etc at a particular time. Climate is the sum of weather conditions over a larger period of times. It determines which nematodes are generally found in a locality, while weather determines which one can develop and infect their host at a particular place at a particular time of a particular year. To avoid confusion and contradictory conclusions, it is necessary that these two variables must be distinguished in assessing their effect.

Bioclimatographs: These explain the distribution in space and time of larval nematodes on pasture and represent the first rational attempt to utilize climatic observations to explain important features of epidemiology of helminthic diseases. Initially climatographs were used to observe the effect of temperature and precipitation on development and survival of supra-population of parasites. These are of value in predicting the general pattern of parasitism to be found in locality in question.

Bioclimatographs based on climatic data from 1991 to 2011: In order to determine the existence of favourable climatic conditions and suitable time periods for development, survival and dissemination of exogenous stages of *H. contortus* and *Trichostrongylus* spp. on pasture, bioclimatographs for different states of the country were constructed using av. monthly T_{max} v/s av. monthly TRF and av. monthly T_{min} v/s av. monthly RH, respectively. The state-wise climatic data for the period from 1991-2011 were obtained from National Initiative on Climate Resilient Agriculture (NICRA) project in operation at Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad. The data were pooled for each state and the monthly means were utilized for the study. Based on these bioclimatographs, the region-wise favourable periods for translation of parasites are presented in table 2.

Table 2. Region-wise favourable periods for translation of parasites in India

Region	State	*H. contortus*	*Trichostrongylus spp*
Sub-Temperate Himalayan region	J&K	Jan - Apr, Jun - Late Sep	Feb-Late Apr, Mid Sep-Late Nov
	Himachal Pradesh	Jan - Oct	Mid Feb - Late Nov
	Uttarakhand	Mid Feb - Oct	Mid Mar - Mid Oct
North Eastern Hill region	Sikkim	Late Feb - Nov	Whole year except Jul - Aug
	Assam	Feb - Mid Oct	Early Oct - Apr
Eastern region	Odisha	Early Apr - Nov	Nov - Feb
	Jharkhand	Late Apr - Mid Oct	Mid Jan - May, Sep - Dec
	Bihar	Late Mar - Mid Sep	Mid Oct - Late Mar
	West Bengal	Jun - Mid Oct	Early Oct - Mid Mar
North-Central region	Uttar Pradesh	Jun - Late Sep	Late Sep - Mid Mar
	Haryana	Mid Jun - Mid Oct	Feb - Mid Apr, Mid Sep- Mid Nov
	Punjab	Mid May - Late Sep	Feb - Mid Apr, Mid Sep- Mid Nov Oct - Apr
	MP	Jun - Oct	Mid Oct - Mid Mar
	Chhattisgarh	Jun - Oct	
Western region	Arid Rajasthan	Jul - Late Aug	Oct - Early Mar / Apr in all states The period was marginally longer in Gujarat state
	Semi-arid Rajasthan	Jun - Early Sep	
	Gujarat	Late May - Late Sep	
	Maharashtra	Mid May - Mid Oct	
Southern region	Kerala	Mid Mar - Mid Nov	NIL
	Andhra Pradesh	May - Mid Oct	Nov - Feb
	Karnataka	Early Apr - Late Oct	Sep - Mar
	Tamil Nadu	Mid Mar - Mid May, Mid Aug-Dec	Dec - Late Feb

Decade-wise bioclimatographs and variation in favourable periods for development of H. contortus: In order to prepare bioclimatographs for different states of India, the data available on website of Indian Meteorological Department were utilized. The data for each state were pooled and monthly means were calculated for each decade staring from 1901-10 to 1990-2000. The extent of decade-wise variation in favourable periods for development of *H. contortus* in different zones/ states was determined by visual assessment of bioclimatographs and summarized in table 3.

Real-time validation of bioclimatographs and epidemiology of gastrointestinal nematodes in livestock of India

To validate the predictions made by bioclimatographs (constructed from different set of climatic observations), the real-time data generated under All India Network Programme on Gastrointestinal Parasitism by different centres in various agro-climatic regions of country were utilized. Attempts are being made to compare bioclimatographs for *H. contortus in whole of India* and their real-time validation is summarized in table 4. Real-time observations of some of the AICRP centers are further detailed as under:

CSWRI, Avikanagar (Rajasthan): Incidence of strongyle worms in Rajasthan ranged from 29.37% (March) to 69.27% (June) and remained >50.0% during the period from June to October without any major zonal variation. The overall monthly intensity of strongyle infection varied from 72 (March) to 792 epg (September). The mean epg counts remained higher from June to September. On community grazing area, the pasture larval burden starts rising from June and reached to the maximum in August and declined thereafter to zero level during April. The pasture larval burden was higher during July-August in semi-arid and during August-September in arid region. The dynamics of strongyle larvae on coproculture exhibited predominance of *H. contortus* in both the regions of Rajasthan with an overall higher proportion (>80.0%) from April to October. The proportion of *Trichostrongylus* spp. was found to increase moderately from December to January in semi-arid and from December to April in arid regions.

ICAR Research Complex for NEH region, Gangtok (Sikkim): Monthly incidence of gastrointestinal nematodes in Sikkim was quite low in both cattle and yak and varied from 21.95% (February) to 32.89% (June) in cattle and from 12.27% (May) to 22.91% (October) in yaks. However, in goats it ranged from 27.65% in January to 77.59% in September. The faecal egg count variation ranged from 48.17 (January) to 355.26 epg (August) in cattle, while the same for yaks and goats ranged from 24.66 (May) to 130.06 epg (September) and 130.15 (January) to 2240.32 epg (September), respectively.

Table 3. Decade-wise variation in favourable periods for development of *H. contortus* in different zones/ states

Region	Observations based on decade-wise bioclimatographs
Sub-Temperate Himalayan region	A rise of around 2ºC in average monthly temperature in all the months during 1991-2000 compared to other decades, good precipitation during Dec - Mar/Apr, first favourable period- Jan to Feb/Mar during 1901-1950, later on initiation of first spell of favourable conditions Feb to mid Feb, second period extends from May to Sep, no major variation in the terminal period of observation, where favourable climatic conditions lasted, practically no gap between two favourable periods appreciable over the last four decades and favourable conditions existed for the larval translation from mid Feb to late Sep/Oct, regular occurrence of rainfall (>50 mm) with temperature ideal during spring might be responsible for occurrence of spring-rise phenomenon. A progressive decline in the period of unsuitable conditions during summer was observed in J&K. Over the decades In HP, period suitable for translation remained more or less similar (FebOct). In Uttarakhand, two spells (Jan/Feb to Mar, Apr/May to late Sep/Oct) of suitable conditions were observed (except during 1981-2000).
North Eastern Hill region	A moderate rise in average monthly temperature over the years during winter season, favourable period: mid-Feb to Dec (1901-10), Feb to Nov (1921-80), mid- Jan to Nov (1980-90), whole year (1990-2000). The state-wise analysis exhibited that in Sikkim, though there is relative decrease in monthly T_{max} and an increasing trend in monthly T_{min}

	over the decades (particularly during Oct-Nov), favourable period remained almost similar from late Feb/early Mar to late Oct/Nov.In Assam, mean monthly T_{min} increased slightly during winter and suitable period ranged from mid-Feb to mid-Oct in the initial phase. Later on, there was a shift from mid-Feb to mid-Jan lasting till Feb, however, the end period (Oct) remained unchanged. A bilateral expansion of suitable period (from Feb to late Jan and from Nov to Dec) during later part of the century in Manipur. A rise of > 1 ºC in average monthly T_{max} maximum during Oct-Dec and Feb-Apr lead to progressive increase in favourable period over the decades (Mar-Nov during 1901-10, Feb-Dec during 1990-2000)in Meghalaya. There was reduction in length of suitable period from mid Mar-late Oct (1991-2000) to late Jan-late Oct (1981-90) in Mizorum.
Eastern region	Moderate (1-2 ºC) rise in average monthly T_{max} in all the months over the decades, however, it did not affect the optimal range of temperature required for translation of exogenous stages of *H. contortus* and suitable period ranged from Apr to Oct/Nov. In Odisha, Suitable period remained more or less similar with minor variation (Apr/May - Oct/Nov). An unilateral expansion of favourable period from late May to mid Mar/Apr was observed after 1970 in Jharkhand. In Bihar, decline in length of favourable period (from mid May-mid Oct to mid May-late Sep) during 1921-1940 was attributed to significant rise in mean monthly T_{max} (by >2-3 ºC) during Apr-May. Over the century the climatic data remained largely unchanged and favourable period existed from Feb/Mar to Oct/Nov in West Bengal.
North-Central region	Over the entire span of 100 years, the onset of the favourable period remained unchanged, the month of May marked the beginning of the favourable conditions and it remained almost constant at mid May, the favourable conditions seem to cut-short by a fortnight from Oct (1901-1940) to late Sep (1941-2000). In Haryana and Punjab, there was marginal decline in mean monthly T_{max} from Jun to Mar over the decades with no evident decade-wise variation in suitable periods (Jun-Sep/Oct). Decade-wise more or less similar pattern was observed in occurrence of suitable conditions (May to Sep/Oct) in MP and Chhatisgarh. In UP, the onset of suitable conditions was from late May (1901-1970, except during 1911-20) to mid May (1971-2000).
Western region	Over the decades, the mean monthly T_{max} showed progressive increase from Nov to Mar, suitable conditions persisted from May to late Sep, except in 1951-60 where it extended up to Oct mainly due to occurrence of >50 mm monthly TRF in Oct. The suitable conditions persist from mid Jun to late Aug/Sep and from late May to late Sep in arid and semi-arid Rajasthan, respectively. The suitable conditions extends from mid May to late Sep except during 1941-1950 (Jun to late Sep) in Gujarat. In Maharashtra, The favourable conditions usually exist from May to Oct and found to extend up to Nov/Dec during 1931-80 mainly due to occurrence of higher monthly TRF during these months.

Southern region	Progressive rise of around 2 ºC in average monthly T_{max} over the decades for all the months, usually TRF was > 50 mm from Apr to Nov, favourable conditions existed from late Mar/early Apr to mid Nov/Dec with minor variation among the different time periods over the decades. Favourable period for larval translation was from Mar/Apr to Nov/Dec in Kerala, early May to Nov in Andhra Pradesh, late Mar/Apr to Nov in Karnataka. In plains of Tamil Nadu two favourable periods from mid Mar to Apr and from mid Jun to mid Nov during 1951-60 due to occurrence of low rainfall in May-Jun, in rest of the period, favourable conditions exist from late Mar/Apr to late Nov/Dec. In hill area of TN, for a short spell (Jan-Feb), the conditions remained largely unsuitable during some decades; other-wise the whole year was conducive for propagation of *H. contortus.* In Lakshadweep during initial two decades, favourable conditions existed from mid Mar to late Nov but later on, they shifted from early Apr to Dec.

Table 4. Comparison of bioclimatographs for *H. contortus* and their validation

State	Prediction based on bioclimatographs			Observed parasitological observation			
	Decade-wise	**1991-2011**	**2001-11**	**Higher incidence**	**Higher intensity**	**Higher PLB**	**Predominance on culture**
Semi-arid Rajasthan	Jun - L. Sep	Jun - M. Sep	Jun - M. Sep	Jun-Oct	Jun-Sep	Jul-Sep	Apr-Oct
Arid Rajasthan	L. Jun- E. Sep	Jul -L. Aug	L. Jun - Sep	Jun - Oct	Jun - Sep	Mar & Jun-Sep	Apr - Oct
Sikkim	Mar - Nov	L. Feb - Nov	Feb -M. Nov	Mar- Nov (G) Jun-Sep (C) Jun-Oct (Y)	May-Nov (G) Jun-Dec (C) Aug-Oct (Y)	Aug-Nov	Jun-Nov
Meghalaya	Feb-Nov	-	L. Feb- E. Nov	Mar-Sep (G) May-Dec (C)	May-Sep (G) May-Nov (C)	Apr- Oct	Whole year
West Bengal	Mar- Oct, Jun- M. Oct	Apr-L. Oct	E. Mar / Apr - L. Oct	Jun-Nov (SR) Jul-Dec (LR)	Jun- Nov (SR) Jul-Oct (LR)		
Uttarakhand	Jan-L. Mar May-Nov	L. Feb-Oct	May-Dec (T) L. Jan-M. Feb / Apr- L. Sep (H)	Feb, Apr & L. Jun-Nov (S) Whole yr (G)	Apr-Jan (S), May-Nov (G)	Feb-Mar, Jul-Nov	
UP	Jun-L. Sep	Jun- L. Sep	E. Jun-L. Sep	Jul-Mar	Jun-Oct		
Tamil Nadu	L.Mar-Dec (P) M.Feb-M Jan (H)	L.Mar- E. May & M. Aug-Dec (P)	Mar-May, Aug-Dec (P) M.Feb-Dec (H)	Jun - Feb Jun - Feb			
MP	L.May- L. Sep	Jun L. Sep	L. May-L. Sep	Jun-Nov/ Dec	Jun/Jul - Oct/Nov	Jun - Nov	Mar/Apr - Aug/Sep

(G-Goat, S-Sheep, C-Cattle, B-Buffalo, Y-Yak, SR-Small ruminants, LR-Large ruminants, P-Plains, H-Hlls, T-Tarai)

On community grazing area, the pasture larval burden ranged from 5.33 L_3 / kg of grass (January) to 25.89 L_3 / kg of grass (September). The composition of strongyle larvae on coproculture exhibited predominance of *H. contortus* in Sikkim for the period from June to November. However, the proportion of *Trichostrongylus* spp. remained almost similar throughout the year.

ICAR Research Complex for NEH region, Barapani (Meghalaya): Real-time profile in Ribhoi / subtropical to mild tropical hill zone revealed that the monthly incidence of strongyle worms ranged from 14.65% (March) to 45.51% (August) in cattle and from 29.85% (November) to 61.23% (July) in goats. Monthly intensity of infection ranged from 174.19 (January) to 724.78 epg (July) in cattle and from 308.72 (December) to 2015.54 epg (June) in goats. The pasture larval burden varied from 79.00 L_3 / kg dry matter of herbage in January to 2835.10 L_3 / kg dry matter of herbage in July. The pasture larval burden is found to increase from March with a continuous build-up till October. The composition of strongyle larvae on coproculture exhibited predominance of *H. contortus* throughout the years. The second parasite of importance in Meghalaya is *Oesophagostomum* spp.

WBUAFS, Kolkata (West Bengal): Real-time profile showed that the incidence of strongyle worms vary from 39.05% (May) to 55.70% (September) in cattle, 39.69% (May) to 56.78% (September) in buffalo, 65.26% (February) to 81.28% (September) in goats and from 64.29% (May) to 83.35% (September) in sheep. Almost similar pattern was noticed in both new alluvial and coastal zones. The intensity of infection ranged from 180.83 (May) to 349.7 epg (August) in cattle, 151.25 (May) to 312.92 epg (September) in buffalo, 556.25 (April) to 899.58 epg (September) in goats and from 422.50 (May) to 889.17 epg (September) in sheep. Similar to the incidence pattern, the intensity of strongyle infection also show no significant variation between the zones and across all the species of livestock.

GBPUAT, Pantnagar (Uttarakhand): Real-time profile revealed that overall incidence of strongyle worms vary from 11.3% (February) to 18.4% (October) in cattle, 11.6% (January) to 19.8% (May) in buffalo, 58.7% (March) to 76.6% (September) in sheep and from 61.0% (March) to 76.4% (September) in goats. There is a minor variation with regard to the period of higher incidence in all the three agro-climatic zones. The overall intensity of infection (EPG) range from 12.7 (February) to 52.1 (May) in cattle, 10.8 (January) to 27.6 (May) in buffalo, 212.0 (March) to 815.7 (September) in sheep and from 248.9 (March) to 819.0 (May) in goats. Irrespective of different agro-climatic conditions of Uttarakhand, the dynamics of strongyle larvae on coproculture exhibit predominance of *H. contortus* throughout the years. Regional variation is also evident as relatively higher proportion of *Trichostrongylus* spp. is seen in the hilly region. The pasture larval burden is generally low during December and January which it seems to increase slightly during February-March and declined thereafter up to June. Higher pasture infectivity is seen during July to November. In hilly region, it is lowest in May and tends to increase gradually to peak in October. In tarai region, higher level of pasture infectivity is noticed from July to October.

IVRI, Izatnagar (UP): Real-time profile showed that incidence of strongyle worms vary from 44.15% (May) to 66.53% (August) in sheep and from 41.18% (May) to 61.13% (August) in goats. In Rohillkhand region, it varies from 41.66% (May) to 86.77% (March) in sheep and from 32.36% (May) to >70% during December-March in goats. An additional peak of higher incidence is also seen during August in sheep flocks of Rohillkhand region. The intensity of strongyle infection (EPG) appears to range from 154.70 (March) to 420.80 (September) in sheep and from 190.41 (March) to 494.64 (August) in goats. In Rohillkhand region, it is the lowest (187.43) in March, which increases gradually to reach the first peak (504.41) in September followed by a second peak

(543.49) in January in sheep. However, in goats only a single peak of infection (704.87) is noticeable in October. The overall dynamics of strongyle larvae on coproculture in U.P. show a predominance of *H. contortus* throughout the years in both sheep and goats. The proportion of *Trichostrongylus* spp. is higher (>10.0%) during the period from February to May in sheep and from January to June in goats. The proportion of *Oesophagostomum* spp. in faecal culture remains more or less similar (<10.0%) in all the months in both the species. On community grazing area, the pasture larval burden vary from 359.70 L_3 / kg dry matter of herbage (November) to 737.24 L_3 / kg dry matter of herbage (September). In Rohillkhand region, it ranges from 357.37 L_3 / kg dry matter of herbage (May) to 742.86 L_3 / kg dry matter of herbage (January).

TANUVAS, Chennai (Tamil Nadu): Real-time profile showed that incidence of strongyle worms is marginally higher in small ruminants in all the seasons compared to large ruminants. The incidence is highest during south-west monsoon (June to August) which is on the lower side during north-east monsoon (September to November) followed by winter (December to February) and the lowest during summer (March to May). Among different agro-climatic conditions, the pattern of incidence is more or less similar, however the magnitude seems to vary with the highest from Cauvery delta region. The intensity of infection is marginally higher in small ruminants in all the seasons compared to the large ruminants. The intensity of infection is generally high during south-west monsoon followed by north-east monsoon followed by winter and the lowest during summer. The overall dynamics of strongyle larvae on coproculture showed predominance (> 60%) of *H. contortus* throughout the year.

MPPCVV, Jabalpur (MP): Real-time profile showed that incidence of strongyle worms ranged from 19.15% (May) to 45.59% (July) in cattle, 17.16% (May) to 45.12% (August) in buffalo, 43.97% (April) to 88.52% (August) in sheep and 31.44% (May) to 72.45% (October) in goats. There is a minor variation with regard to the period of higher incidence in all the three agro-climatic zones. The intensity of strongyle infection (EPG) varied from 79.36 (May) to 546.73 (August) in cattle, 85.89 (April) to 459.78 (July) in buffalo, 238.13 (February) to 1228.72 (July) in sheep and from 255.54 (April) to 1293.95 (September) in goats. A minor variation in the period of higher intensity is also evident in all the three agro-climatic zones. In large ruminants, higher intensity (> 200) is seen from June to October in the eastern plateau, June to November and March in the central plateau and from July to October in the eastern plateau. In sheep, higher intensity of strongyle infection is seen from July to October in the central plateau and July to November in the eastern plateau. In goats, higher intensity is observed from June to November in the eastern plateau, July to October in the central plateau and during July and September in the eastern plateau. The dynamics of strongyle larvae on coproculture showed the predominance of *Haemonchus* spp. throughout the year. The other strongyle nematodes of economic importance are *Trichostrongylus spp.* and *Oesophagostomum* spp. The regional variations in monthly proportion of different strongyle larvae on coproculture were non-significant. On community grazing area the pasture larval burden ranged from 29.0 L_3 / kg dry matter of herbage in May to 1634.7 L_3 / kg dry matter of herbage in July. The regional pattern in pasture larval burden exhibited that it was higher during the period from June to August in Eastern plateau and hills, from June to November in Central plateau and hills and from July to November in Western plateau and hills region.

Conclusions

- Livestock represent the major stores of wealth that are mobilized in response to climatic shocks
- For endemic pathogens, the main effect of climate change may be through increased flooding and over-grazing
- For exotic diseases, the main effect of climate change may be an increase in the geographic range and an increase in competence of the non-vertebrate vector
- Consideration on the rights of indigenous, migratory and pastoral people in formulation of strategies
- Need to develop a comprehensive plan (e.g. health, disaster reduction) to deal with the migration of disease due to climate change
- Develop positive animal welfare contingency plans to control zoonoses caused by climate change
- Use vaccinations as a preventive measure where appropriate in regions where disease is endemic
- Limit transportation of live animals
- To counter the adverse effect of climate change on animal production and health, human intervention for physical modification of the environment and improvement in nutritional management practices would be additionally required
- By combining improved empirical data and refined models with a broad view of the livestock system, robust projections of disease risk can be developed

CLIMATE RESILIENT SMALL RUMINANT PRODUCTION IN DRYLANDS

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Introduction

Small ruminant (goats and sheep) production systems plays a vital role in sustenance of livelihoods of rural poor of dryland agro-ecosystem and especially important to landless and small/marginal farmers, where crop production is a risk-prone enterprise due to uncertain rainfall and frequent droughts. It contributes 15 to 27 % of family income of smallholders and provides gainful employment of 180 to 330 man-days per annum depending on the size of the flock (Misra *et al.,* 2000). Most of the small ruminant population (>70%) is in arid and semi-arid areas of western region and southern peninsular region of India. These arid and semi-arid areas are low in biomass production, high climatic variability and dearth of water. The productive potential of small ruminants in these areas is influenced by high grazing intensity, exposure to harsh climatic conditions (high ambient temperatures) and long distance walking in search of grazing resources and limited wholesome water resources. In the climate changing scenario, thermal stress along with feed and water scarcity is going to be the major impeding factors affecting productivity and wellbeing of small ruminants. There is an urgent need to formulate strategies to overcome these problems and improve the productivity of small ruminants in order to meet the growing demand of meat and meat products in the country. The following are some of the climate resilient small ruminant production strategies under rural conditions in drylands.

Nutrition management strategies

Animal production within the mixed farming systems is predominantly dependent on available feed and fodders resources including grazing. Feeding and nutrition are the primary constraints for optimum animal production in drylands. During lean/drought periods, shepherds migrate along with their animals in search of fodder. This migration sometimes creates social conflicts with local people for available scarce fodder resources. Further, this could invite new diseases and parasites which pose health problems in small ruminants. Protein is the first limiting nutrient in many grazing forages, particularly in drylands, and protein availability declines in forages as the plant matures towards the end of winter season. When daytime temperatures and humidity are elevated, special precautions must be taken to keep small ruminants comfortable and avoid heat stress. An adequate supply of cool, fresh and clean water is essential to keep the animal's internal temperature within the normal limits and minimize the effect of heat stress. Allow for grazing early in the morning or later in the evening to minimize stress. Monitor mineral feeding closely during periods of high temperatures. Mineral bricks should be made available 24 hours during the summer. Adequate Copper, selenium, zinc, and phosphorus should be supplied through mineral mixture. Maintaining an adequate selenium level ensures the immune system is prepared to fight off respiratory infections. Concentrate mixture (18% DCP and 70% TDN) prepared with locally available feed ingredients should be supplemented @ 1% body weight to all categories of animals. When no green fodder is available, addition of vitamin supplement in concentrate mixture helps in mitigating heat stress. Further, in severe summer or famine conditions, energy intake becomes less compared to expenditure as the animal has to walk more distance in search of grazing resources which are poor in available nutrients. Hence, all the animals should be maintained under intensive system with cut and carry of available fodder. The concept of complete feed using crop residues (60%) and concentrate ingredients should be promoted for efficient utilization of crop residues like redgram stalk, etc. Further, productivity and profitability from small ruminants can be increased by strengthening feed and fodder base both at village and household level with the following possible fodder production options.

a. Revival of common property resources (CPRs): It is estimated that 60% of the total feed requirements of small ruminants are met by the CPRs. There is no control over the number of animals allowed to be grazed, causing severe damage on the re-growth of number of favourable herbaceous species in grazing lands. Thus causing severe impact not only on herbage availability from CPRs but also quality of herbage affecting the productivity of animals adversely; hence there should be some restriction on number and species of animals to be grazed in any CPR as a social regulation. CPRs need to be reseeded with high producing legume and non-legume fodder varieties at every 2-3 years intervals as a community activity. Further, grazing restriction till the fodder grows to a proper stage and rotational grazing as community decision would improve the carrying capacity of CPRs.

b. Intensive rainfed fodder production systems: Growing of two or more annual fodder crops as sole crops in mixed strands of legume (Stylo or cowpea or hedge Lucerne, etc) and cereal fodder crops like sorghum, ragi in rainy season followed by berseem or Lucerne etc., in rabi season in order to increase nutritious forage production round the year.

c. Short duration fodder production from tank beds: Due to silt deposition, tank beds are highly fertile and retain adequate moisture in the soil profile for cultivation of short season fodder crops like sorghum and maize during winter and or summer.

d. Integrated fodder production systems: Fodder crops like *Stylo hamata* and *Cenchrus ciliaris* can be sown in the inter spaces between the tree rows in orchards or plantations as hortipastoral and silvopastoral systems for fodder production.

e. Fodder production systems through alley cropping: Alley cropping is a system in which food/fodder crops are grown in alleys formed by hedgerows of trees or shrubs (*Leucaena leucocephala, Gliricidia, Calliandra, Sesbania etc*.). The essential feature of the system is that hedgerows are cut back at planting and kept pruned during cropping to prevent shading and to reduce competition with food crops. The main objective of alley cropping is to get green and palatable fodder from hedgerows in the dry season and produce reasonable quantum of grain and stover in the alleys during the rainy/cropping season. This calls for cutting back (lopping) of hedge rows during the dry season. A welcome feature of alley cropping is its ability to produce green fodder even in years of severe drought.

f. Perennial non-conventional fodder production systems: Perennial deep rooted top feed fodder trees and bushes such as *Prosopis cineraria, Hardwickia binata, Albizia* species, *Zizyphus numularia, Colospermum mopane, Leucaena leucocephala, Azadirachta indica, Ailanthus excelsa, Acacia nilotica* trees and modified plants of cactus are highly drought tolerant and produce top fodder should be planted in CPRs and farm bunds. Sowing of inter spaces of tree rows with drought tolerant grasses such as *Cenchrus ciliaris, Cenchrus setigerus* and *Lasirius sindicus etc*., further enhance forage production from waste lands.

g. Fodder production systems in homesteads: *Azolla*, a blue green algae which has more than 25 % CP and a doubling time of 5-7 days can be grown in pits at backyards depending on the number of milch animals owned by the farmer. *Azolla* yield is much more than the perennial fodder varieties like APBN-1/CO-3 etc and is around 1000 MT per ha at the rate of 300 gm/m^2/day even after taking into account of unused space between two beds. It is more nutritious than the leguminous fodder crops like lucerne, cowpea, berseem, etc and can be fed to small ruminants after mixing with concentrate mixture at the ratio of 1:1.

h. Hydroponic Fodder Production Systems: By this method, fodder can be produced in large quantities within 8 days from seed to grass for all livestock. These include barley, oats, lucerne and rye grass. Growing grass fodder systems hydroponically is now becoming popular in drought prone areas. Hydroponic fodder production however requires large investment in the form of a commercial greenhouse, continuous supply of water and power. The state governments must encourage entrepreneurs to take up this activity in chronically drought prone areas.

i. Intensive irrigated fodder production systems: High yielding perennial (hybrid Napier varieties like CO-3, CO-4, APBN-1 etc.,) and multicut fodders varieties (MP Chari, SSG etc.) could be choice of fodder crops under this system as it efficiently utilizes limited land resources and other agricultural inputs for getting maximum forage per unit area. It can be done where ever water is available and transported to deficit areas and fed to small ruminants.

j. Year-round forage production systems: Cultivation of a combination of suitable perennial and annual forages for year round nutritious fodder supply using limited water resources. It consists of growing annual leguminous fodders like cowpea or horse gram, etc. inter-planted with perennial fodders like Co-3, CO-4, APBN-1 varieties of hybrid Napier in kharif and intercropping of the grasses with berseem, Lucerne, etc. during rabi season.

k. Fodder production through contingency plan: During early season drought, **s**hort to medium duration cultivated fodder crops like sorghum (Pusa Chari Hybrid-106 (HC-106), CSH 14, CSH 23 (SPH-1290), CSV 17 etc.) or Bajra (CO-8, TNSC 1, APFB 2, Avika Bajra Chari (AVKB 19)etc.) or Maize (African tall, APFM 8 etc.) which are ready for cutting by 50-60 days and can be sown immediately after rains under rainfed conditions in arable lands during kharif season. If a normal rain takes place in later part of the year, rabi crops like Berseem (Wardan, UPB 110, etc.), Lucerne (CO-1, LLC 3, RL 88, etc.) can be grown as second crop with the available moisture during winter. In waste lands fodder varieties like Bundel Anjan 3, CO-1 (Neela Kalu Kattai), *Stylosanthes scabra,* etc. can be sown for fodder production.

In case of mid-season drought, suitable fodder crops of short to long duration as mentioned above may be sown in kharif under rainfed conditions. Mid season drought affects the growth of the fodder crop. Once rains are received in later part of the season, the crop revives and immediate fertilization helps in speedy recovery. If sufficient moisture is available, rabi crops like Berseem (Wardan, UPB 110, etc.), Lucerne (CO-1, LLC 3, RL 88, etc.) can be grown during winter. In waste lands fodder varieties like Bundel Anjan 3, CO-1 (Neela Kalu Kattai), *Stylosanthes scabra* etc., can be sown for fodder production.

As late season drought affects seed setting, normal short duration fodder crops may be sown. Avoid multicut fodder varieties under rainfed conditions. All the available fodder must be harvested before drying out to preserve nutritive quality. Depending on availability of moisture, rabi fodder crops especially low water requiring varieties of lucerne may be planted. Normal intensive fodder systems may be followed under irrigated conditions.

In case of complete or major failure of grain crops in Kharif, contingency strategies for ensuring fodder supplies include re-sowing with short to medium duration fodder varieties of millets, pulses or forage crops such as:

- Sorghum varieties / hybrids CSV-17 and CSH 14 in red soils; CSH 16, CSH 18 and CSH 21 in black soils
- Bajra - short duration varieties like Rajko, JB, PSB-2, GHB-526, HHB-67, ICMH-356, Shraddha, GK-1004 or medium duration varieties like GHB-558, Proagro-9443 and for late assured rain fall areas in light to medium soils varieties like AHB-251
- Finger millet - medium duration varieties like GPU 28, PR 202, HR 911 and Pusa Composite 612, MP 480 for second fortnight of July to first fortnight of August; short duration varieties: GPU 26, GPU 45, GPU 48 and Indaf 9 for late sown conditions from second fortnight of August to 20 September
- Maize African tall, APFM 8, PEHM-3 and FH-3077 which produce some grain and fodder
- Intercropping cowpea Varieties Bundel Lobia-1, CO 5, CO (FC) 8, IFC 8401, UPC 8705, DFC 1 and UPC- 625 after 8 to 10 rows of finger millet
- *Rabi* fodder crops like berseem (Mescavi, Wardan, UPB 110), Lucerne (CO 1, LLC 3, RL 88) should be sown in arable lands and tank beds.
- Current fallows should be used for fodder production by sowing short duration varieties of sorghum or bajra or ragi or maize or cow pea in *kharif* season and or berseem or Lucerne in rabi season.
- In wastelands, grasses like *Cenchrus ciliaris, C. setigerus, Chloris gayana, Panicum maximum, Desmanthus virgatus, Stylosanthes scabra* can be taken up to increase forage production.
- In areas that receive north east monsoon rains, multi-cut fodder varieties of sorghum (CO 27, Pant Chari-5 (UPFS- 32), COFS- 29 or pearl millet (Co-8) or maize (African tall) are recommended
- In areas that receive summer rains, fodder crops like cowpea and maize are recommended

Use of unconventional resources as feed

The available waste products form food industries like palm press fibre, fruit pulp waste, vegetable waste, brewers' grain waste and all the cakes after expelling oil etc., and thorn-less cactus should be used as feed to meet the nutritional requirements of animals.

Shelter management strategies

Small ruminants fully exposed to summer conditions had a higher respiration rate and a higher body temperature than sheep with access to shade (Nissim, 1987). Nevertheless, feed intake and water intake of non-sheltered animals was not different from that of sheltered ones and both maintained their body weight on medium quality hay. Apparent digestibility of organic matter, mean retention time of undigested feed in the rumen and in the entire digestive tract and water turnover rate was higher in the non-sheltered animals than in the sheltered ones (Nissim, 1987). Thus, productivity of sheep and goat is influenced by the type of shelter provided. The details of shelter management strategies are presented in a separate chapter.

Breeding management strategies

In drylands, with small flock sizes, large fluctuations in rearing conditions and management between flocks, and over time within a flock, lack of systematic livestock identification, inadequate recording of livestock performances and pedigrees, and constraints related to the subsistence nature of livestock rearing, the accuracy of selection will be much lower, resulting in even lower rates of genetic gain. However, locally adapted breeds are likely to be highly variable and the highest performing animals of such breeds can have great productive potential. Therefore, the screening of livestock populations previously not subjected to systematic selection is likely to give quicker results to provide high genetic merit foundation stock for nucleus flocks.

Cross-breeding with a more productive breed can yield faster improvement. However, an appropriate improver breed has to be available, which will adapt to the conditions where it is to be introduced. If it is a completely new introduction, it is better to conduct a trial and monitor the performance of crosses for a few years before undertaking large-scale cross-breeding.

Changing the breeding ram/buck for every 2-3 years (ram lamb exchange from other district herd) or artificial insemination with proven breed semen will help in enhancing the productivity. This may be supplemented with supply of superior rams through formation of nucleus herd at mandal/block level. Synchronization of breeding period depending on the availability of feed and fodder resources results in healthy offsprings and better weight gain. Concentrate mixture supplementation to breeding animals should be initiated atleast 1 month before breeding season and continued till the weaning of lamb/kid. Local climate resilient breeds of moderate productivity should be promoted over susceptible crossbreds.

Genetic improvement, to be successful, usually needs to be accompanied by improvements in nutrition, health and management.

Health management strategies

Increased prevalence of endemic diseases due to malnutrition is becoming a potential threat to the profitability of small ruminant farming in drylands during summer by bringing down the production and income. Hence, preventive vaccination against endemic diseases especially PPR, FMD should be given to small ruminants. Increase in humidity along with temperature would result in more of internal worm burden, hence deworming should be planned accordingly. Continuous rains may lead to more vector population and outbreaks of diseases like blue tongue and this needs proper hygiene and sanitation measures in sheds and surroundings. Small ruminants have every chance of getting intoxication due to consumption of toxic plants, which are green during summer/famine and also feeding spoiled/fungal feed ingredients. All this needs proper care of each animal during famine conditions. In case of severe heat stroke, oral rehydration therapy should be advocated along with feeding gruel mixed with jaggery and salt. Mapping animal disease outbreaks through advanced technology like GIS and providing updated information related to small ruminant management and health aspects through mass communication systems in the villages certainly facilitate knowledge empowerment of the stakeholders and containment of animal diseases in rural areas.

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SHELTER MANAGEMENT- A MEANS TO RESIST EXTREME CLIMATIC VARIABLES

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Introduction

Sheep are multi-faceted animal since they provide meat, wool, hide, milk, etc. to human beings. They form an important component of rural economy particularly in the arid, semi-arid and mountainous areas of the country. Sheep are dependable source of income to the shepherds through sale of wool and animals. They readily adapt to a wide range of climates and available feed supplies. Sheep also do not need expensive buildings to house and on the other hand require less labour than other kinds of livestock. In developed countries, sheep farming is on a large scale within fenced area whereas it consists of a large number of migratory small units in India. There is need to be an improvement in common pasture land and units, forest grazing and shift of migratory flocks towards stationary flocks by providing proper sheep housing in India. There is a continuous decrease of grazing land, forest and pressure for grazing from unproductive cattle and excessive increase of population of wild ruminants in certain areas are all exerting negative pressure on the growth of sheep. This demand for reorganized flocks to semi-migratory or stationary flock requires some kind of housing for sheep. About more than 20 million people in India are partially or fully dependent on sheep rearing. About two-third out of them in rural areas are engaged in sheep rearing for wool production, spinning, tanning etc. and others in rural and urban areas are engaged in meat production and distribution. This comparative advantage enforces rearing sheep in stationary flock even at higher cost and raising the prices of the sheep products.

Sheep husbandry in India

Sheep can be seen almost everywhere in India. But for production purpose mostly found in Rajasthan, Gujarat, Punjab, Haryana, Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu and Kamataka. In India, sheep are mostly reared on community or caste bound and hence the management practices they adopting are inherited from their ancestor.

In Rajasthan to overcome the adverse climate, the sheep keepers have adopted various types of sheep housing within their limited availabilities, ranging from primitive system to semi-migratory system. In the southern and north-eastern parts of the state, the flocks maintained are all stationary in habit and are grazed during the whole day on community fallow lands. In the evening they are brought back to home and are penned in mud huts prepared for the purpose. These typical low huts are always attached to the outer side of the owner's dwelling. The roofs are mostly seen to be thatched with long and rough grass. In northern and western parts, all the flocks are semi-nomadic or nomadic. In semi-migratory system the sheep are kept continuously on grazing for two days and kept at night in the open fields. Then they come back to their native village for watering. Here it is peculiar to note that the sheep are given drinking water only once in 48 hours. Lambs generally take their birth under the open sky. In Gujrat flocks are mostly stationary and in some cases semi-migratory. Semi-migratory flocks move only 6 -10 km from their village.

In Jammu & Kashmir migratory, semi-migratory and stationary type of husbandary are followed. Majority of the big flocks of the state are migratory. In winter from September to April they remain in the shivalik or submountain areas of Jammu. When summer starts in the month of May, these flocks migrate to the highland grazing pastures closer to them i.e flocks of Jammu migrate to the highlands of Jammu and that of Kashmir to Alpine pastures of Kashmir, whereas, smaller flocks of 10-20 sheep are reared under semi- migratory system. The flock are collected by one or two shepherds and grazed on the outskirt of the village pasture in the winter and taken to alpine pasture in summer. In stationary system, the flock size is very small and the flocks are maintained generally in the agricultural villages of the valley. In winter they are mostly stall fed and in summer as usually collected by some professional shepherd and grazed in the nearby forest grazing lands. In Himachal Pradesh and Uttar Pradesh also migratory, semi-migratory and stationary system are followed.

Housing

There are various housing and floor designs that can be used depending on the production system employed and local climate. Cost of construction, ease of cleaning, proper ventilation and drainage, and adequate lighting are important aspects to be considered in designing a house. During the dry season almost all village owners release their animals to roam around and look for feed by themselves. However, during the rainy season animals are either herded or tethered to prevent animals from destroying the crops. At night, small ruminants are either housed, tied under a shelter, tied without shelter, kept within an enclosure or just provided with a shelter. Management with respect to grazing confirms that small ruminants are kept extensively or in a low input system. The amount of shelter needed will depend on the climate, topography and the lambing system. An intensive system (Egan *et al*., 1976) may employ only 4 ha/1000 ewes during the critical period. An extensive system requires more shelter as ewes will not seek it unless recently shorn (Alexander and Lynch, 1976) thus exposing their lambs unless shelter is nearby.

The basic requirement of good animal housing is that it should alter or modify the environment for the benefit of animals and also protect them from predation and theft. Animal housing should buffer the animal from climate extremes to reduce stress allowing optimal animal performance in terms of growth, health and reproduction. The main climatic factors from which protection is needed are high and low ambient temperatures, environmental humidity, solar radiation, wind and rain. Additionally, houses are important in protecting feed and equipment from damage, in saving labour, and in aiding effective management, including breeding. Sheep and goat housing should meet animal requirements and serve a producer's needs at the lowest possible cost.

Traditional housing

Traditional sheep and goat housing is made of varying designs and construction materials depending upon local custom and availability of materials. Some main types of housing include:

- Housing at one corner of the main family house;
- An overhang attached to the roof of a house;

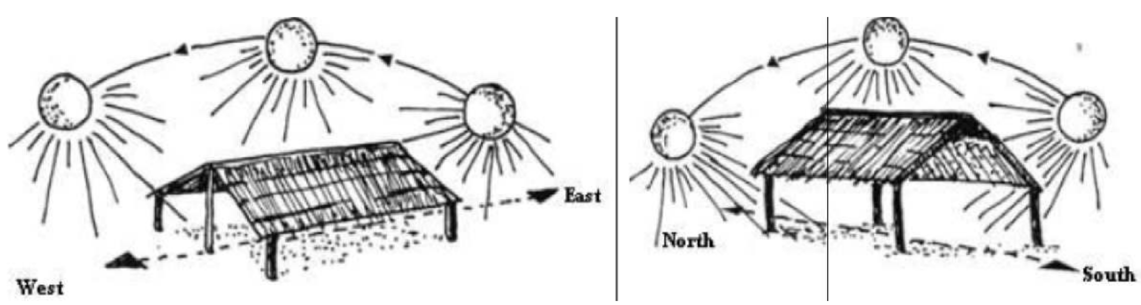
- Open yards with no roof
- In a basement under the family home
- Separate houses of thatched roofs
- Lambs and kids are, in some areas, kept in a dome made of bamboo or other locally available material. This prevents the young from straying or mixing with the flock, except during suckling. The dome is usually kept outdoors during the day if there is no rain.

Shortcomings: Traditional sheep shelters are usually poorly lit and have inadequate ventilation and drainage. There is always chance of outbreak of diseases in housing within the family. Housing animals in close quarters also encourages spread of external parasites, and bacterial and viral infections among animals.

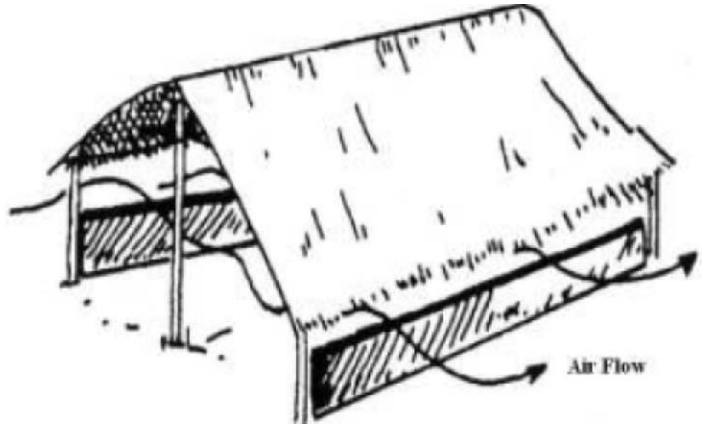
Types/designs of recommended housing options

Location of animal sheds: The location of the shed is important for animal comfort and safety. Sheep housing should be built near to the family house to keep an eye on the animals but far enough to minimize smell (at least 10 meters) and floor should be 1-1.5 m above the ground to prevent waterlogged. And always should be provision to expand.

Orientation for mitigating environmental stress: The orientation of the shed can be important depending on the climate. One can prevent the sun from heating up the stall too much by placing the longitudinal axis of the stall east - west. If, on the other hand, one wants the sun to shine on the floor so that the floor dries up and parasites die, it is better to build the shed along a north - south axis (This is preferred in humid areas). Since the sun is higher in the sky during the summer, the roof of a building picks up most of the solar radiation whereas, in winter, south facing walls pick up most of the solar radiation. The lambing shed is, therefore, aligned along an east-west axis to maximize the surface area facing south. Further, the shed should be constructed at a place where there is no obstruction to direct light, and the duration of the winter sun is more than six hours. The lambing shed should be constructed close to where flocks are stationed during the lambing period and if possible close to the family settlement. Positioning the lambing shed close to the homestead will allow utilization of the shed for other purposes after the lambing period is over.



Ventilation: The purpose of ventilation is to provide the desired amount of fresh air, without drafts, to all parts of the shelter; to maintain temperatures within desired limits; and to maintain ammonia levels below specified levels. Ventilation is of utmost importance to maintain a desirable interior temperature of 28 to 30°C. Majority of pneumonia cases can be traced to excessively warm and humid interior and sudden changes in temperature. It is, therefore, necessary to make the shed sufficiently high and make sure there are openings for ventilation in the roof or walls. It is essential to note that ventilation is good, but draughts are bad. The ventilation openings must, therefore, be placed high enough so that air does not blow directly past the animals (draught). In warm climates, where the stalls are fairly open, a low wall of about 1 meter on the side the wind comes from is sufficient.



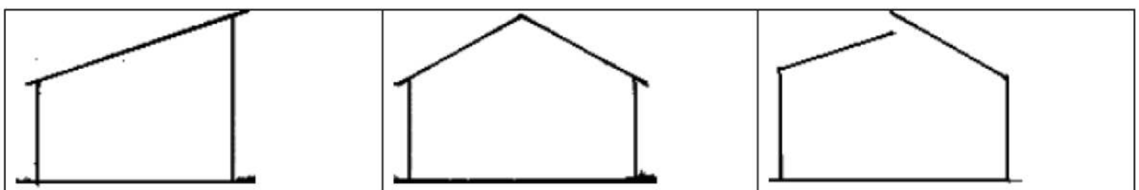
Materials for building an animal barn: Sheep and goat barn construction need not be complicated or expensive. The materials used in construction should be those locally available that will result in a long-lasting structure. Animal safety and welfare is very important in the design and construction of housing.

Space requirement: Adequate flood space must be provided for optimum production and health. Overcrowding promotes ill health. Recommended space requirements vary depending on animal size and the type of floor used. Adjustments may also be made depending on local climate and flock size. Additionally for animals managed totally indoors, an open yard for exercising is required. Sheep and goats should not be crowded and must have room to lie down. On an average, four square feet should be allowed for each goat/sheep. A 12 x 24 sq-ft shed can accommodate 60 to 80 sheep and/or goats. The recommended floor and trough space for sheep/ goats in intensive production related to live weight is given below.

Animal	Weight (Kg)	Floor Space			Trough Space (m/animal)
		Solid Floor (m^2/animal)	Slatted Floor (m^2/animal)	Open Yard (m^2/animal)	
Ewe	35	0.8	0.7	2	0.35
Ewe	50	1.1	0.9	2.5	0.40
Ewe	70	1.4	1.1	3	0.45
Lamb	3.0	0.4 - 0.5	0.3 - 0.4	-	0.25 - 0.30
Ram	80	3.0	2.5	-	0.5

Type of housing: There is no one, single blueprint for housing; the form that best suits for prevailing condition should be adopted. Structure should be built in such that sheep and goats can easily live, eat and rest and where people can work comfortably. The type of housing built will vary depending on the type of production system, size of operation and environmental conditions. Animal housing in tropical and semi-tropical regions should be kept to a minimum except for intensive production systems. In the arid tropics, no protection other than natural shade may be required. In humid climates, a simple thatched shelter will provide shade and protection from rain.

Roof: The roof provides protection from sun and rain and can be of a shed, gable or modified gable style. Slope is important in removing rain and thatched roofs need a greater slope than iron sheeting. A greater slope is also beneficial in areas with high rainfall. The roof should be waterproof with sufficient overhang to prevent rain from blowing in. A high roof encourages air movement but is more likely to be damaged by strong winds. For dryland areas, provision for rain water harvesting from roof should be made to avoid wastage of scarce resource. A roof vent can assist in proper ventilation. Roofs can be constructed from iron sheet, grass/bushes, wood, stone/brick or earth depending on production system, material availability and climate.



Shed	Gable	Modified Gable

Wall: The wall should not be completely solid to allow air movement through the house. Good air movement (ventilation) is essential to remove moisture, excess heat in hot weather and/or odor and gasses from animal waste so that animals stay cool, dry and clean. Inadequate ventilation can lead to problems such as pneumonia. While good ventilation is essential for animal health, drafty conditions must be avoided. Air circulation should be above the animals' heads and ventilation openings should be placed high enough so that air does not blow directly past the animals. Air movement can be effected through mechanical (e.g., ventilator) or natural means. Providing openings or short side walls of about 1 meter height will provide sufficient ventilation. A hedge can also fulfill this function.

Floor: The floor could either be packed earth, concrete or slatted. Packed earth or concrete floors should have a slope of about 5% for good drainage. Raised platforms where sheep and goats can lie above the floor and away from manure and urine are beneficial. These can be placed along the longest wall of the barn. Slatted floors should be raised about 1-1.5 meters above ground level to facilitate easy cleaning and collecting of dung and urine. Sand floor is also helpful to prevent foot disease and lameness. The gap between the slats should be 1.4 to 1.6 cm to allow easy passage of fecal material and provide safe footing for the animals. A raised, slatted floor in tropical and subtropical areas also preferable because of no need of bedding, allows manure, urine and debris to drop and prevent parasitic infestation, reduces labour to clean, remains relatively dry and clean. Newborn and young lambs should not be put on slatted floors. A piece of wood temporarily placed on the slats will prevent leg injury to very young lambs and kids. A raised, slatted floor in arid and semi-arid areas has the following advantages:

- No need of bedding
- Allows manure, urine and debris to drop through the slatted floor, thus removing a major source of disease and parasite infestation
- Requires less labor to clean and maintain
- Remains relatively dry and clean
- Reduced space requirements
- Manure is easily collected for fertilizer use or for sale

The main disadvantage of raised, slatted floors is the high expense of construction. Some materials, such as bamboo, may be cheaper (north-eastern states, Jharkhand, Chhattisgarh, Odisha) than wood but may provide less secure footing.

Recommended housing options

The kind of house and equipment will depend upon the particular kind of sheep/goat enterprise and the climatic conditions under which it must be operated. Below are examples of housing types for different production systems and agro-ecologies.

Shelter options as per production systems

a. Smallholder producer: Smallholder producers with few animals are characterized by low input, low output production systems where costs need to be kept to a minimum. Cost reduction techniques such as making the animal shelter attached to the main house (lean-to house); using locally available, inexpensive materials; or, depending on the climate, providing minimum shelter (e.g., open yards) need to be considered. Designing animal houses for multipurpose use, such as including roof space to store farm implements, feed, seed, etc. is one way of reducing the cost of housing sheep and goats. Thatched roof houses are often adequate.

b. Small scale commercial producers: Small scale commercial farmers produce sheep and goats from a business perspective and require improved management than that of smallholder producers. Basic requirements for good sheep and goat housing must be followed with the size of the barn commensurate with the number of animals expected to be raised. In arid and semi-arid areas, a house with a packed earth floor can be used since moisture buildup within the house would be minimal. In humid areas, a raised floor house is advisable to keep animals clean and facilitate waste removal. The type of wall (open, semi open, closed) and type and height of roofing should be made according to prevailing local climate.

c. Large scale commercial producers: Large scale commercial sheep and goat production requires more elaborate housing than those of small scale producers. Large scale producers may have several different barns for different types of animals viz., breeding ewes, breeding males, growing and fattening lambs after weaning, weaned young, isolation pen for sick animals, hay storage shed, storehouse for concentrates and additional facilities like dipping tank, watering trough, etc.

Shelter options as per agro-ecology

a. Highland: Most highland areas are characterized by high rainfall and low temperature. Under these conditions, houses with raised floors, gable roofs with sufficient overhang to protect from heavy rain and solid lower walls are suitable. The upper portion of walls should allow air movement to provide sufficient ventilation in order to avoid development of high humidity inside the shed as both sheep and goats are susceptible to pneumonia if houses are damp and poorly ventilated. In some highland areas where the rainfall is low, a well-drained packed earth or concrete floor can be used.

b. Mid-altitude: In mid-altitude areas where the climate is humid, houses with raised floors or on stilts provide a numerous advantages. Ventilation is good and dung and urine drops through the slatted floor minimizing parasite and disease problems. In drier areas, packed earth or concrete can be used providing they are kept clean and barn ventilation is sufficient to keep walls and floors dry.

c. Lowland: Lowlands are mainly arid and semiarid areas with hot temperature for most of the year. Most pastoral and agro-pastoral production systems are found in these areas. Traditionally, sheep and goat housing consists of open yards for night time enclosures. Natural shade from trees and shrubs provides protection against intense heat during the day. More elaborate animal housing for intensive and semi-intensive production requires partially covered long walls with roofing made of materials which do not create hot conditions beneath them at high ambient temperatures. Packed earth would be as suitable as slatted floors under this condition since moisture buildup is very low.

Modified shelter to protect from extreme climatic variables

While new knowledge about animal responses to the environment continues to be developed, managing animal to reduce the impact of climate remains a challenge. Changing animal housing to reduce the magnitude of heat stress offers the most immediate and cost-effective approach.

Bamboo dome:

Lambs are in kept in a dome made of bamboo or other locally available material. This prevents the lambs from cold stress as it maintains higher minimum temperature during extreme cold. So, this dome structure which is made up of locally available bamboo provides a comfortable micro-climate. This helps to gain better body weight and growth rate.

Cold and heat protected shed: This type of shed provides comfortable microclimate to the animals during summer and winter. In this chamber, floor is at lower level than the outside. It helps to maintain temperature. Along with that the roof is made up of tharmocol enclosed with PV sheet. This shed helps to maintain lower maximum temperature and higher minimum temperature than conventional shed.

Yangya type shed: It is mainly a similar structure where Yangya is performed in Hindu rituals in various festivals. The shed is made up of bamboo and 3 storied. This type of structure helps for better ventilation. The walls are made up of 2 layers of brick with hollow space at the middle.

This hollow space is filled with sand. The wall is kept cool by dripping water in the sand layer of wall. This intervention helps to reduce the temperature of the shed and protects from heat stress. Along with that, side walls also protect the animals from hot wind and act as wind breaker. All these modifications provide the animal optimum comfort during extreme heat to maintain their production, reproduction and health.

Conclusions

Productivity of sheep is largely depending upon the shelter where they kept. Production system and local climate mostly influence the housing type. Cost of construction, ventilation and drainage, and adequate lighting are also bring under consideration during designing a house. The main objective of shelter management should be, whatever the shed it is, it must render the animal maximum comfort for optimum production.

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HSP-GENE EXPRESSION PROFILE AND THEIR RELATIONSHIP WITH PHYSIOLOGICAL AND HORMONAL VARIABLES IN HEAT AND COLD ADAPTED GOATS

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Introduction

Small ruminants' goat and sheep are found in most of the areas in the world and contribute to economy through wool, meat, milk, skins and manure. They are important livestock for rural economy particularly in arid, semi-arid and mountainous area of our country. Small ruminants are among the main meat-producing animals in India. At present milk of goat and sheep contribute about 4% in the country's economy, some of the breeds like Jamunapari and Barbari goats have great potential for milk production. Sheep breeds like Patanwadi and Malpura produce 0.8-1.00 kg milk daily and the yield is much lower compared to Awassi sheep which produces 300 kg milk in a lactation period. The total wool produced in the country is about 50.0 million kg and the pashmina wool produced by Cashmere goat is 0.4 million kg.

Goats are well adapted to different environmental and geographical conditions and are found in extreme hot areas as well as in areas of extreme cold conditions. Goat is capable of tolerating extreme heat accompanied by a significant elevation (up to 41C) of the whole body temperature. Goat is drought tolerant and most disease resistant. Goat must have developed signalling pathways that allow their survival at very high temperatures of 48-50 degree Celsius as well as cold temperatures of -20 to -40 degree Celsius. Therefore goat is an ideal species for studying the effect of heat and cold stress and to investigate the factors affecting the heat and cold tolerance. Goat also inhabit the extremes of the climatic conditions, a direct comparison of the known genes and some of the unknown genes affected by the two types of extreme thermal stresses may reveal both important similarities as well as critical differences. The expression profiling may contribute to the effort of identifying elements not previously known to be involved in the cellular response to heat and cold stress. A detailed understanding of the genes involved in the heat and cold tolerance may help in integrating the understanding of function and interaction of the involved elements.

Thermal stresses trigger a complex program of gene expression and biochemical adaptive responses. These cell stress responses are of great interest both to basic biology and to medicine. Biologically, the ability to survive and adapt to thermal stress appears to be a fundamental requirement of cellular life, as cell stress responses are ubiquitous among both eukaryotes and prokaryotes, and key heat shock proteins (HSPs) involved in these responses are highly conserved across evolutionary lines. HSPs or stress proteins are a group of highly conserved proteins that represent between 2% and 15% of total cellular proteins and are expressed by all living organism. HSPs allow cells to adapt to gradual environment changes. These molecular chaperones encompass several families and play important physiological roles and are key components of anti-stress mechanisms. Proteins under HSP70 family are the most temperature sensitive and highly conserved of the HSPs. The HSP70s are ATP binding proteins and demonstrate a 6080% base identity among eukaryotic cells.

The genes and pseudogenes related to hsp70 in human are distributed over 18 chromosomes, some of which had both protein-coding genes and pseudogenes. 17 genes and 30 pseudogenes under HSP70 family have been reported in human.

Analyses of hsp70 genes at the genome level have been carried out for a few organisms, however the information on goat on the specific reference to HSP related genes and their relationship with physiological and hormonal parameters was lacing. Keeping in mind the above study was carried out on heat and cold adapted breeds of goats in their home tract .

Methodology

Twenty each of non pregnant and non lactating female of heat adapted (Sirohi and Barbari) and cold adapted (Chegu and Gaddi) breeds of goat (1.5 to 2 years) were selected from CIRG, Makhdoom and HPKVV, Palampur respectively. The experiments were conducted on different breeds of goats during winter (mid-December- mid-February), spring (mid-February-mid-April) and summer (mid-April-mid-June) season. The climatic data viz. ambient temperature and relative humidity was obtained from Meteorological observatory at the CIRG, Makhdoom and HPKVV, Palampur. The physiological parameters viz. respiration rate, pulse rate, rectal temperature of heat and cold adapted breeds were recorded during summer (>38°C), comfortable (21-26°C) and winter season (<10°C). Blood samples from all the breeds of goats were collected during different seasons for hormones (cortisol, Triiodothyronine, thyroxine) and for the following gene expression study.

- HSPA6 (Heat shock 70kD protein 6): Also known as HSP70B
- HSPA1L (heat shock 70kDa protein 1-like) : Also known as hum70t; hum70t; Hsp- hom
- HSPA1A (heat shock 70kDa protein 1A) : Also known as HSP70-1; HSP72; HSPA1
- HSPA8 (heat shock 70kDa protein 8): Also known as HSC70; HSC71; HSP71; HSP73
- HSPA2 (heat shock 70kDa protein 2)

Findings

The findings of the present study indicated that HSP70 genes express in both heat and cold adapted goats during different seasons. The expression level was observed to be moderate to higher levels during summer in both cold and heat adapted breeds than that of winter. Among the five genes studied in goat during present study, HSPA8, HSPA1A and HSPA6 were highly expressed in blood lymphocytes but the relative expression levels of HSPA1L and HSPA2 were very low. It has been found that the expression levels of HSPA1A and HSPA8 are comparatively higher in blood than HSPA1L and HSPA2 that express at a very low level in blood. The expression of HSPA6 can be considered as moderate (Brocchieri *et al.* 2008)

In the goats during present study, a higher expression of HSPA1A and HSPA8 during summer was noticed. A moderate expression was seen for HSPA6 gene. The expression level of HSPA1L and HSPA2 was observed to be low (Table 1). Increased HSP72 or HSPA1A mRNA levels in PBMC of Brown Swiss cows have been reported by Lacetera *et al.* (2006). The HSP70 has a well established role in conferring the thermo-adaptability and high level of thermo-tolerance and this heat stress induced HSP70 expression has also been found in in-vitro cultured bovine, equine, ovine and chicken lymphocytes (Guerriero and Raynes, 1990). However, continuous temperature rise do not protect cellular damage due to an imbalance between various physiological and cellular functions (Patir and Upadhyay, 2010). Heat stress induced up regulation of HSPA8, HSPA6, and HSPA1A gene expression has also been reported in human blood (Sonna *et al.* 2004)

Interestingly, HSPs and the associated stress response have been shown to be induced by cold and a range of other stresses (Herring *et al.* 2009). During the present study, HSP70 gene expression especially of HSPA1A and HSPA8 was observed in all goat breeds during winter. The moderate to higher expression of HSPA1A and HSPA8 during winter may be attributed to cold stress experienced by goats during winter. The rise in expression level of HSPA1A and HSPA8 may also occur due to the re-warming after the cold rather than effect of cold stress. An earlier study on *Drosophila* suggested that the induction of HSPs following cold exposure (0ºC) was due to the shift from 0ºC back to the control temperature of 25ºC, i.e. due to heat shock, rather than to the cold treatment itself (Burton *et al.*, 1988).

The studies on goat indicate that HSP induction takes place due to both heat and cold stress. The magnitude of expression during summer is moderate to high but during cold the expression is low to moderate. The physiological changes and the deviation from normal reflects that increased stress level, indicated by heat tolerance coefficient or other heat adaptation Indices (physiological parameters) applied to goat similar to that of cattle, cause expression of HSP genes. Different goats adapted to different climatic conditions like hot dry, cold dry, cold- humid, hot humid, altitude etc are likely to compound effects and expression of HSP and its components as has been observed during present study. The expression of HSPA8in Barbari is different from that of Sirohi HSPA1A (table 1). Similarly the changes in expression of HSP during cold were different in high altitude dwelling goat like Chegu from that of Gaddi. Also in a mammalian study the induction of HSP70 gene expression after cold treatment (4ºC) occurred upon recovery at control temperature (37ºC). The magnitude and the kinetics of the response were, however, related to the duration of cold stress (Liu *et al.*, 1994).

A moderate rise in expression of HSPA8 and HSPA1A was seen during winter but the expression of other three genes during winter was very low. Cold stress induced up regulation of HSPA1A or HSP72 has been reported in different animal cells (Human keratinocytes, squamous cell carcinoma; SCC12F cells, IMR-90; fibroblasts and HeLa; cells; mouse testis, TAMA; 6 Sertoli cells, NIH3T3; fibroblasts; rat neonatal; cardiomyocytes). This may be due to the re-warming after cooling (Laios *et al.*, 1997; Liu *et al.*, 1994). HSPA8 or HSC70 up regulated Human keratinocytes due to cold shock. But this was also due to re-warming after cold shock (Holland *et al.*, 1993).

Increase of HSP70 genes level during summer was higher in Gaddi and Chegu breeds as they experience stress during summer. Heat shock proteins (Hsps) are considered to play crucial roles in environmental stress tolerance and in thermal adaptation (Sorensen *et al.*, 2003). HSP70 gene expression during summer with higher mean values for cold adapted goats (Gaddi and Chegu) to heat adapted goats

(Sirohi and Barbari) was observed. Whereas during winter the expression of hsp70 genes were higher in heat adapted (Sirohi and Barbari) goats than the cold adapted (Gaddi and Chegu) goats. The heat adapted breeds (Sirohi and Barbari) goats are adapted to dry hot environment in Rajasthan and parts of U.P. region in India while the cold tolerant breeds (Gaddi and Chegu) goats are native to the relatively cold and hilly regions (Jammu-Kashmir and Himachal Pradesh) of India. Initially, stress-induced HSP accumulation was associated with thermotolerance, the ability to survive otherwise lethal heat stress, and later with tolerance to a variety of stresses. The difference in relative expression of hsp70 genes in cold tolerant breeds (Gaddi and Chegu) goats and heat tolerant breeds (Sirohi and Barbari) could be purely related to breed difference and their adaptation to different environmental conditions. The ability of the HSPs to confer thermotolerance in both cultured cells and in animals is well documented (Li *et al.*, 1985). The mechanism by which the HSPs confer stress tolerance is not completely understood but may relate to the important role of HSPs in the processing of stress denatured proteins (Mizzen and Welch, 1988).

Table 1. Relative HSP70 expression levels ($2^{-\Delta\Delta C_T}$) measured in blood leukocyte samples from the four goat breeds during winter and summer in comparison to spring

Genes	Sirohi			Barbari			Gaddi			Chegu		
	W	SP	S	W	SP	S	W	SP	S	W	SP	S
HSPA8	2.55 ±0.70	1.10 ±0.23	5.51 ±1.72	2.33 ±0.68	1.07 ±0.24	6.89 ±1.80	1.83 ±0.66	1.03 ±0.14	7.21 ±2.63	1.71 ±0.47	1.49 ±0.66	8.90 ±2.17
HSPA6	0.59 ±0.09	1.58 ±1.10	2.06 ±0.75	0.75 ±0.28	1.13 ±0.35	2.38 ±0.52	0.71 ±0.15	1.03 ±0.12	4.36 ±1.76	0.87 ±022	1.19 ±0.41	5.99 ±1.20
HSPA1A	1.83 ±0.39	1.26 ±0.42	10.20 ±4.50	1.83 ±0.45	1.31 ±0.50	7.69 ±2.43	1.72 ±0.41	1.03 ±0.14	16.30 ±6.48	1.36 ±0.42	1.03 ±0.13	18.15 ±8.09
HSPA1L	0.05 ±0.01	1.06 ±0.21	1.87 ±0.35	0.19 ±0.05	1.02 ±0.11	2.03 ±0.47	0.68 ±0.29	1.07 ±0.22	1.48 ±0.27	0.10 ±0.03	1.51 ±0.78	2.31 ±0.53
HSPA2	0 0	1.09 0.22	0.31 0.16	0.61 0.50	1.06 0.19	0.38 0.10	0.15 0.04	1.11 0.28	0.24 0.03	0.31 0.08	1.31 0.58	0.56 0.12

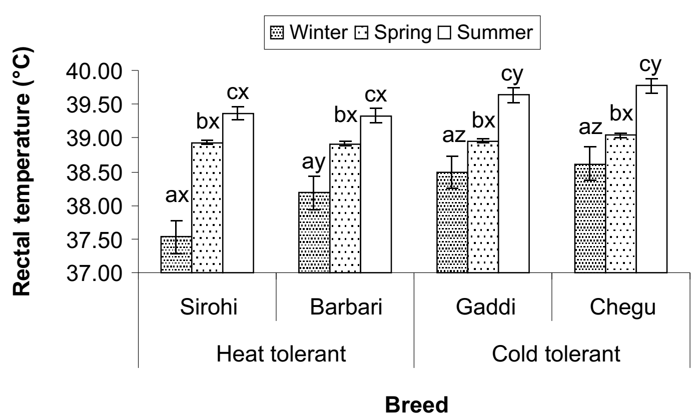
W: Winter, SP: Spring, S: Summer

Among the two cold adapted breeds Chegu is more susceptible to heat stress than Gaddi breed. Among the two heat adapted breeds Sirohi and Barbari showed almost similar pattern of expression but the expression level in Sirohi goat was a little low. Thermotolerance refers to an organism's ability to survive an otherwise lethal heat stress from a prior heat exposure sufficient to cause the cellular accumulation of HSPs In marked contrast to thermotolerance, heat acclimatization refers to the organism's ability to perform work in elevated environmental temperatures as well as to continue work under elevated but non lethal core temperatures. There is a growing body of literature supporting the role for HSPs in the whole organism's adaptation to heat other than through thermotolerance. There is a lack of information on HSP70 in animals therefore evidences from other species have been useful to interpret the results of this study. That is, the higher the temperature of the environmental niche, the greater the amount of constitutive HSP70 family found during non stress conditions. In different species of *Drosophila* decreased Hsp70 expression after acute heat stress seems to be the evolutionary consequence if the lines are exposed to chronically stressful high temperature conditions or originate from natural populations that inhabit warm environments (Sørensen *et al.*, 2003).

Physiological reponses

The values of the physiological parameters (RT, RR) observed for goat in present study are within the reported ranges in goat (Phulia *et al.* 2010). The average rectal temperature observed in this study (Sirohi: 38.61±0.15, Barbari: 38.81 ±0.10, Gaddi: 39.03 ±0.09, Chegu: 39.15 ±0.10) are within the reported range in several studies which were carried out for determining the effects of high environmental temperature on rectal temperature (Keskin *et al.* 2006).

Physiological responses viz. rectal temperature and respiration rate showed a significant variation between heat and cold adapted goat breeds and during different seasons (Fig. 1). The significant breed difference in heat and cold adapted goats for RT and RR with higher mean values for cold adapted goats (Gaddi and Chegu) to that of heat adapted goats (Sirohi and Barbari) was recorded. This may be due to breed difference and adaptation to different climatic conditions. The heat tolerant (Sirohi and Barbari) goats are adapted to dry hot environment while the cold adapted breeds (Gaddi and Chegu) goats are native to the relatively cold and hilly regions. So the results indicate that the variations in physiological responses under different environmental condition are an indicator of adaptability of that animal to that environmental conditions and the level of stress. Rectal temperature and respiration rate are the parameters which illustrate the mechanism of physiological adaptation and their variations have been used for assessment of adaptability under different conditions as well as to elucidate many physiological mechanisms (Keskin *et al.* 2006).



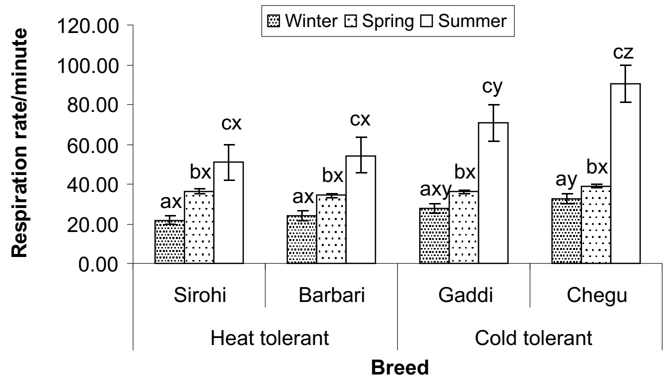


Figure 1. Mean values of rectal temperature and respiration rate of goat during different seasons
[abc] Bars with different superscripts are significantly different ($p<0.05$) between seasons.
[xyz] Bars with different superscripts are significantly different ($p<0.05$) between breeds.

A positive and negative relationship was observed among physiological parameters and HSP genes expression during summer and winter season respectively in both cold and heat adapted breeds of goats.

Cortisol and thyroidal hormones

Plasma cortisol levels observed during the study were within the ranges reported in goat (Kannan *et al.* 2010). Activation to the hypothalamic-pituitary-adrenal axis and the consequent increase of plasma glucocorticoid concentrations are perhaps the most important responses of animals to adaptation to environmental stressors. A significant variation in cortisol level was seen between heat and cold adapted goats (Fig.2). The level was higher in heat adapted goats than the cold adapted breeds. The cortisol level of Chegu was lower than other three breeds and the cortisol level was higher in Barbari breed. The difference in the cortisol levels may be due to adaptation of heat and cold adapted goats to different climatic conditions. The results reflect that the level of cortisol helps in physiological adjustment to the environment and enables animals to tolerate stressful conditions.

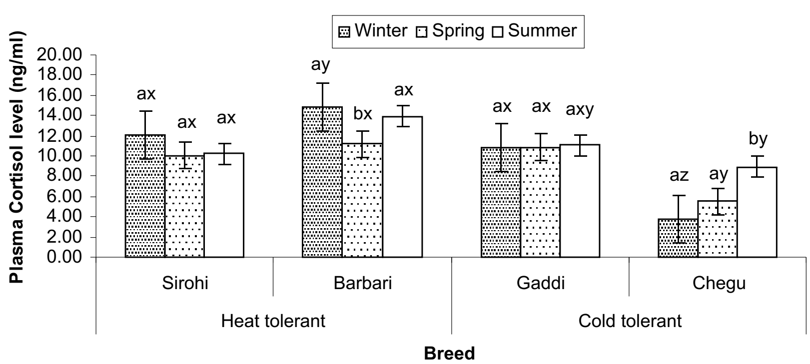


Figure 2. Cortisol (ng/ml) levels of different breeds of goat during different seasons
[abc] Bars with different superscripts are significantly different ($p<0.05$) between seasons.
[xyz] Bars with different superscripts are significantly different ($p<0.05$) between breeds.

The significant breed difference for blood thyroid hormone (T3 and T4) level with higher mean values for cold adapted breeds (Gaddi and Chegu) than heat adapted breeds (Sirohi and Barbari) goats was observed. The higher values for cold adapted breeds (Gaddi and Chegu) goats than heat adapted breeds (Sirohi and Barbari) could be related to breed difference and their adaptation to different climatic conditions. Webster, 1974 and Slee, 1985 also reported that adapted to cold results increased plasma concentrations of thyroid hormones associated with energy metabolism (Fig.3).

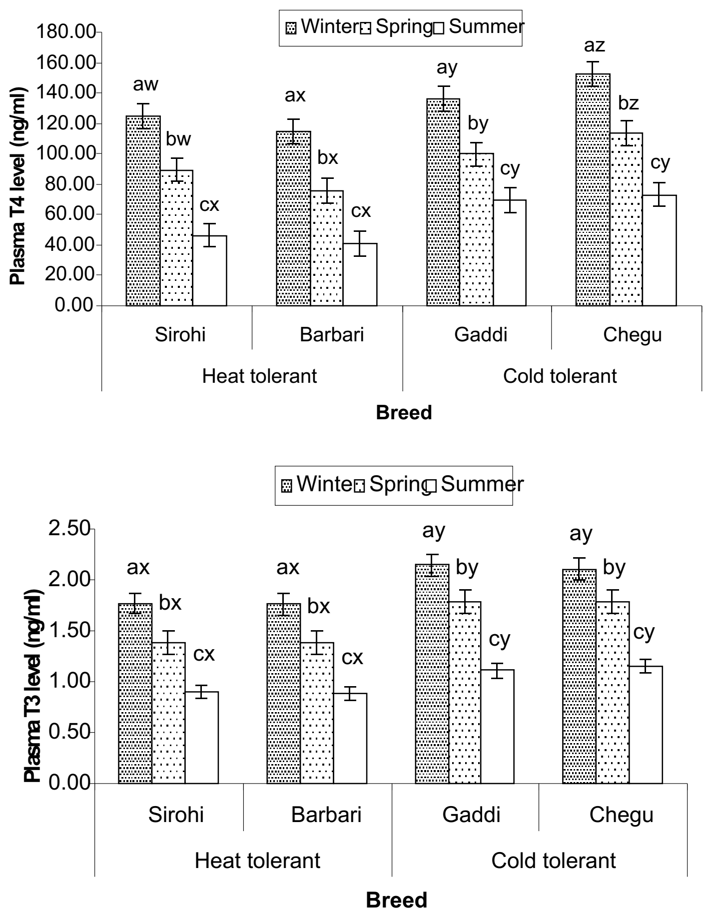


Figure 3. Thyroxine and triiodothyronine levels of different breeds of goat during different seasons

[abc] Bars with different superscripts are significantly different ($p<0.05$) between seasons.

[xyz] Bars with different superscripts are significantly different ($p<0.05$) between breeds.

The levels of both thyroid hormones (T3 and T4) were higher during winter and lower during summer in all the goat breeds. The higher levels of thyroid hormones may be due to low ambient temperature during winter to increase metabolic rate and increased body heat production to maintain core body temperature. Cold stress in ewes (Hocquette *et al.*, 1992) and ram lambs (Doubek *et al.*, 2003) induced increases in blood thyroid hormone levels. The seasonal pattern of blood thyroid hormone levels often showed maximal values during winter months and minimal during summer months (Menegatos *et al.*, 2006).

Conclusion

There exists a wide variation in the expression of different HSP genes during different seasons and in cold and heat adapted breeds of goats. Physiological responses showed a positive relationship with expression of different genes during heat stress and negative correlation during winter seasons. The thyroidal hormones were significantly lower during heat stress in both cold and heat adapted breeds of goats. Therefore to maintain the normal physiology and homeostasis the different Strategies viz. Physical modification of the micro-environment, Improvement of nutritional management and development of thermal tolerant breeds could be suggested.

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SHEEP HUSBANDRY UNDER CLIMATE CHANGE SCENARIO IN INDIA

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Introduction

Sheep kept 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. 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. The anticipated negative impact of global warming on the climate of India is severe (Nordhaus 1998; Sirohi and Michaelowa, 2007). India needs to take a serious view of this impending danger, which will bring about disastrous consequences. 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 monsoons grasses (Shinde and Bhatta, 2002). Thus, changing rainfall pattern in western and central India would cause scarcity of grazing resources. Concurrently, there will be lengthier droughts in dry areas, which will subsequently affect grazing resources, water scarcity and will reduce sheep husbandry activities. The potential impacts of climate change on livestock sector in India are: (1) 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; (2) Given the vulnerability of India to rise in sea level, the impact of increased intensity of extreme events on the livestock would be large and devastating for the low-income rural masses; (3) The predicted negative impact of climate change on Indian agriculture adversely affecting livestock production by aggravating the feed and fodder shortage. This chapter collates and synthesizes literature on effect of changing climate on sheep production in Indian scenario and the mitigation strategies that need to be addressed 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. 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 the development of social economy by acting on agriculture, animal husbandry and water resources. If the global warming is continually accelerated, it is possible that occurrence of flood and drought will further increase. Because 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. The increase of temperature will lead to the decline in the yield of crops which in turn will decrease the forage for livestock resulting in decrease of livestock production to different degrees (Mader, et al., 2006). 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 will also influence etiological bacteria and parasites of sheep.

Genetic merits of sheep in India

India is rich in sheep genetic resource diversity having 42 established sheep breeds with more in process of evaluation and characterization: as per World Watch List the approved breed are 50. Majority of Indian sheep breeds are medium stature carpet wool or hairy type. Sheep rearing 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 Orissa and West Bengal states. Climate plays an important role in nature of produce from sheep. Prolific sheep breeds in hot and humid coastal region of West Bengal and Orissa, 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 plain 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 two different sets of condition. Similarly, prolificacy trait in coastal sheep breeds is associated with higher temperature coupled with humidity. Research and development 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 poor adaptability to prevailing hot environmental conditions and low plane of nutrition for most part of the year.

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 for livelihood and economic sustenance in harsh climate (Karim and Shinde 2007). In present scenario of climate change, the fate of sheep husbandry in the country raises many questions. It is expected that 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, re-emergence of newer diseases etc.

Climate change and sheep husbandry

The current shift in sheep population from Rajasthan to Andhra Pradesh indicates the effect of climate change. The sheep population in 1997 in Rajasthan was 10.62 million, which declined to 10.05 million in 2007 livestock census with overall reduction of 5.72%. On the other hand, the sheep population in Andhra Pradesh increased by 13.99% to 21.4 million. The frequent drought and famine situations and continuous declining of grazing resources both in term 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.

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. 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. Further in recent past, reduction of area under grazing land and stubble due to intensive cropping pattern in neighbouring state and shifting crop pattern made the situation all the more vulnerable. Climate change and its subsequent effect on rainfall and grazing resources adversely affect the young stock and also the lactating ewes, which need supplementary feeding to protect from vagaries of malnutrition/undernutrition. 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.

Preference for adaptable and higher producing sheep breed

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. It's a widely accepted 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). 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. Farmers are also 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 are being made to develop prolific sheep breeds in the country for enhancing mutton production. At NARI, Phaltan, Suwarna strain of Deccani sheep developed to make the sheep production system more sustainable in the changing demographics, economic, and agricultural milieu. Similarly, at CSWRI, Avikanagar, three breeds cross of Malpura, Garole, and Pattanwadi is under progress which can produce twins/triplets with milk yield and higher body weights and can withstand the harsh climate of arid and semiarid region in the country.

Depleting grazing resource and nutritional scarcity

Common property resources (CPR) are main source of forage for sheep in the country. This 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 of cultivable waste, 11.3 million ha of permanent pasture, 23.5 million ha of fellow, 3.66 million ha of tree crop, groves (Dept of Statistics and Economics, Ministry of Agriculture, GOI). Besides 38.5 million ha (50% of 77 million ha) forest areas are 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 utilized for grazing purpose and in extreme arid region of Rajasthan, 90% of the land is utilized for grazing. Despite a rapid decline in area and productivity, CPR constitute an important component of community assets in the dry areas (Singh et al 2005) and community's livelihood in responses to the scarcities and stresses created by agro-climatic conditions. It has been observed that continuous declining of total precipitation in dry zones of the country due to climate change sizably reduced the forage yield from CPR.

Increase impeachment on animals is evident due to rise in earth's temperature. Sheep are exposed to ambient temperature ranging from 10-12^{0}C in winter to 45-46^{0}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. 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.

Challenge to sheep health and 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 for animals leading to metabolic disease of varying nature. The interactive consequences of rise in ambient temperature on animal health are detailed in table 1. 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 and D, B_1 and minerals calcium, phosphorus, zinc, copper are not only prevailing unabated but also 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 have also been 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 increase morbidity, 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 hemorrhagic septicemia, skin, pneumonia and foot diseases. Moreover, short-term fluctuations in temperature seriously cause heat or cold stress leading to increased death from respiratory diseases.

Table 1. 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,

Source: Dubey and Shinde 2010.

Early embryonic losses increase in sheep and goats bred during summer months 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 part of Rajasthan, drinking water contains fluoride, nitrate, TSS more than tolerance levels, which will affect health, production and reproduction of animals. Although, native sheep of desert region tolerate this salted/saline water but climate change would adversely affect their tolerance and production potential. Nutritional and multiple stress and compromised immunity to emerging and re-emerging 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.

Sheep husbandry and socio-economics

Drought and famine borne migration of sheep of arid region to other region during long period of the year, may lead to socio-economic imbalances. Climate-change driven shrinkage of grazing lands, scarcity of feed and fodder resources and compulsion driven marketing structure will force the farmers to resort to early disposal of lambs for mutton purposes. Earlier, farmers sold their lambs at 9-12 month of age weighing 20-22kg body weight. Now they are selling at an age of 3-4 months when they hardly attain body weight of 12-14kg 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. Further, 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 shifting to heavier sheep, yielding more meat. On the other hand, the input cost of feed and medicines may create a vulnerable situation, if the output price is less profitable and it may concern sustainability.

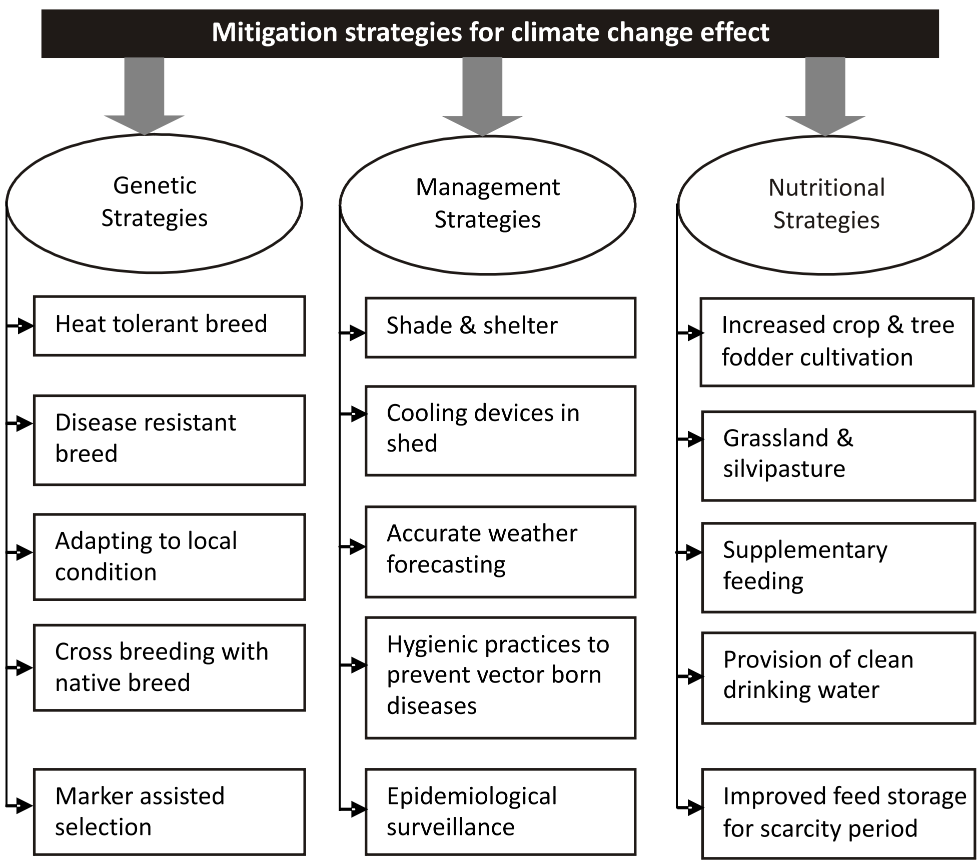
Mitigation strategies

Climate change plays a huge impact on reducing the productive and reproductive efficiency of sheep and hence, it is imperative to concentrate on reducing the effects of climate change to withstand sustainability issues. Various mitigation strategies are summarized in fig. 1. 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 create a constraint on continued improvement in production efficiency.

Conclusion

Climate change and food security are two emerging issues faced by people all over the world. 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 the development of the sheep sector in India.

Figure 1. Salient mitigation strategies for countering climate change effect



Responding to the challenge, formulation of appropriate adaptation and mitigation options are required for this sector. The projected trend of population growth indicates 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 damaged most by climate change. A collaborative scientific approach can help the livestock sector in the battle against climate change. Till now the effort in selecting animals has been primarily oriented toward productive traits, and from now on, must be oriented toward robustness, and above all adaptability to heat stress. Climate change is seen as a major threat to the survival of many species, ecosystems and the sustainability of livestock production systems. It is expected that the sheep systems based on grazing (extensive production system) and the mixed farming systems (Semi-intensive production system) will be more affected by climate change than an industrialized system (Intensive system). While new knowledge about animal responses to the environment continues to be developed, managing animal to reduce the impact of climate remains a challenge. Reducing environmental stresses on sheep requires a multi-disciplinary approach with emphasis on animal nutrition, housing and animal health. At present shelter management in sheep is the most neglected aspect of sheep husbandry which may become still more important due to impending climate change in the future. 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.

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Role of sheep in water conservation

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Introduction

While discussing water conservation, many questions arise i) is the availability of water the only issue, or is the way water is managed at different levels equally crucial? ii) is there any way out of the expensive, large-scale projects like dams have led us into? iii) is there any viable low cost alternative available for water saving or restricting its movement? or iv) is saving and conservation equally important? If we look at water conservation, sheep seems to be an ideal livestock that contributes to saving of water (physiologically equipped with wool coat to minimize heat and water dissipation) and its wool in soil moisture conservation and usage as a part of geotextile application. Role of wool in water conservation may even be more crucial in sandy soam soils of Rajasthan which receives scanty to low rainfall and has been facing the problem of water crisis. The chapter discusses both the aspects (sheep as well as wool) that contribute to water conservation and also highlight the findings from a short experiment conducted at Central Sheep and Wool Research Institute (CSWRI), Avikanagar on 'Coarse wool utilization in agriculture for moisture retention in sandy soil'.

Water resource and potential threat

During the past century, mean world temperature has increased by 0.74^{o}C and this rate is likely to increase in the near future. Such climatic changes are likely to affect all aspects of human development. Studies have shown adverse impacts of climate change on forests, water resources, health, agriculture (food production), housing and industry (IPCC, 2007). Water resource is a great matter of concern today. As countries are using their water resources with growing intensity, poor rainfall increasingly leads to national water crises as water tables shows a continual fall and many reservoirs, wetlands and rivers are getting dried/emptied. Global warming could cause further changes, further variability and further uncertainty in rainfall, which is a key constraint to agricultural production and economic growth in many developing countries. In India too, the availability of water in future will be different due to changes in the rainfall patterns. Climatic changes, associated with increasing population, urbanization and industrialization have drastically reduced the availability of water in India. Concurrently, the livestock population needs to be on the rise to meet the the growing demand of rising human population. It is estimated that the demand for water will rise by 20-40% in the next 20 years due to rapid urbanization, modernization and associated changes in lifestyle (India vision, 2020). It is projected that India will have per capita availability of water as low as 1140 m^3/year by 2050 (MOWR, 2008). Thus on one hand, the demand for water in the country is likely to rise significantly but on the other hand the water availability is rapidly declining, thus compounding the problem.

Scenario sheep husbandry and wool in India

Sheep is an important species of livestock and constitutes the major small ruminant population in the world. Sheep also contribute greatly to the agrarian economy, especially in areas where crop and dairy farming are not economical, and play an important role in the livelihood of a large proportion of small and marginal farmers and landless labourers. So sheep husbandry is a part of subsistence agriculture rather than a system of trade. India has vast genetic resources in sheep and it ranks second in sheep population. Although goat population predominates compared to sheep in India, contribution to two basic requirements of life out of the three 'Roti, Kapda aur Makkan' is unique. Besides, sheep has long been evolutionized as an animal to conserve environment and its contribution to water economy has got significant bearing in the present day water-crisis.

The produce from sheep, most significantly, the wool faces a crisis in marketability in India due to varied reasons. Out of total wool production in India 75% is of carpet grade, 20% coarse grade and 5% apparel grade. Because of this diversity and climatic conditions, wool obtained is not fine and not suitable for apparels. Requirement of coarse grade wool for carpet is stationary and becoming non-lucrative. Moreover, the extra coarse wool is considered as waste, since there is no industrial product available who can consume this bulk amount of wool at very cheap rate. So the time has come to look for alternative usage to fetch good price to support the sheep farmers. In this perspective, wool is a good source of bio-fertilizer and rich in nitrogen. However, the recycling feasibility of wool has not been scientifically investigated in Indian scenario, which could cater to agriculture sector. Geotextiles made from wool is relatively a new area of research and not much information is available.

Role of sheep and wool in water use efficiency

Sheep reduce the heat loss required by panting due to its thick coat of wool which insulates and protects the animal underneath from the full heat of the day. This also helps conserve water. Amongst the species, Merinos have a very well developed wool coat and thus cope very well to heat. Mammals and birds can produce urine both more and less concentrated than plasma in order to conserve or excrete water. Unlike other animals, sheep, camels, Kangaroos who have limited access to water and say live in more arid environments have evolved very good mechanisms to reabsorb lots of water and produce very concentrated urine. A comparison between the maximum concentrating abilities of the kidneys of various mammals is given in table 1. Animals which are native to desert environments such as camels and sheep tend to tolerate heat better than none familiar animals such as cows and dogs as evident from decrease in body mass per day without water in 40 degree heat by 2 and 4% in camel and sheep versus 8% in cattle.

Table 1. Urine concentrating ability in various mammalian species

Species	Maximum urine osmolarity (mosmol/l)	Urine/Plasma concentration ratio
Beaver	520	2
Calf	500	2
Pig	1100	4
Humans	1200	4
Cow	1400	5
Sheep	3500	11
Horse	2000	7
Dog	2500	8
Cat	3000	10
Kangaroo Rat	5500	18

Source: Physiology of Domestic Animals - Sjaastad, Hove and Sand, 2004

Sheep are also able to minimise water loss in the urine and can when needed lose very little water in their faeces. Sheep are able to tolerate water losses of up to 30% like camels and also drink very quickly when given access to water to try and replenish supply. Also, the water is stored in the fore stomachs of sheep and absorbed at a steady rate. They tend to use the evaporative cooling of sweating in order to maintain body temperature. An experiment conducted at CSWRI, Avikanagar validate some of the following findings in this line.

- Malpura ewes have the capability to adjust their physio-biochemical responses to cope with multiple stresses (heat, nutrition and both) under hot-semi arid environment (Sejian et al., 2013). Further, it is not only the heat stress that is causing severe damage to livestock productivity but also the multiple stresses which occur simultaneously as a result of changing climatic conditions.
- Malpura sheep have shown capability to adapt water restriction without significant decline in production at 20%, an adaptive physiological response at 40%, but there was a reduction in feed intake coupled with digestibility, while the effect was more during alternate water availability (Sahoo et al., 2013).
- Sheep tried to conserve water by reducing excretion in faeces (more dry) and urine and N by minimizing excretion vide urine (Sahoo et al., 2013).

On the other hand, wool has unique property to retain 30 % moisture on its own weight. Wool as 'geotextiles', a permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain. This can be used as an innovative way to improve soil strength, conserve water and thus can contribute to economic water usage for the growth of plant.

Technical application of wool for soil moisture retention

There is very limited research on use of wool waste as soil amendments and nutrient sources for agricultural crops. Sheep production and wool processing generates a significant amount of waste materials such as woolscour sludge and other unused materials that are usually landfilled or unusually thrown creating environmental problems (Zheljazkov, 2005). Some of the research studies are conducted at International level to study the wool waste as a source of fertilizer or as mulch in agriculture application. Some of them are mentioned here as a reference.

- Wool and hair waste may be excellent soil amendments and nutrient sources for high value crops for both greenhouse and field production systems (Zheljazkov, 2005).
- Wool is a rich source of important nutrients for plant growth. It contains high quantities of nitrogen, sulphur and carbon (Mcneil *et al*, 2007).
- As a result of partial break-down of wool, keratinous materials are formed which may be purposely produced, e.g. in the process of alkaline hydrolysis (Gousterova *et al*, 2003) and are easily available sources of nutrients and thus can be used for the development of slow-release fertilizers.
- Nustorova *et al* (2006) reported that, due to amendment of wool hydrolysate, content of K, Mg and Ca increased in general in the biomass of ryegrass collected during the first mowing, whereas content of these elements in the biomass of ryegrass from the second mowing decreased.
- Ryszard (2010) reported that waste sheep wool is a valuable fertilizer in production of many species of plants (Ryszard, 2010). Enrichment of basic substrates with sheep wool caused an increase in yields or fruit number, e.g. yields of tomato and pepper were increased by 30%. After one growing season the applied wool contained still an abundance of easily accessible mineral compounds and organic undecomposed particles which can be a rich source of nutrients.
- Amending substrate with wool also caused changes in chemical composition of growing medium, especially regarding increased salinity and nitrogen content and decreased content of P, K, Mg, and Ca, which might in part be caused by dilution effect (Ryszard, 2010).

Experiment conducted at CSWRI: An experiment was conducted at CSWRI, Avikanagar to study the effect of different forms of coarse wool in soil for moisture retention and its efficacy for agriculture application. A small field level experiment in sandy soil with pH 7.6 and organic carbon content of 0.26% with five treatments (3 replicates per treatment) that include different forms of wool with certain specifications. All treatments were implanted into soil 21 days before the date of sowing to allow the same for partial decomposing. Barley crop (*Hordeum vulgare*) of variety RD 2618 was raised during October to February season of 2012-13. The manual sowing was done on 15^{th} Oct. 2012 with a seed rate of 100kg/ha. The weight based seed quantity per plot was determined and kept constant for all plots. Controlled irrigation was given to all the plots, as per need, throughout the crop duration. To study the effect of different treatments in soil moisture retention, the soil samples of about 50 g were taken up to 20 cm depth from the experimental plot by using soil sampling auger. The plant growth parameters like germination%, plant height, tillers, dry matter accumulation, joint/node, etc. were physically measured. For green fodder calculation, one row from each plot at young age stage (90 days after sowing) were collected into separate bag and weighed. The crop was harvested after 130 DAS and sundried followed by threshing and seeds were collected for assessing yield.

The study has shown significant improvement in plant germination; *viz.* 71% maximum. The five months average moisture content in soil revealed that treatment plot retained 25% higher moisture content in the soil over the control plot. Maximum 57% improvement in green fodder production was recorded. Moisture content and grain production were found significantly higher. Soil test was conducted on monthly basis. The pH shifted towards alkaline scale. Electrical conductivity declined. Soil parameters like organic carbon content, nitrogen, phosphorous and potash has shown significant improvement.

Whole farm nutrient management

One of the most important aspects of any animal-based agricultural operation is having an effective waste management plan which reaps the benefits and helps reduce the risks associated with the use and disposal of animal wastes. Improper manure management can have a detrimental effect on water quality. A complete manure management system involves collection, storage (temporary or long-term) and ultimate disposal or utilization. The disposal of wool waste also comes under this scheme and its proper disposal, e.g. composting, manuring, use in water and soil conservation will have added revenue to the sheep farmers.

Conclusion

The physiology and physiological adaptation of sheep to arid and semi-arid environment with scarce water resources is indirectly a boon for the local farmers who thrive on this small livestock species in the evnts of drought and other natural calamities. On the other hand, non-apparel grade coarse wool that does not have any textile application may thus be used in agriculture, horticulture, nursery raising and terrace gardening. Fibrous wool in suitable shape may give young plants to sustain for longer time in case of water stress. Such product is also useful in busy life in metro Politian cities where a person could spend time to watering his in-house horticulture plants on daily basis. The potential application of wool may be in agro-forestry system and green-house plants. Further experimentation in this direction is required to generate more scientific data that could be gainfully utilized for the sustainable development and effective management of water resource. To guide the evolution of livestock production systems under climate-change scenario, better information is needed regarding biophysical and social vulnerability, and this must be integrated with agriculture and livestock components.

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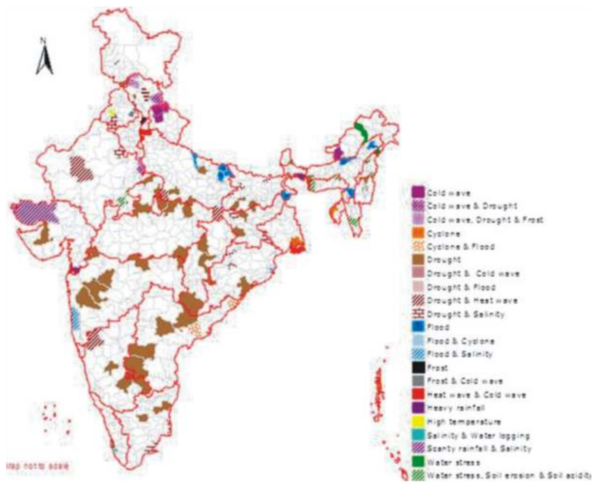

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