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Climate Resilient Animal Husbandry

Edited by

Dr. Prabhat Kumar Pankaj
Dr. Shahaji Phand
Dr. G. Nirmala
Dr. R. Nagarjuna Kumar
Ms. Pushpanjali

ICAR-Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad
&
National Institute of Agricultural Extension Management, Hyderabad

ICAR-CRIDA & MANAGE, Hyderabad

Climate Resilient Animal Husbandry

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This e-book is a compilation of resource text obtained from various subject experts of ICAR-CRIDA, Santoshnagar, Hyderabad & MANAGE, Hyderabad on **Climate Resilient Animal Husbandry**. This e-book is designed to educate extension workers, students, research scholars, academicians related to veterinary science and Animal Husbandry about climate resilient for improving livestock productivity. Neither the publisher nor the contributors, authors and editors assume any liability for any damage or injury to persons or property from any use of methods, instructions, or ideas contained in the e-book. No part of this publication may be reproduced or transmitted without prior permission of the publisher/editor/authors. Publisher and editor do not give warranty for any error or omissions regarding the materials in this e-book.

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MESSAGE

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is an autonomous organization under the Ministry of Agriculture & Farmers Welfare, Government of India. The policies of liberalization and globalization of the economy and the level of agricultural technology becoming more sophisticated and complex, calls for major initiatives towards reorientation and modernization of the agricultural extension system. Effective ways of managing the extension system needed to be evolved and extension organizations enabled to transform the existing set up through professional guidance and training of critical manpower. MANAGE is the response to this imperative need. Agricultural extension to be effective, demands sound technological knowledge to the extension functionaries and therefore MANAGE has focused on training program on technological aspect in collaboration with ICAR institutions and state agriculture/veterinary universities, having expertise and facilities to organize technical training program for extension functionaries of state department.

Presently, the climate change is the burning issue and a big challenge before agricultural sector worldwide. The changes in the environmental factor such as temperature, rainfall, relative humidity, wind speed and solar radiation are directly and indirectly affecting the livestock productivity. Livestock sector is also affecting due to climate change. Among the climate variables, heat stress seems to the most intriguing factor which negatively affects the livestock production. Livestock production is exposed due to high temperature by decreasing growth, reproductive performance, milk component and milk production, meat production and animal health. The effect on livestock can be evidenced through reduction in milk production by two percent every year. The livestock production system needs to be made climate resilient through producing climate resilient fodder, improving feeding strategies to address heat stress, constructing proper housing for livestock animals, using various breeding techniques to make livestock more climate friendly, ensuring safe water for livestock, ensuring necessary veterinary care to protect the animals from drought induced parasites and diseases, ensuring access to market, capacity building of farmers and local institutions etc. Therefore, adaptation and mitigation of the detrimental effects of extreme climate events plays important role to counter the impact of climate on livestock production.

It is a pleasure to note that, ICAR- Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad and MANAGE, Hyderabad, Telangana is organizing a collaborative training program on Climate Resilient Animal Husbandry and coming up with a joint publication as e-book on **"Climate Resilient Animal Husbandry"** as immediate outcome of the training program.

I wish the program be very purposeful and meaningful to the participants and also the e-book will be useful for stakeholders across the country. I extend my best wishes for success of the program and also I wish ICAR-CRIDA, Hyderabad many more glorious years in service of Indian agri and allied sector ultimately benefitting the livestock farmers. I would like to compliment the efforts of Dr. Shahaji Phand, Center Head-EAAS, MANAGE and Dr. Prabhat Kumar Pankaj, Principal Scientist (LPM), TOT Section, ICAR-CRIDA for this valuable publication.

Dr. P. Chandra Shekara
Director General, MANAGE

Foreword

ICAR-Central Research Institute for Dryland Agriculture is a premier research institute in the field of natural resource management for dryland agriculture in India under the Ministry of Agriculture and Farmers Welfare, New Delhi. ICAR-CRIDA is working closely with different stakeholders (farmers, line department officials, SAUs, other ICAR institutes, different ministries, etc) towards the development of climate resilient agriculture in India apart from production enhancement and revenue generation through introduction of easily adaptable cost-effective advance technologies in a sustainable ecosystem based approach.

ICAR-CRIDA is currently implementing the ICAR flagship programme, National Innovations on Climate Resilient Agriculture (NICRA), which is playing an important role at national level in evolving adaptation and mitigation strategies in agriculture and allied sectors and also taking up their demonstration in more than 150 villages representing key climate vulnerabilities. Efforts are being made for scaling up these technologies through the National Mission for Sustainable Agriculture (NMSA). Apart from this, ICAR-CRIDA has developed almost 650 district agriculture contingency plans involving all agricultural universities, several ICAR universities, Krishi Vigyan Kendra's (KVK's) and other stakeholders related to all the sectors of Agriculture. Extreme climatic events such as drought and floods occurring in the same crop growing season can seriously undermine our efforts to enhance production using current technology.

There is a vast scope for accelerating agricultural growth in rainfed areas through diversification into high-value crops, horticulture, and livestock-based enterprises with available water. Livestock based systems are important in semi-arid regions to ensure livelihood security.

Keeping this in view the training programme has been proposed to sensitize different officials involved in extension activities about the importance of livestock for enhancing the nutritional security of the farmers as well as estabilishing climate resilient animal husbandry in India.

This e-book contains important topics on basics and new researchable areas which is linking meterorological concepts with vulnerabilities and resilience to be achieved in the livestock sub-sector. The book has also covered topics to create awareness amongst the professionals about easily adaptable technologies as well as gender issues with precision farming through better managemental interventions. Lectures delivered by the interdisciplinary group of experts from social, veterinary, agriculture and allied subjects are captured in this book. Hope wide circulation of this book will help a large number of readers to enrich their knowledge on this important topic of achieving climate resilient animal husbandry in India.

August, 2021.

Dr. Vinod Kumar Singh
Director, ICAR-CRIDA

PREFACE

This e-book is an outcome of collaborative online training program on “Climate Resilient Animal Husbandry”. This book is intended for SVUs/Veterinary officers, and livestock owners who are key players in the livestock sector as they are to address the problems regarding impact of climate change, adaptable and mitigating technologies for optimal livestock production. There is dire need to compile recent advances in technologies and innovations for better management of livestock especially reared under limited resource conditions. Bringing views of experts from different fields of agriculture and animal husbandry through this training programme suffice opportunities for cross-learnings among trainees.

Climate change impacts all sectors of ecosystem in an unbiased manner, however, such impacts need to be quantified systematically. Food and nutritional security under climate change scenario depend upon our ability to adapt animal-agricultural systems to climate change. Agricultural systems are multi-faceted and complex because of the range of plant and animal commodities affected by the interactions between climate and management. The content of proposed training programme has been designed in such a way, so that it can provide updated information towards capacity building in proposed area. Attempt has been made to cover topics about advances in climate resilient animal husbandry with special reference to NICRA programme, indicators of climate change, vulnerability and risk assessment, agro-meteorological and physiological basis of climate change with abiotic stress management (adaptation and mitigation). Topics like gender basis of climate impact, fodder production models, sustainable nutrient management, precision farming, contingency plans and climate smart livestock has also been included. Looking into diversified agro-ecosystem of India, experts from different regions and different universities as well as ICAR institutes have been called for providing a common platform for the officials involved in the field of animal husbandry extension to understand the subject for better preparedness towards climate resilient livestock management. Approaches for common managemental (genetic, nutritional, shelter, health) practices for livestock have been followed for the benefit of veterinary officials.

The valuable suggestions for future improvements are always welcome.

August, 2021

Editors

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DRYLAND AGRICULTURE AND ANIMAL HUSBANDRY UNDER CLIMATE CHANGE SCENARIO

Vinod Kumar Singh

Director, ICAR-Central Research Institute for Dryland Agriculture, Hyderabad

Dryland Agriculture refers to cultivation of crops entirely under natural rainfall without irrigation. The major characteristics of drylands are deficit in the absolute amount of rainfall (500 and 1200 mm), length of wet season is small, and rainfall is less than 40% of potential evapotranspiration. Soils of the drylands are not only dry but also deficient in macronutrients like nitrogen and phosphorous (called as thirsty and hungry soil). Once we consider the soil-plant-animal continuum, these deficiencies percolate to animal level (called as hollow gut syndrome) to imposing them to be deficient in certain micro-nutrients making them more vulnerable to climate change impacts.

Livestock rearing is one of the major occupations in dryland as well as other parts of India and is making significant contribution to the country's GDP. The animal husbandry sector has a good growth potential. Livestock rearing in India provides manure, draught power for agriculture and local transportation and forms important source of food and cash income to millions of households spread across various parts of the country.

The temperature in dryland varies greatly imposing impacts on livestock in terms of heat stress directly. However, during the period of moisture stress and drought, the temperatures accelerate the crop development resulting into forced maturity affecting both fodder as well as grain yields on which livestock production system is dependent.

Small size of land holdings (less than 2 hectares) usually fragmented and scattered, lack of market facilities, poor economic condition and other socio-economic issues related to drylands make the problem of farmers bigger under climate change scenario. Thus, present chapter has been made to sensitize the stakeholders about problems, prospects, role and livestock management under climate change scenario in the drylands.

Prospects of dryland areas and livestock under climate change

Majority (more than 75%) of farmers involved in dryland farming are small and marginal. Therefore, improvement in dryland farming would raise the economic status of farmers thus helping in poverty elimination. Dryland farming holds immense significance especially in the context of fluctuating food grain production and expanding population in our country. By enhancing the productivity of crops like *jowar*, *bajra* and *ragi* which are mainly grown in dryland farming would increase the nutrient consumption levels of our nation.

Marginal lands in the semi-arid regions offer potential for fodder production to feed the livestock population which is an integral component of farming practice of this region. Moreover, it would also be helpful in eliminating the problem of hunger and malnutrition prevailed in below poverty line society of the country by virtue of quality protein content of meat, eggs and milk.

Climate change is thought to be the most important cause of unstable productivity in ruminant production systems in India through crop failures, feed and fodder scarcity and increased incidence of endemic and emerging animal diseases. Alterations in rainfall affect the water availability for feed and fodder production and also curtail drinking water resources for livestock. Further, scenario of feed and fodder availability and demand in India indicates the necessity of efficient utilization of available resources from crop and cropping systems and development of integrated farming systems for sustainability of livestock production as well as farmer's income. Thus, adaptive livestock management practices are important in view of diversified and heterogeneous groups of farmers of drylands.

Role of Livestock in economy of dryland

The livestock plays an important role in the economy of farmers. The farmers in India maintain mixed farming system i.e. a combination of crop and livestock where the output of one enterprise becomes the input of another enterprise thereby realize the resource efficiency. The livestock serve the farmers in different ways.

1. Draft: Although an increasing mechanization is replacing the animal power in the villages, reducing the total DAP, yet India has to depend on animal energy for many years to come from agricultural operations and transport of farm produce. The farmers especially the marginal and small depend upon bullocks for ploughing, carting and transport of both inputs and outputs.

2. Dung: In rural areas dung is used for several purposes which include fuel (dung cakes), fertilizer (farm yard manure), and plastering material (poor man's cement).

3. Employment: A large number of people in India being less literate and unskilled depend upon agriculture for their livelihoods. The land less people depend upon livestock for utilizing their labour during lean agricultural season.

4. Food: The livestock products such as milk, meat and eggs are an important source of animal protein to the members of the livestock owners. The livestock provides food items such as Milk, Meat and Eggs for human consumption. India is number one milk producer in the world.

5. Income: Livestock is a source of subsidiary income for many families in India especially the resource poor who maintain few heads of animals. Cows and buffaloes if in milk will provide regular income to the livestock farmers through sale of milk. Animals like sheep and goat serve as sources of income during emergencies to meet exigencies like marriages, treatment of sick persons, children education, repair of houses etc. The animals also serve as moving banks and assets which provide economic security to the owners.

6. Social security: The animals offer social security to the owners in terms of their status in the society.

Major areas of concern with respect to livestock

- Improving productivity in a huge population of low-producing animals
- Conservation of soil/water/fodder resources
- Need to evolve high yielding and drought resistant crop/fodder varieties
- Proper breeding policy for different categories of animals
- Evolving and implementation of adaptive measures for climate change
- Proper marketing and price policy to animal products and insurance
- Extension of climate resilient technologies

Climate change and livestock management in drylands

Heat waves, which are projected to increase under climate change, is directly impacting the livestock. Exposure to high temperature events can cause heat-related losses to livestock farmers. Heat stress affects animals both directly and indirectly. Over time, heat stress can increase vulnerability to disease, reduce fertility, and reduce productivity. Drought may impact pasture and feed supplies. Drought reduces the amount of quality forage available to grazing livestock. Some areas could experience longer, more intense droughts, resulting from higher summer temperatures and reduced precipitation.

For animals that rely on grain, changes in crop production due to drought could also become a problem.

Climate change may increase the prevalence of parasites and diseases that affect livestock. The earlier onset of spring and warmer winters could allow some parasites and pathogens to survive more easily. In areas with increased rainfall, moisture-reliant pathogens could thrive. Increases in CO_2 may increase the productivity of pastures but may also decrease their quality.

Most of the farmers in dryland keep few cattle, goats, sheep and chickens. Herds are small, as available grazing areas are limited. Only some of the progressive farmers who has the resources keep a bigger herd of animals. The livestock are usually fed on crop residues or are allowed to graze nearby. Even if the crop fails, the animals can graze on it or animals graze on the harvested fields also. Livestock provide manure for the fields, either by grazing on the stubble after the harvest, or through composting. Special fodder crops are meagerly used in drylands as farmers are not ready to put the fodder whenever water availability is there. The opportunity cost to divert cultivable land for fodder production in a big way might be very high. The only plausible option, therefore, is to revitalize the degrading common fodder and pasture resources in the country and improve their productivity. Small livestock are a source of ready cash and a safeguard in times of distress.

Population growth, urbanization and increasing per capita incomes are stimulating a rapid growth in demand for animal-based products in developing countries, especially in the dryland parts of world as well as India. Hence, in addition to improving crop production, it is important to pursue ways to improve dryland livestock production and crop-livestock systems. Vast tracts of arid and semi-arid lands are unsuitable for crop production but support livestock, especially small ruminants (sheep and goats). Livestock is not only a vital source of protein but also constitutes an important sector of the economy which makes use of land that would otherwise be unproductive, providing livelihoods to millions of people around the world. In order to fulfil crop needs like manure and animal traction, farmers move towards crop-livestock integration.

In arid and semi-arid regions where crop failures and draught are frequent dependency on livestock increases. Most people depend on the sale of livestock products like milk, meat and hide and livestock itself for their livelihood. Livestock is the main source of food and people different species that cope well with harsh dry environment. The most common and well adapted and acclimatized livestock in these regions are breeds of sheep, goats, camels and cows as per the necessity and purpose to rear these animals.

Provisioning of fodder banks: Livestock derive major part of their energy requirement from agricultural by-products and residues. Hardly 5% of the cropped area is utilized to grow fodder. India is deficit in dry fodder by 11%, green fodder by 35% and concentrates feed by 28% which aggravate due to draught. The common grazing lands too have been deteriorating quantitatively and qualitatively. Though meeting human needs is of immediate priority during drought, but saving the livestock is also great concern because of the economic benefits that livestock can provide in times when agriculture fails. Inadequate availability of good quality fodder is the major limitation in further development of the animal husbandry sector in the country. India has vast tracts of grazing and, most of which has fragmented or become degraded due to lack of appropriate policy interventions and management inputs. Pastoralism and nomadism are important land use systems with a high degree of dependence on browse trees for livestock production especially in dry season.

Migration of pastoralists: It is a common phenomenon in drylands which involves male family members who take along their livestock herd and look after the dry period in the irrigated areas. But sometimes, this migration involves all the family members moving along with their children and livestock for the same period and travels long distances (i.e., more than 200km). Although their return depends upon the rainfall. While migrating, the farmers have to travel long distance to reach the places where they can find food and feed for themselves as well as for their livestock.

Few of the initiatives taken up as a support to livestock component of drylands under climate change scenario

- Basic and strategic research of NICRA
- Technology demonstration of climate resilient technologies under TDC-NICRA
- Fodder cafeteria
- Contingency plans
- Promotion of improved fodder, backyard poultry, indigenous sheep breeds and group formation under FFP
- Training and promotion of fodder and backyard poultry under SCSP/TSP
- Promotion of climate resilient technologies through CRIDA-KVK
- Organic fodder production and sheep production

Conclusion: Livestock production is one of the important activities in arid and semi-arid regions of India. Livestock plays an important role by ensuring subsistence and security against crop failures under drought conditions. There is need of building synergy between adaptable appropriate technologies and climate change impacts. Our first task is to remove the void created by climate change and promote the convergence of technology and services leading to self-sufficient, supporting and strong agriculture-livestock and farmers in India. Apart from this, there are number of socio-economic and environmental challenges that need to be overcome through appropriate technologies and strategies in order to harness the potential of livestock reared by landless, small and marginal farmers in India.

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AN OVERVIEW OF NATIONAL INNOVATIONS IN CLIMATE RESILIENT AGRICULTURE (NICRA): LIVESTOCK SPECIFIC ACHIEVEMENTS

M. Prabhakar

ICAR-Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad

Background

Increasing impact of climate variability on agriculture is evident. Therefore, need for coping with current climate variability, preparing for future climate change is very crucial. It is also important to assess crop losses due to extreme events. The need for continuous data generation for identifying trends and building scenarios is also important. To meet the challenges of sustaining domestic food production in the face of changing climate and to generate information on adaptation and mitigation in agriculture to contribute to global fora like United Nations Framework Convention on Climate Change (UNFCCC), the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare, Government of India launched a flagship network project 'National Innovations in Climate Resilient Agriculture' (NICRA) during 2011. NICRA is the unique project which brings all sectors of agriculture viz., crops, horticulture, livestock, fisheries, natural resource management (NRM) and extension scientists on one platform.

Objectives

- To enhance the resilience of Indian agriculture to climatic variability and climate change through strategic research on adaptation and mitigation
- To validate and demonstrate climate resilient technologies on farmers' fields.
- To strengthen the capacity of scientists and other stakeholders in climate resilient agriculture
- To draw policy guidelines for wider scale adoption of resilience-enhancing technologies and options

Mission

Enhancing the resilience of Indian Agriculture to climate variability and climate change through both application of improved technologies and new policies

Vision

To develop and promote climate resilient technologies in agriculture which will address vulnerable areas of the country and the outputs of the project will help the districts and regions prone to extreme weather conditions like droughts, floods, frost, heat waves, etc. to cope with such extremes.

Components: The scheme involved components viz. strategic research through network as well as sponsored/competitive grants mode, technology demonstration & dissemination and capacity building.

Strategic Research

In the strategic research, both short term and long-term research programs with a national perspective have been taken up involving adaptation and mitigation covering crops, horticulture, livestock, fisheries and poultry. The main thrust areas covered are (i) identifying most vulnerable districts/regions, (ii) evolving crop varieties and management practices for adaptation and mitigation, (iii) assessing climate change impacts on livestock, fisheries and poultry and identifying adaptation strategies. In the strategic research component, both short term and long-term research programs with a national perspective have been taken up to evolve adaptation and mitigation strategies in crops, horticulture, natural resources, livestock, fisheries and poultry About 41 ICAR institutes representing different sectors of agriculture are undertaking climate change research in a network mode focusing the respective them areas.

Some of the significant achievements of the NICRA under Livestock sector:

- State of the art climate change research facilities to understand the impact of climate change on different livestock species has been established at various research institutes across the country (Ex: Animal calorimetric system, Thermal imaging System, Methane analyzer, Psychrometric chamber, Environmental growth chamber, Laparoscope, Blood chemistry auto analyser, Hematology analyser, Chicken isolator & Growth chambers etc.)
- GHG emissions for different livestock production systems have been quantified
- Unique traits for thermal tolerance in livestock mapped, heat care mixture for poultry ready for commercialization
- Characterized physiological and metabolic markers and effect of various feed supplements for amelioration of thermal stress in cows and buffaloes
- Identified molecular markers in indigenous livestock which make them resilient to climatic stress
- Evaluated the impact of heat stress on milk production and quality parameters
- Risk maps were developed for Bluetongue disease for Karnataka and Tamil Nadu states
- Livestock Diseases Forewarning (LDF), a web enabled, and mobile based application was developed for forewarning of the thirteen livestock diseases
- Studied impact of climate change on important vector borne and zoonotic diseases
- Studied impact of climate change on emergence of vector-borne infectious diseases and their effects on livestock production system in mid hills of Western Himalayas region
- Lifecycle assessment of greenhouse gas emission was done from different animal production system of Karnataka State

- Assessed the thermal stress in growing and lactating goats and supplementary strategies developed to ameliorate
- Supplementation of Herbal powder & herbal extract & administering of Vit. E-Selenium was found effective to reduce the climatic stress in goats
- Developed Stressol –G an herbal crude powder-based tablet to reduce the climatic stress in goats
- Studied the effect of climatic stress variables on productive parameters of sheep
- Assessed the effect of climate-driven multiple stress on metabolic profile, oxidative stress and immunity in sheep
- Determined comfort-zone and quantified threshold level of THI under simulated as well as in fixed model of microclimate for sheep
- Studies different feed formulations and phyto-chemicals for promoting resilience against thermal stress in sheep
- Supplementation of Beataine (0.1%), OTM (Zn 40 mg, Cr 2mg or Se 0.3mg/kg) reduced the ill effects of heat stress in broiler & rural chicken
- Supplementation (0.1%) of prebiotics (MOS/FOS) enhanced the immune responses in rural chicken
- Dietary inclusion (0.2 to 1%) of herbal extracts (Aswagandha, Tulasi, Amla and Turmeric) improved growth in broilers under heat stress

Many of these technologies developed have been evaluatedin the farmers' fields for further refinement and upscaling. Research proposals addressing critical gaps not covered in the Strategic Research Component but have a major bearing of the productivity of principle commodities in the region are being funded through competitive and sponsored grants. So far, 18 sponsored and 33 competitive projects have been funded to undertake critical areas of climate change research in agricultural sector including Livestock.

Technology Demonstrations

Under NICRA demonstrations of proven technologies were given to enhance the adaptive capacity and to enable farmers cope with current climatic variability. Location specific technologies which are developed by the national agricultural research system which can impart resilience against climatic vulnerability are being demonstrated. TDC is being implemented in 121 climatically vulnerable districts of the country through Krishi Vigyan Kendras (KVKs) spread across the country. A representative village in each climatically vulnerable district was selected for implementation. The interventions are broadly divided into four modules viz., natural resource management, crop production, livestock and fisheries and creation of institutional structures for sustaining the activities envisaged and scaling up of interventions. Under the livestock module demonstrations on fodder production, especially under drought/flood situations, improved shelter for reducing heat stress in livestock, silage making methods for storage of green fodder and feeding during the dry season, breed selection and integrated farming system models in diverse agro-ecosystems are being taken up. Village level institutional mechanisms such as Village Level Climate Risk Management Committees (VCRMC), custom hiring centers are created for managing infrastructure created and to improve the timeliness of operations during the limited window periods of moisture availability in rainfed areas and to promote small farm mechanization for adoption of climate resilient practices. These interventions helped farmers to reduce the yield losses and enhanced their adaptive capacity against climatic variability.

Capacity building

A large-scale capacity building program on climate resilient agriculture is being undertaken with more than 1200 scientists, 450 research scholars and 100s of post graduate students are involved on climate change research and dissemination of climate resilient technology across the country. These resilient practices are being adopted by communities and spreading beyond NICRA villages. In the past 10 years 16,407 training programs were conducted throughout the country under NICRA project to educate farmers on various aspects of climate change and resilient technologies, covering 5.5 lakh beneficiaries. This will enable for wider adoption of climate resilient technologies and minimizing climatic shocks.

Conclusions

As per the recent IPCC report, Climate Change 2021, the scale of the climate crisis is very fast. Globe is on the path to 2^{o}C warming by mid 2100s. The report also highlighted increase in extreme weather events, ice melting, sea level rise, ocean warming etc., some of which cant reverse any more, at least for next thousand years. The commitments of the country to emission reductions require generate appropriate information and data on emissions as well as options that help reduce emissions. Techniques standardized so far under NICRA for estimation of GHG emissions from different management practices will be used for further reducing the carbon footprint of production systems in the country. Government of India has committed for the reduction of emission intensity of GDP by 32-35% by 2030 from 2005 levels, and the outputs of NICRA project contributing to several national project reports i.e., Intended Nationally Determined Contribution (INDC), Biennial Update Report (BUR), Nationally Appropriate Mitigation Action (NAMAs), National Mission on Sustainable Agriculture (NMSA) and several other Missions under National Action Plan on Climate Change. The system-wide impacts and responses to climate change need to be understood better and more comprehensively. NICRA findings have been published in high impact factor journals (280

International research papers, 8 policy briefs, 168 Technical bulletins).NICRA model village expansion in Maharashtra in the 4500 villages under world bank funded project (PoCRA) with a budget out lay of Rs 5000 crores. In many other states upscaling of climate resilient agriculture is being taken up (Ex: Bihar, Odisha, Telangana, etc). The efforts in this direction, which have begun, should expand to all the risk prone areas in the country. It is therefore, necessary to identify and prioritize various location specific adaptation and mitigation options. To sum up, the activities initiated few years back under NICRA should continue and expand in scope and content, and enable to develop multi location multi sector mitigation and adaptation strategies, so that we combat major challenge posed due to climate change in Agriculture.

INDICATORS OF CLIMATE CHANGE IN LIVESTOCK PRODUCTION AND MANAGEMENT

Prabhat Kumar Pankaj[1], Shahji Phand[2] and R. Pourouchottamane[3]

[1]*ICAR-Central Research Institute for Dryland Agriculture, Hyderabad*
[2]*National Institute of Agricultural Extension Management, Hyderabad*
[3]*ICAR-Central Institute for Research on Goats, Mathura*

Introduction

Climate change impacts all sectors of agricultural ecosystem; however, such impacts on food and nutritional security depend upon our ability to adapt animal-agricultural systems to climate change. Agricultural production systems are involved in producing food, feed, and fiber, and disruptions due to climate change impact our capability to feed the future. Agricultural systems have a range of plant and animal commodities affected by the interactions between climate and management. Agriculture is one of the key sectors impacted by climate change, and these assessments highlight many of the components vulnerable to climate change and require robust indicators to determine if the impact is increasing and our food and natural resource security is at risk (Melillo *et al*., 2014).

Indicators of climate change (CC) can provide a signal of the impact of climate change on animal-agriculture production systems which would be beneficial for the development of strategies for effective adaptation practices. In this chapter, a series of indicators have been discussed to determine their potential for assessing animal-agricultural response to climate change in the near term and long term and those with immediate capability of being implemented and those requiring more development. Apart from this, refinement of these available tools to assess climate impacts on agriculture will provide guidance on strategies to adapt to climate change.

Concepts of animal-agricultural systems and climate change

Animal-agricultural systems represent the primary linkage between the climate system and production from grasslands, crops, or livestock (Fig-1) (Hatfield *et al*., 2011, Izaurralde *et al*., 2011, Walthall *et al*., 2012). We can understand that climate regulating services, e.g., temperature, carbon dioxide, solar radiation, or precipitation, directly impact grassland, cropping systems and ultimately livestock production system.

Precipitation directly affects water supply to livestock, however, it indirectly affect the livestock production system through feed and fodder productivity where soil moisture plays an important role. The water cycle is a critical part of agricultural systems, and variation in the cycle lead to modified amount of water available to the grassland or cropping system. Variation in water availability is direct related to variability in production and is tempered by variation in temperature (Hatfield *et al*., 2011; Izaurralde *et al*., 2011). The potential indicators under this framework relevant to livestock production system directly are increased cold stress and heat stress, however, indirect factors are changes in the length of the growing season, onset of monsoon, yield, quality of feed and fodder, etc.

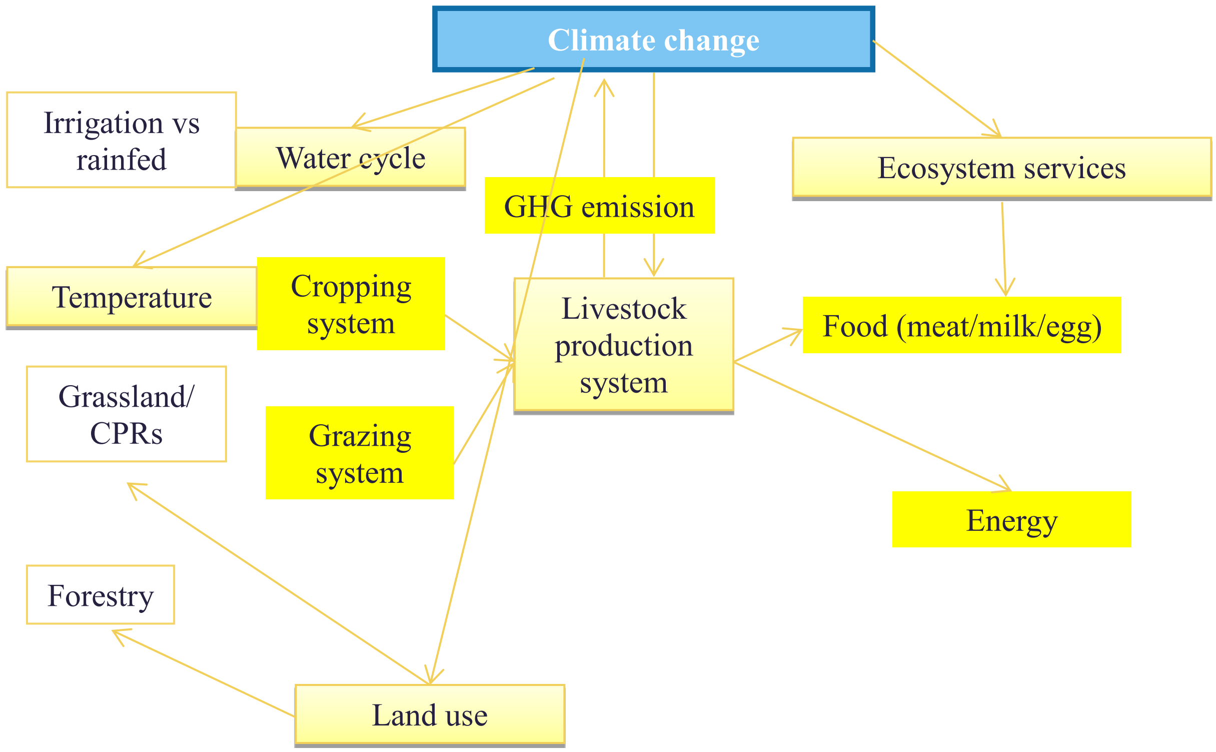

Fig-1. Indicators of climate impacts on animal-agricultural systems (Modified Hatfield *et al*., 2020)

Candidate indicators

There are different layers of climate change indicator in livestock production system. In the ambience the major indicators are temperature and RH/rainfall. However, th eanimals are impacted by micro-climate of the shed they are residing. Indicators meeting these criteria and assessed for their potential as viable indicators to detect agricultural response to climate change are described in Table 1.

Table-1. Indicators of animal-agriculture to climate change

Components	Climate factor	Impact	Indicator
Livestock	Extreme cold/heat stress	Morbidity, mortality, productivity	THI/HLI/Animal based indicators
	Extreme climate events	Morbidity, mortality, productivity	Annual sum of climate index
	Interaction of moisture, temp	Disease incidences	Morbidity/mortality
Soil/water	Intense rainfall	Soil & nutrient loss	Rainfall intensity
	Rainfall	Soil water content	Water availability for crop
Plant	Temperature	Phenology/growth period	Phenology, quality
	Combinations of temp., humidity, rainfall	Productivity/biomass/pests	Productivity/pest incidence
Economics	Extreme temp./ precipitation/contingencies	Loss of productivity/ crop-livestock losses	Insurance claims/indemnities

1. Livestock heat stress

Livestock are impacted by climate change, and the potential occurrence of extreme temperature events can disrupt the ability of animals to produce. The immediate indiactors of heat stress in livestock have been compiled in fig 2.

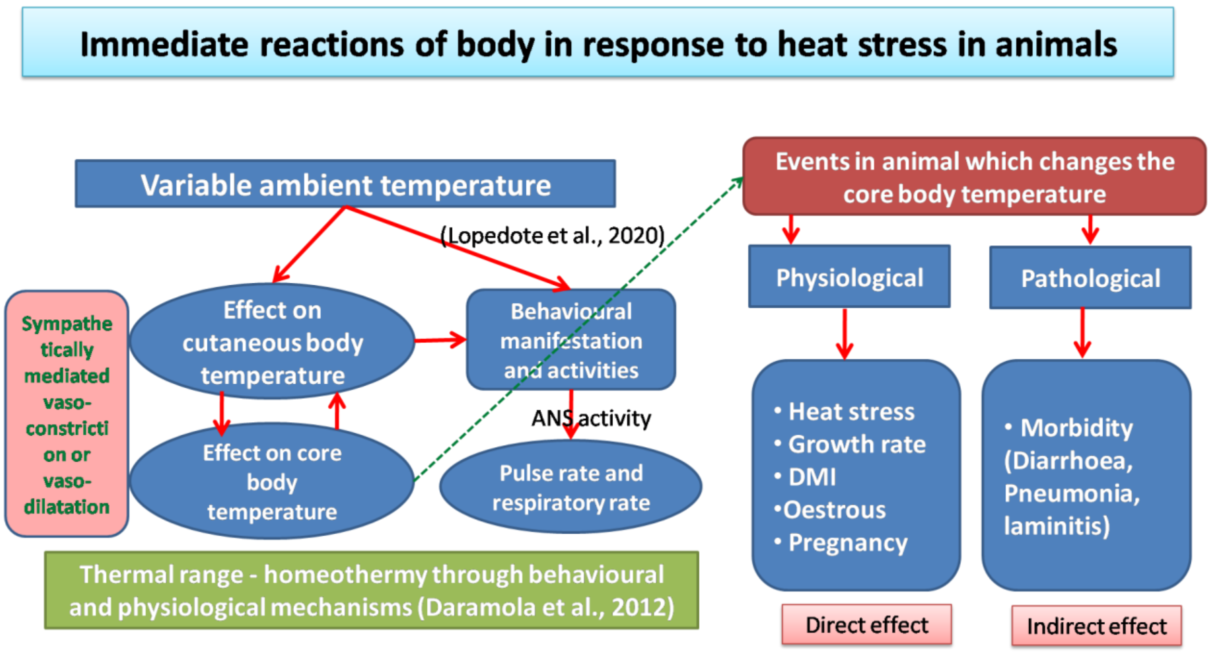

Fig 2. Immediate reaction of body in response to heat stress (Compiled by author)

Economic losses from reduced performance of livestock experiencing severe environmental stress is the major indicator apart from morbidity and mortality. Exposure to heat stress has a large impact on livestock performance and well-being. Moisture and heat content of the air, thermal radiation, and airflow impact total heat exchange between the atmosphere and an animal. Thus, the effective, or apparent, temperature that an animal responds to is a combination of environmental variables and is indicated in livestock in terms of performance, health, and well-being.

Indices, because they combine several environmental components, are much more robust for characterizing environmental effects on animal productivity and well-being. To overcome the shortcomings of using ambient temperature as the only indicator of animal stress, thermal indices have been developed to better characterize the influence of multiple environmental variables on the animal. The temperature-humidity index (THI) has been extensively applied in moderate to hot conditions, even with recognized limitations related to wind speed and radiation heat loads. For cold conditions, the wind-chill index (WCI), relating air temperature and wind speed to the time required for freezing a small cylinder of water, serves as a rough guide for measuring cold stress.

Physiological and metabolic responses can also be better assessed based on apparent temperature. Multi-factor indices are needed that are comprehensive in nature, which allow for greater application across a range of conditions and have potential for use in assessing environmental effects on animal health, welfare, and productivity. Increased probabilities of extreme events and the impact on livestock productivity increase the potential use of an indicator capable of quantifying the extent of disruption in livestock production.

2. **Land use:** Soil erosion rates respond to climate change for a variety of reasons, including climatic effects on plant biomass production, plant residue decomposition rates, soil microbial activity, evapo-transpiration rates, soil surface sealing and crusting, and shifts in land use necessary to accommodate a new climatic regime. Due to direct and indirect impact of CC on agricultural resources, land use pattern is a wonderful indicator at field level.
3. **Soil organic matter changes:** Soil organic carbon, a key indicator of ecosystem productivity and health, is affected by abiotic and biotic factors. Soil organic carbon monitoring in agricultural fields can serve as an indicator of how agriculture might be affected by climate variability and change and how these effects and changes affect carbon reservoirs as part of mitigation strategies. However, differentiating the interacting effects of climate and management has proven difficult.
4. **Crop and livestock productivity:** Production of food from crops and livestock is necessary to sustain life, and there is continuous need to produce more food. Impacts of climate change on plant production can be summarized as being positive under the effects of increasing carbon dioxide (CO_2), negative with effects of increasing temperatures, and variable from precipitation timing and amounts. The effect of increasing CO_2 on plant productivity is generally positive with enhanced production and improved water use efficiency (Hatfield et al. 2011). There is impact on quality of the produce also like milk quality, feed and fodder quality, meat quality apart from quantity.
5. **Productivity of agricultural systems:** is the most used indicator of climate impacts. This approach allows for a quantitative assessment of the ability of the crop to achieve its potential yield and the inability of closing the yield gap is ascribed to climatic stress.
6. **Economic impacts of climate change:** One measure of the potential economic impacts of extreme events within the agricultural sector, as well as an indicator of whether such impacts are increasing as climate conditions change, could be derived from crop-animal insurance claims and payouts. Developing indicators related to the change in the distribution of indemnities provide a quantitative measure of the effect of changing climate; however, not all commodities are crop insurance eligible, so the economic impact is more difficult to assess. Many researchers have assessed the economic impact of different diseases like mastitis, FMD, Blue tongue, etc.
7. **Natural resource indicators in livestock production systems:** Several sets of indicators are available with respect to natural resource available at a particular location. It is important to assess whether the particular area is more climate resilient as compared to others. The details of such indicators have been portrayed in Table 2. They are in general response indicators, because these can be most easily defined for the animals put under grazing system at the small and marginal farmer's household.

Table 2. General response indicators for animals reared under grazing system of management

Category	Natural resource base	Livestock	Socio-economic
Soil/land	• Erosion • Land use • Presence and use of legumes • Manure collection & application practices	• Herd mobility • Stocking rate • Productivity trends	• Livestock carrying capacity of the land • Vulnerability to drought • Infrastructure • Diversity of land use
Vegetation	• Proportion of ground cover • Plant species • Presence and use of leguminous plants • Utilization of crop residues • Pastures and native rangelands • Rate of deforestation	• Forage demand • Diet preferences • Animal productivity • Species composition	
Water	• Water turbidity • Water quality	• User requirements	
Air	• Greenhouse gas balance • Manure application techniques	• Greenhouse gas balance • Quality of animal diets • Number of animals	

Apart from this, there are indicators related to industrial livestock production systems. Sustainability as well as climate resilience can be assessed very well by using such indicators as shown in Table 3.

Table 3. General response indicators for animals reared under intensive system

Input-related	Production-related	Output-related
• Land use changes • Land requirements for feed production	• Conversion efficiencies for N and P by animal species	• Manure discharge • Nutrient balances
• Percentage of grains in concentrates and diet	• Farmgate N and P balance	• Fertilizing value of manure
• Rangeland requirements	• Ammonia emissions	• Methane emissions
• Livestock breeds used	• Methane emissions	• Tons of live weight slaughtered
• Inputs to feed production (fuel, fertilizer)	• Fossil energy consumption	• Tons of raw milk
	• Animal welfare index	• Tons of raw hides processed
	• Chemical use	• Manure storage

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VULNERABILITY AND RISK ASSESSMENT OF CLIMATE CHANGE FOR ANIMAL HUSBANDRY

C. A. Rama Rao

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad

Livestock is an important component of the broader agricultural sector in the country. While the contribution of agriculture to country's GDP is decreasing over time because of the faster growth in secondary and tertiary sectors, the contribution of livestock to agricultural GDP is increasing over time. At present, livestock accounts for nearly a third of value of agricultural production. There have been tremendous gain productivity and production in case of milk, meat, eggs and other livestock products. The growth in livestock sector is largely influence by demand growth occurring due to increasing population, rising incomes, expanding urbanization and changing food and dietary preferences. The performance of livestock is key to achievement of sustainable development goals related to poverty reduction, zero hunger and climate action. That the distribution of livestock is more egalitarian than that of land, dominance of female workers in livestock rearing further underscores the importance of livestock sector. Livestock sector is also largest emitter of greenhouse gases within agriculture.

However, as with other sectors, livestock sector is also challenged by increasing climate variability and climate change among other things. What is unique with respect to livestock is its role in adaptation as well as in mitigation. There are, broadly, three types of livestock systems in practice in the developing countries of Asia and Africa: (i) Agro-pastoral and pastoral systems, (ii) Small holder crop-livestock systems and (iii) Industrial livestock systems (Thornton *et al*., 2007). Livestock rearing in India is largely done in the form of mixed crop-livestock systems, though there are pastoral communities that predominantly rely on grazing. Nomadic communities rearing the small ruminants in the arid parts of north-west India, dairy sector and poultry sector are dominant examples of these three livestock typologies respectively.

The impacts of climate change on livestock is both direct, by affecting growth and physiology of animals or birds, the pest and disease incidence, and indirect, by affecting the availability of fodder and water. In order to minimize the adverse impacts of climate change on livestock sector and on those whose livelihoods are linked to sustained well-being of livestock systems, planning and implementation of adaptation strategies is essential. A purpose-oriented vulnerability and risk assessment is a necessary and useful precursor to such adaptation planning.

Climate change risk and vulnerability assessment

Climate change literature is rich with studies on such aspects as vulnerability, resilience, adaptation, risk, hazard, etc. many of which have been used with different connotations and in varying contexts. It is therefore important to understand what these terms and concept mean in the context of climate change. Given the multiple definitions and conceptualizations by researchers from various fields, the views on such terminology given by the IPCC may be more pertinent and acceptable while we are concerned with climate change.

The IPCC's Fifth Assessment Report (AR5) proposes a framework where in vulnerability is placed as one of the determinants of risk, the other two being 'exposure' and 'hazard'. The definitions given by AR 5 for risk and its components (Oppenheimer, et al., 2014) are given below:

Exposure:

The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability:

The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

A broad set of factors such as wealth, social status, and gender determine vulnerability and exposure to climate-related risk.

Impacts:

(Consequences, Outcomes) Effects on natural and human systems. In this report, the term impacts are used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Hazard:

The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

Risk:

The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.

Risk = (Probability of Events or Trends) × Consequences

Risk results from the interaction of vulnerability, exposure, and hazard.

The AR5 risk conceptualization furthers the risk analysis by identifying two kinds of risk: key risks and emergent risks. Key risks are potentially severe consequences arising when systems with high vulnerability interact with severe hazards. Different criteria are suggested to categorize a risk as key which are based on the magnitude of the risk, high vulnerability of a particular group of population, criticality of the sector in the economy. Emergent risks are those that are not direct consequences of climate change hazard but are results of responses to climate change. For example, migration of population from a region due to climate change related hazards may increase the vulnerability and thus risk of receiving regions; similarly, increased groundwater extraction during a drought may increase the vulnerability and risk in future. Thus, emergent risks are a result of spatial linkages and temporal dynamics related to responses to changing climate.

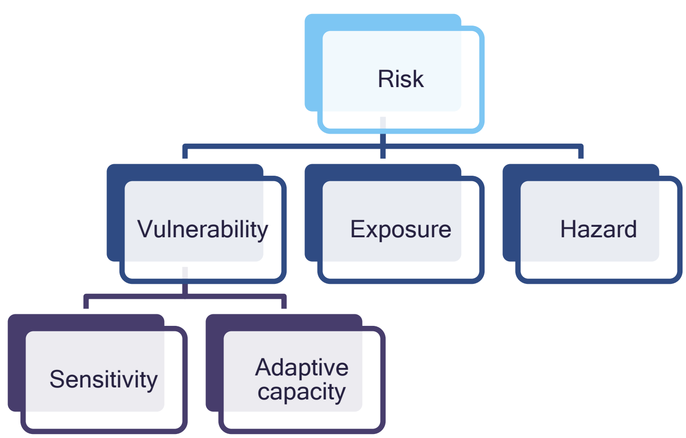

Fig. Schematic diagram of climate change risk

Vulnerability and risk assessment

There are a variety of approaches and methods to assessing vulnerability and risk. Simulation modelling, physical experimentation, agro-ecological modelling, statistical or econometric modelling, and indicator method are some of such methods. The choice of approach and method is determined by the purpose of assessment, scale of assessment, availability of data, financial and human resources. While most of these methods vary in terms of data requirements produce a quantified measure of vulnerability or risk. For example, various modelling-based studies showed possible reduction in milk production due to the climate-change induced rise in temperature and rainfall. Indicator method is somewhat different from other methods in that it leads to an assessment that gives relative vulnerability or risk of different entities subjected to assessment. Thus, this method helps identify 'hot spots' for targeting and prioritizing investments and interventions. It is one of the most frequently used method in vulnerability assessments.

The following diagram summarizes the process of indicator method of climate change risk assessment (Rama Rao et al., 2019):

Selection of indicators

As mentioned above, climate change risk contains three components: exposure, vulnerability and hazard. Indicators are those variables that reflect the underlying phenomenon of interest. It is this 'significance' to the phenomenon/ issue being addressed that makes an indicator out of a variable. Further, the indicators ideally should have a monotonic relationship with the underlying phenomenon over a reasonable range of values that they may take. In the present context, the three components of risk are represented through a number of indicators that would reflect these components. These indicators were chosen from a broader list of indicators based on review of literature, discussions with the experts and nature of relationship with the three components. The determinants of hazard are derived from climate projections and/or historical climate data depending on the context and purpose (Rama Rao et al., 2013).

Normalization of indicators

Often the indicators to be aggregated are measured in different units. It is necessary to bring all the indicators to be aggregated to a common scale. Statistics offer a gamut of normalization techniques. Choice of normalization technique depends on the data properties, context of the study and objectives of the composite index. Min-max, standardization, ranking, distance to a reference point are some of the frequently used normalization methods.

Assigning weights to different indicators

Assigning weights to normalized indicators while aggregating is at the core of the composite index building. Though no universally agreed methodology exists in this regard, different data driven and participatory methods can be used. The weights should reflect the relative importance of indicators in determining vulnerability. The methods of weighting may be classified in to three groups: (a) Equal weights, (b) Differential weights based on statistical models and (c) Differential weights based on public/expert opinion.

Method of aggregation to build a composite index

Method of aggregation also has a bearing on results. It is usual practice to use linear aggregation method. It proves to be a better choice if strength indicated in one dimension can compensate weakness indicated in another dimension which is known as compensability. If some degree of non-compensability is desired in the composite, multiplicative or geometric aggregation is a better choice. Geometric aggregation rewards those units with higher scores. Rama Rao et al. (2013, 2016) used linear aggregation while assessing vulnerability of agriculture to climate change in India at district level. UNDP (2016) used geometric aggregation to construct human development index (HDI), a composite of health, education and income.

Categorization of study units

Planners and policy makers usually like to have the output in the form of groups of study units like poor, better, best; which indicate action. Categorization of study units into groups should be done with consideration of normalization technique used and the objectives of the composite index. If Min-Max normalization technique is used, the composite index serves as a measure of relative vulnerability. Composite score of zero implies lowest and a score of one implies highest degree of (vulnerability/risk etc) among study units.

Some example indicators for various components of climate change risk Vulnerability:

Indicator	Rationale and relationship
Crop-livestock integration	The higher ratio indicates higher amount of organic matter available thereby improving moisture retention capacity of soil for a longer duration and hence lesser vulnerability to drought
Employment diversification	More diversified income sources offsets the income loss due to crop failure in uncertain rainfall. Hence, the more the employment diversification, the lesser the vulnerability
Herd size	The more the livestock holding, the lesser the vulnerability
Access to Technology	Access to technology reduces vulnerability
Access to land resources	The more the land holding, the lesser the vulnerability because it can serveas a cushion to absorb shock by utilizing this asset as a collateral to get loanin dire need or sell in hard times
Access to irrigation	The more the ratio, the lesser the vulnerability
Dependency ratio	The higher the ratio, the higher the vulnerability
Literacy	The more the education of the farm manager, the less the vulnerability
Farming experience	The more the farming experience, the lesser the vulnerability
Gender	Women can have a more difficult time during recovery than men, often due to sector-specific employment, lower wages, and family care responsibilities
Access to social networks	Access to social networks decreases vulnerability
Access toagricultural training	Access to agricultural training, decreases vulnerability
Access to market	Lesser the distance, the more the access to market, hence the lesser the vulnerability.

Source: Gurung et al., (2011)

In such cases, the units should be ranked based on composite score and be divided into equal groups and the number of groups may be determined from planning perspective. If the method of normalization used is z score, the units with composite score around zero may be regarded to have moderate vulnerability or risk. Absolute value of composite score will have a meaning if distance to a reference is used as a normalization method.

Exposure

- No. of livestock
- No of improved/cross-bred animals
- No. of farmers having livestock
- Area under forage/fodder crops

Hazard:

Changes in temperature, rainfall, relative humidity and the resultant changes in Thermal Heat Index.

Summing up

Livestock is an important sector contributing to livelihood security, food and nutrition security. Within agriculture, it is an important adaptation and risk management component against climate variability and risk. It is however a significant emitter of GHG gases. Given that the sustainability of livestock sector is challenged by a number of factors including global environmental change, there is a need to evolve and promote appropriate adaptation and mitigation strategies. A properly planned vulnerability and risk assessment will help identify 'hot spots' and interventions for vulnerability reduction and risk management. Out of the three components of risk, addressing vulnerability through appropriate measures is likely to be more useful as the other two components take longer to be managed through policy measures.

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AGRO-METEOROLOGICAL BASIS OF EXTREMES OF TEMPERATURE WITH SPECIAL PERSPECTIVE TO LIVESTOCK AND POULTRY

Santanu Kumar Bal

PC, AICRPAM, ICAR – Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad

Introduction

Livestock is an integral part of agricultural system since the majority of the world's poorest and hungry people depend on it for their livelihoods. However, livestock production in turn is critically affected by weather and climate related variability and extremity. In spite of large-scale development of breeds and production technologies to optimize and sustain the livestock productivity in the recent past, the latter continues to be affected significantly by number of climate variability factors. These factors like temperature, relative humidity, light, availability of water, mineral nutrients, CO_2, wind, ionizing radiation or pollutants determine livestock growth and development (Bal and Minhas, 2017). Effect of each atmospheric factor on the livestock depends on their intensity and duration of act. For optimal growth, the animals require a certain quantity of each of the environmental factors, and any deviation from such optimal conditions adversely affects its productivity through animal growth and development. Stress factors especially extreme temperatures play critically on the growth and development of livestock and poultry. As climate change has become a reality, the implications of global warming for changes in extreme temperature events are of major concern for agrarian as well as civic society (Bal and Minhas, 2017). Over the last couple of years, we experienced typical events, i.e., Kuwait reporting snow; Paris sweltering in 40°C heat; Delhi froze with below 0°C; across pan India there were unprecedented hailstorm events; and many more. in this chapter, we will look at few aspects of impact of extreme temperatures on livestock and poultry and some of the management strategies to cope with it.

1. Impact of high and low temperature on livestock

1.1. High Temperature

1.1.1. Livestock

Under heat stress, a number of physiological and behavioral responses of livestock vary in intensity and duration in relation to the animal geneticmakeupandenviron-mental factors (Freeman, 1987). Heat stress is one of the most important stressors especially in hot regions of the world. In humid tropics along with extended periods of high ambient temperature and humidity, the primary non-evaporative means of cooling (viz., conduction, convection and radiation) becomes less effective with rising ambient temperature, and hence under such conditions, an animal becomes increasingly reliant upon evaporative cooling in the form of sweating and panting to alleviate heat stress (Kimothi and Ghosh, 2005). In north Indian condition, livestock begins to suffer from mild heat stress when thermal heat index (THI) reaches higher than 72, moderate heat stress occurs at 80 and severe stress is observed after it reaches 90. Thermal stress lowers feed intake and reduces animal productivity in terms of milk yield, body weight and reproductive performance. Heat stress reduces libido, fertility and embryonic survival in animals. Enhanced heat dissipation during heat stress may also lead to electrolyte losses (Coppock et al., 1982).

The poor reproductive performance in buffaloes especially during summer months is due to inefficiency in maintaining the thermo-regulation under high environmental temperature and relative humidity (RH) as those have dark skin and sparse coat of body hair which absorb more heat alongwith poor heat dissipation mechanism due to less number of sweat glands (Maraiand Haeeb, 2010). Similarly, heat stress in lactating dairy cows causes significant loss of serum $Na^{+}$and K^{+} (West, 1999) and also reduces birth weights of Holstein calves (Collier et al., 1982). High ambient temperature can adversely affect the structure and physiology of cells as well as functional and metabolic alterations in cells and tissues including cells of immune system (Iwagami, 1996). Heat stress in lactating animals results in dramatic reduction in roughage intake, gut motility and rumination which alters dietary protein utilization and body protein metabolism (Ames *et al*., 1980). Temperature extremes can influence disease resistance in dairy calves (Stott *et al*., 1976).

1.1.2. Poultry

Heat stress interferes with the broilers comfort and suppresses productive efficiency, growth rate, feed conversion and live weight gain (Etches *et al*., 1995; Yalcin et al., 1997) due to changes in behavioural, physiological and immunological responses. With rise in ambient temperature, the poultry bird has to maintain a balance between heat production and heat loss. This forces the bird to reduce its feed consumption by 5% to reduce heat from metabolism to a tune for every 1°C rise in temperature between 32-38°C (Sohail *et al*., 2012). In addition, heat stress leads to reduced dietary digestibility and decreased plasma protein and calcium levels (Bonnet *et al*., 1997; Zhou *et al*., 1998). Heat stress limits the productivity of laying hens, as reflected by egg production and egg quality, as the bird diverts feed metabolic energy to maintain its body temperature and also lower egg production and egg quality (Hsu *et al*., 1998). The resulting hyperventilation decreases CO_2 blood levels, which may decrease egg shell thickness (Campos, 2000). Plasma triiodothyronine and thyroxine, which are important growth promoters in animals, adversely affect heat-stressed broiler chickens (Sahin *et al*., 2001).

There are direct effects on organ and muscle metabolism during heat exposure which can persist after slaughter (Gregory, 2010); however, chronic heat exposure negatively affects fat deposition and meat quality in broilers (Imik *et al*., 2012). In addition, heat stress is associated with depression of meat chemical composition and quality in broilers (Dai *et al*., 2012). Chronic heat stress decreased the proportion of breast muscle, while increasing the proportion of thigh muscle in broilers (Lara and Rostagno, 2013) and protein content lower and fat deposition higher inbirds subjected to hot climate (Zhang *et al*., 2012). Heat stress causes decrease inproduction performance, as well as reduced eggshell thickness and increased egg breakage (Lin *et al*., 2004). Additionally, heat stress has been shown to cause a significant reduction of egg weight, egg shell weight, eggshell per cent (Lara and Rostagno, 2013) and all phases of semen production in breeder cocks (Banks *et al*., 2005). In hotter climate, immune-suppressing effect of heat stress is more on broilers and laying hens (Ghazi *et al*., 2012) and will alter global disease distribution (Guis *et al*., 2012) through changes in climate. This may also increase the insect vectors, prolong transmission cycles or increase the importation of animal reservoirs. Climate change would almost certainly alter bird migration and directly influence the virus survival outside the host (Gilbert *et al*., 2008).

1.2. Low Temperature

1.2.1. Livestock

Despite the absence of a challenge to homeothermy in cattle, there are marked seasonal fluctuations in the cattle’s level and efficiency of production which probably arise from hormonal and adaptive changes occurring as a consequence of mild cold stress (Young, 1981). In cold stress, cow’s requirement for nutrient and energy intake increases due increased metabolism rate (FAO, 2016). Prussic acid poisonings occur in areas associated with light frost. Cold condition stimulates appetite of animals, which may be slightly beneficial for production but the same may reduce utilization efficiency of dietary energy (Young 1981). Cold environment increases the whole-body glucose turnover and glucose oxidation, thus resulting in less production of ketones and resulting increased metabolic rate (Ravussin *et al*., 2014).

1.2.2. Poultry

Cool temperatures are the primary triggers for the accumulation of fluid causing abdominal swelling (ascites) during commercial broiler production (Wideman, 2001) which accounts for losses of about US$1 billion annually worldwide (Maxwell and Robertson, 1997). The incidences are higher in the colder environ-mental temperatures (Yahav *et al*., 1997), because cold ambient temperatures increase the cardiac output, oxygen requirement and blood flow and result in increased pulmonary arterial pressure overload on the right ventricle (Julian *et al*., 1989). In white Leghorn hens, a reduction in environmental temperature from 20 to 2°C almost doubles the oxygen requirement (Gleeson, 1986). During the development of ascites, birds exhibit classic haemato-logical changes. Haematocrit, haemoglobin and red blood cell counts (RBC) allincrease dramatically (Maxwell *et al*., 1987). Birds exposed to cold stress have severely injured liver and affects thyroid hormones which play a key role in energy expenditure and body temperature homeostasis (Nguyen *et al*., 2016). Moderate cold exposure during early post-hatching period causes long-term negative effect on growth performance of chicken (Baarendse *et al*., 2006).

2. Management Strategies to cope with high and low temperature

Global climate change will have significant impacts on future agriculture, and therefore climate change mitigation for agriculture is a global challenge. In a country like India, one of the most vulnerable countries owing to its large agricultural sector, vast population, rich biodiversity, long coastline and high poverty levels will be severely affected by climate change if new strategies for amelioration are not devised (Fischer and Edmeades, 2010). For this a thorough, understanding is required for various physical, physiological, metabolic and biochemical processes that occurs in normal as well as stresses environments so as to form the basis for developing climate smart mitigation strategies. Nevertheless, plant and livestock responses to high temperatures clearly depend on genotypic parameters, as certain genotypes are more tolerant (Prasad *et al*., 2006). Though plants adapt to various stresses by developing more appropriate morpho-logical, physiological and biochemical characteristics, analysing plant phenology in response to heat stress often gives a better understanding of the plant response and facilitates further molecular characterization of the tolerance traits (Wahid *et al*., 2007). As far as atmospheric stresses are concerned, a complete insight of the bio-logical processes behind the atmospheric stress response combined with classical and emerging technologies in production, breeding and protection engineering is likely to make a significant contribution to improved productivity and reduction inlosses. The following section contains some of the adaptation and management options available to mitigate those atmospheric stresses.

2.1. High Temperature

2.1.1 Livestock

In animal husbandry, physical modifications of environment, genetic development of heat tolerant breeds and nutritional stress management are the three major key components to sustain production in hot environment (Beede and Collier, 1986). Antioxidants, both enzymatic and non-enzymatic, provide necessary defense against oxidative stress as a result of thermal stress (Rahal et al., 2014). Additional supplementation of electrolytes (Na, K and Cl) is one among the nutritional strategies which has beneficial effects in heat-stressed dairy cows in terms of milk yield, acid base balance and lower temperature (Sanchez *et al*., 1994). Lactating cows and buffaloes have higher body temperature of 1.5-2°C than their normal temperature. Therefore, to maintain thermal balance, they need more efficient cooling devices to reduce thermal load.

2.1.2 Poultry

In hot and humid environment, poultry shades should be designed as an open style house with proper shading for adequate air movement, grass cover on the ground surface to reduce sunlight reflection and shiny surface roof for more reflection of solar radiation. During hot periods, lower-protein diets supplemented with limitingamino acids should be replaced with high-protein diet (Pawar et al. 2016). Glucosein drinking water helps in alleviating the influence of heat stress on whole-blood viscosity and plasma osmolarity (Zhou et al. 1998). Aviaries should be equippedwith overhead sprinkler systems, which cool the air and reduce the chances of heatinjuries. Addition of ammonium chloride and potassium chloride to drinking wateris desired to maintain carbon dioxide and blood pH under control. Vitamin E supplementation is beneficial to the egg production of hens at high temperature and associated with an increase in feed intake (Kirunda et al. 2001).

2.2. Low Temperature

2.2.1 Livestock

The problem of fodder poisoning can be prevented or at least minimized with proper management of the fodder field and feeding pattern. Removing livestock from pastures for several days after a frost is the best preventative management strategy to reduce prussic acid poisoning in case of Sudan grass and sorghum-Sudan grass pastures (Lemengar and Johnson 1997). In periods of coldweather, provision of windbreak is to be made enabling the cows to take shelter inthe leeward side of the cold wave and preferably reducing the walking area so that animals stand in a group to stay warm. Appropriate nutritional supplementation is the key to managing cold stress.

2.2.2 Poultry

Poultry house made up of low-heat-conducting materials like bamboo and wood helps to maintain optimum night temperature in the shelter. In addition, with the help of light bulbs and physical barriers, movement of chicks should be restricted nearer the heat source. The orientation of poultry house should be east-west alignment for proper ventilation and to gain maximum solar energy during winter. Thesurface of poultry house should be covered with a bedding material called litter; it maintains uniform temperature and also absorbs moisture and promotes drying (Banday and Untoo, 2012). In winter season, energy-rich source like oil/fat should be added to the diet so that the requirement of other nutrients will be reduced.

Way forward

Since unusual atmospheric events are becoming usual events, to make future agriculture remunerative, risk-free and sustainable, first the dynamic characteristics extreme temperatures have to be understood. There are, however, ways by which the adverse impacts can be mitigated, and agriculture can be adapted to changing scenarios. With unprecedented increase in demand for animal proteins, our prime focus must be towards developing low-cost environment suitable animal shelter structures for improved animal production and wellness. Future research in livestock must be done keeping a balance between competition for natural resources and projected atmospheric anomalies as unlike crop production where there will be a vertical growth; however, livestock production is expected to have a horizontal growth. A large agenda of work still remains concerning the robust prediction of animal growth, body composition, feed requirement and waste output. Lastly the use of biotechnology can’t be ignored if we want to impart heat-tolerant traits inhigh meat and milk yielding breeds. As poultry meat is the cheapest source of proteins, this sector has potential to provide food and livelihood securities to major chunk of Indian population. With emergence of heat stress as one of the major problems in Indian poultry industry, our primary area of focus should be to explore innovative approaches, including genetic marker-assisted selection of poultry breeds for increased heat tolerance and disease resistance for better productivity. Application of modern molecular techniques in poultry breeding has great potential to improve poultry productivity in a sustainable manner. Simultaneously, the possibilities of heat stress mitigation must be explored in terms of designing of suitable poultry housing for hot regions. Nutrition being one of the major factors in mitigating heat stress, study of the nutrient supplementation and feeding practices should be given priority.

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PHYSIOLOGICAL BASIS OF CLIMATE CHANGE IN LIVESTOCK

Aditya Mishra and Pragati Patel
Department of Veterinary Physiology and Biochemistry, College of Veterinary Science and Animal Husbandry, NDVSU, Jabalpur

Introduction

Climate change is the most important and challenging rigor affecting almost all the livestock species substantially. Climate change is adding a lot of issues pertaining to maintenance of ecological balance amongst the livestock population. Increased demands and present nutrition availability is adding more challenges to livestock in changing climatic scenario. Rising global earth surface temperature is one of the most intriguing factors emerging from the changing climate. According to the fifth IPCC Assessment report (AR5), by the end of 2100 global surface temperature is expected to rise by 1-7 °C (IPCC 2013). Globally, about 17% of the kilocalorie consumption and 33% of the protein consumption is contributed from the various livestock commodities (Rosegrant *et al*., 2009). According to FAO (2015), the global demand for livestock products are expected to double by 2050 due to the improved standard of living and the rising population. Moreover, the climate change induced heat stress has established as one of the crucial factors affecting livestock production. Heat stress may decrease milk production and quality, meat production, reproductive efficiency and animal health (Sejian *et al*., 2016).

Heat stress is said to be the most important factor affecting livestock productivity. Ability of to cope up with adverse climatic conditions is usually defined as Adaptation. Adaptation to prolonged heat stress may lead to production losses (Sejian *et al*., 2010). In order to maintain the body temperature in heat stressed animal, they initiate compensatory and adaptive mechanisms like behavioural and physiological changes to re-establish homeothermy and homeostasis which promote welfare and favour survival in a specific environment (Indu *et al*., 2015). Stress is a reflex reaction revealed by the inability of an animal to cope with its environment, which may lead to many unfavorable consequences, ranging from discomfort to death. It covers the behavioral and biological responses to a wide range of abiotic stressors such as social interactions or rough handling, common farm practices, improper feeding, exposure to adverse climatic conditions, exercise, work and transport etc. Heat stress can be defined as the point where the animal cannot dissipate adequate quantity of heat to maintain body thermal balance. Climatic factors that may influence the degree of heat stress include: temperature, humidity, radiation and wind. The environmental conditions that induce heat stress can be calculated using the temperature humidity index (THI).

THI = (DRY BULB TEMPERATURE ^{0}C) + (0.36 * DEW POINT TEMPERATURE ^{0}C) + 41.2

When the THI is >72°F (22.2°C), heat stress begins to occur in dairy cattle. Table 1 contains some of the signs that cows exhibit as the THI increases. Effect of heat stress on dairy cattle is depicted below.

THI	Stress Level	Effects
<72	None	
72-79	Mild	Dairy cows will adjust by seeking shade, increasing respiration rate and dilation of the blood vessels. The effect on milk production will be minimal.
80-89	Moderate	Both saliva production and respiration rate will increase. Feed intake may be depressed, and water consumption will increase. There will be an increase in the body temperature. Milk production and reproduction will be decreased.
90-98	Severe	Cows will become very much uncomfortable due to high body temperature, rapid respiration (panting) and excessive saliva production. Milk production and reproduction will be markedly decreased.
>98	Danger	Potential cow deaths can occur

Physiological responses and climate change in livestock

Physiological adaptability is the modifications in the behavioural or metabolic esponse in animals to cope with the extreme climatic conditions. The exposure of animal to high quantum of heat stress induces an increase in the dissipation of excess body heat to the environment to negate heat load in their body (Al-Haidary *et al*., 2012). Further, dissipation of excess body heat is brought by the physiological responses including RR, RT, PR, ST, and SR (Sharma *et al*., 2013). The ability of an animal to withstand the rigors of climatic stress under warm conditions had been assessed physiologically by the means of changes in body temperature, respiration rate and pulse rate (Sethi *et al*., 1994). The animals panted in order to increase body cooling by respiratory evaporation. Increase in RR is the first reaction when the animals are exposed to environmental temperature above the thermoneutral zone (Maurya *et al*., 2007). The changes in the RR are an adaptive response of the animal to maintain homoeothermic balance. In domestic animals, RR increases due to the activation of thermo-receptors in the skin when they are exposed to higher ambient temperature. Such activation of the receptors, in turn, sends neural signals to the hypothalamus that increases respiratory activity to accelerate heat loss from the body by respiratory evaporation (Haidary and Ahmed, 2004). The increase in PR causes an increase in the blood flow to the surface and thereby facilitates heat loss (Marai *et al*., 2007). The best physiological parameter to objectively monitor animal welfare in hot environment is the RT (Silanikove, 2000 and Keim *et al*., 2002).

Milk yield increased significantly ($p<0.05$) during summer season while body condition score did not exhibit any significant change in either of the breeds. No significant differences were observed between the two breeds in milk yield within season. Generally, high ambient temperatures depressively affect milk production (Shibata, 1983). Araki *et al*. (1984) reported that lactating cows were more sensitive to the effect of heat than were non-lactating cows, consistent with the greater metabolic heat production. It has been well documented that temperature humidity indices differ in their ability to detect heat stress. Indices with larger weights on humidity seem to be more suitable for humid climates. In climates where humidity does not reach levels that could compromise evaporative cooling, indices with the most emphasis on ambient temperature are preferable (Bohmanova *et al*., 2007).

Jitender *et al*. (2017) reported that relative humidity remained moderate, at 56.71 % during summer season, even though THI was increased to 86.83, signifying that increase in THI is not affecting the milk yield during summers. Whereas, milk yield was reduced during winter season exhibiting that, reduction in ambient relative humidity and THI was not the critical factors affecting milk production but reduction in minimum temperature during winters is acting as the critical factor affecting milk productivity. Leptin concentration increased significantly ($p<0.05$) during summer as compared to winter in both the breeds). Hariana cattle exhibited a significantly ($p<0.05$) lower leptin concentration than Sahiwal cattle during winter Jitender *et al*., (2017). Leptin is the key regulator of feed intake and energy homeostasis (Zhang *et al.*, 1994). Ronchi *et al*. (1999) reported that due to direct effect of heat stress, energy and lipid metabolism and liver enzymatic activities are enhanced in periparturient dairy cows.

Effect of Heat Stress on Female Reproductive Functions

The negative effects of heat stress on dairy cows are multifaceted. Summer heat stress has long been recognized as reducing the reproductive efficiency of dairy cattle. Here are a few ways by which reproductive function is impaired by summer heat.

Oestrus expression:

Cows in heat stress conditions show fewer, less intense heats than in cooler temperatures. Studies have shown that undetected oestrous events were between 76 and 82% from June to September compared to 44 to 65% from October to May. Heat stress also decreases the length and intensity of oestrus. Heat stress decreased follicular estradiol which might decrease the oestrus intensity. Another reason of reduced oestrus expression might be the physical inactivity caused by heat stress. Cows are less active and therefore less likely to ride other cows during oestrus. So, in summer, dairy cows had approximately one-half the number of mounts per oestrus compared to dairy cows in winter. Oestrus activity is also lowered due to the cows' reduced motor activity, a means of trying to decrease her endogenous heatoutput.

Endocrine status:

Females raised under high temperatures have low estradiol. This decrease in estradiol synthesis could influence expression of oestrus, ovulation and corpus luteum. Thermal stress also alters goandotrophin, inhibin and $PGF_{2\alpha}$ secretion. The length of the luteal phase in heat-stressed cows is longer than in females kept in thermo-neutral environment. It seems that the uterus secretes less $PGF_{2\alpha}$ because of the reduction in estradiol synthesis and/or because high temperatures can interfere with the release of $PGF_{2\alpha}$ by endometrial cells. It's well known that the uterine endometrium must be primed by estradiol to produce enough prostaglandin and trigger luteolysis. Thermal stress also alters the concentrations of FSH and inhibin and corpus luteum function, as well as decreases the fluid content of follicles. High temperatures also reduce the number of granulosa cells, aromatase activity and secretion of androstenedione by theca cells (Wolfenson *et al*., 1993).

Follicular selection and development:

The first reproductive challenge facing the heat stressed cow is altered follicular development. Heat stressed cows decrease feed intake causing less frequent pulses of the luteinizing hormone (LH) resulting in longer follicular waves. This lengthening of the follicular wave leads to the selection and ovulation of multiple, smaller dominant follicles (Sartori, 2002). Follicles are responsible for producing estrogen, a hormone that causes cows to show signs of heat. Smaller follicles will produce less estrogen than larger ones; therefore, resulting in less oestrus activity. Ovarian follicles contain oocytes as well as somatic cells that synthesize estradiol. Estradiol has a variety of actions that include causing oestrus and the LH surge. Heat stress impairs follicle selection and increases the length of follicular waves, which reduces the quality of oocytes. It also allows for more than one dominant follicle to develop, explaining the increased twinning seen from cows conceiving in summer time heat.

Corpus luteum:

In addition to influencing the ovarian follicles, heat stress can affect the corpus luteum. Progesterone from the corpus luteum is required for pregnancy and there is an association between low progesterone and infertility. Estradiol from the follicle initiates luteolysis in cattle. The cells of the corpus luteum differentiate from the cells of the follicle. Therefore, if heat stress decreases blood progesterone then the decrease could arise from the effects of heat stress on the follicle which ultimately carries over to the corpus luteum. Alternatively, changes in metabolic rate associated with heat stress may alter the metabolism of progesterone.

Embryo development:

Embryo quality and growth is often reduced during heat stress. Thermal stress also alters the ability of embryos to develop into blastocysts. It causes early embryonic development, increased risk of early embryonic deaths and decreased foetal growth. There are effects of heat stress on the ovary and these effects may influence the ability of cows to become pregnant. The period of greatest susceptibility is immediately after the onset of oestrus and early during the post-breeding period. Putney *et al*. (1989) demonstrated that embryonic development was impaired in heifers subjected to heat stress for 10 hours after the onset of oestrus. The period of embryonic sensitivity to heat stress begins early during the development of the follicle and continues until about 1 day after breeding. The high uterine temperature of the heat stressed cow can impair embryonic development, resulting in poor embryo implantation and increased embryo mortality.

Conclusions

The various physiological responses such as respiration rate, rectal temperature, pulse rate, skin temperature and sweating rate gets altered due to various climatic variables alterations. As a mechanism of general adaptation syndrome, the animal tries to bring all the physiological parameters to physiological limits in changing climatic scenario.

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CLIMATE CHANGE AND ABIOTIC STRESS MANAGEMENT IN SMALL RUMINANTS

R. Pourouchottamane[1], P.K. Pankaj[2], Chetna Gangwar[1] and B. Rai[1]

[1] *ICAR-Central Institute for Research on Goats, Mathura*

[2] *ICAR-Central Research Institute for Dryland Agriculture, Hyderabad*

India has rich diversity of sheep and goat genetic resources and as per 20th livestock census (2019), there are 223.14 million small ruminants (148.88 million goats and 74.26 million sheep) in India. They are mostly found in arid and semi-arid regions of the country and one of the main stay of dryland agriculture system. Dryland agriculture occupies 68% of India's cultivated area and supports 40% of the human and 60% of the livestock population. It produces 44% of food requirements, thereby playing a critical role in India's food security. Geographically dryland agriculture area in India includes the north western desert regions of Rajasthan, the plateau region of central India, the alluvial plains of Ganga Yamuna river basin, the central highlands of Gujarat, Maharashtra and Madhya Pradesh, the rain shadow regions of Deccan in Maharashtra, the Deccan Plateau of Andhra Pradesh and the Tamil Nadu highlands (Rao and Ryan, 2004 and Singh et al., 2004).

Out of 74.26 million of sheep, 67.0 million are found in drylands (arid and semi-arid) of Telangana (19.1 m), Andhra (17.6 m), Karnataka (11.1 m), Rajasthan (7.9 m), Tamilnadu (4.5 m), J&K (3.2 m), Maharashtra (2.7 m) and Gujarat (1.8 m). Similarly, out of 148.88 million of goats, around half of them are found in Rajasthan (20.84 m), Uttar Pradesh (14.48 m), Madhya Pradesh (11.06 m), Maharashtra (10.6 m), Tamil Nadu (9.89 m) Karnataka (6.17 m) and Gujarat (4.66 m).

Hence, Small Ruminant Production System 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. In rural areas, most of the animals are reared under extensive systems, where in animals graze on road side, communal lands and a very few arable tethered systems using biomass from own lands or by products of arable cropping (Ramana, 2014). Further, dryland ecosystem is low in biomass production, accustomed with high climatic variability and water scarcity. The productive performance of animals in this area is affected by high grazing intensity, exposure to high environmental temperature and long-distance walking in search of grazing resources and scarcity of drinking water (Pankaj and Ramana 2013). The animal production is continuously subjected to so many stresses wherein the livestock has to cope with stressful conditions through physiological and behavioural adjustments; reproduce and survive in the given environment. Stress can be defined as the cumulative detrimental effect of a variety of factors on the health and performance of animal. The factors causing stress to the animals may be either of abiotic or biotic origin.

Abiotic stress is defined as the negative impact of non-living factors on the living organisms in a specific environment whereas biotic stress to the animals includes presence of living microorganism like bacteria, fungi, endo and ecto parasites causing mortality and morbidity as well as productivity loss in the herd.

The abiotic stress can be of many types like

1. Changes in temperature, humidity, Solar radiation, wind velocity.
2. Changes in rainfall pattern leading prolonged drought or floods.
3. Changes in availability of feed both quantity and quality (nutritional stress).
4. Stress associated with walking long distance in search of graze.
5. Transportation stress.
6. Improper shelters with high stocking density, less feed and water space etc.
7. Sudden changes in management routines of farm.

If abiotic stress is gradual and progressive over a period of time, the animals acclimatize itself to the changes in the environment, however if the stress is dramatic, it might lead to increased stress on the animal's homeostasis, leading to reduced productivity and affecting its reproduction. In addition to thermal and nutritional stress, water scarcity is another important limiting factor for any livestock production system especially in tropical countries like India. The changes in rainfall pattern may result in extended drought conditions or flood situation for which contingent plan to overcome the problem should be ready with the stakeholders.

India has witnessed around 25 major droughts in last 150 years and reasons for recurrent drought in India is due to multifactor such as

1. Major portion of country is rain fed with less than 50 % of the region covered by irrigation,
2. Over exploitation of ground water and inadequate storage measures for surface waters
3. Wide variation in rainfall across the region in relatively short window of south west monsoon from which 73% of total annual rainfall of the country received.
4. Around 68 % of the total cropped area in country falls under low (33 %) and medium (35%) rainfall zone making them chronically drought prone and drought prone area of the country. (Drought 2002)

These drought-prone areas are confined primarily to the arid, semi-arid, and sub-humid regions of peninsular and western India where sheep and goat production is the main stay livestock activity.

Drought is a temporary aberration, unlike aridity or even seasonal aridity (in terms of a well-defined dry season), which is a permanent feature of climate. Drought in contrast is a recurrent, yet sporadic feature of climate, known to occur under all climatic regimes and is usually characterized by variability in terms of its spatial expanse, intensity and duration (DACFW, 2016). Draughts can be classified into three types which are interlinked

Rainfall deficiency >>>> fall in ground/ surface water >>>>soil moisture depletion >>>> less crop productivity

- Meteorological drought when actual rainfall in given area is significantly lower than the long-term average for that area (even though region as a whole having normal monsoon)
- Hydrological drought when there is a marked depletion in surface and ground water levels leading to drying of water bodies and low water flow in rivers
- Agricultural drought when inadequate soil moisture resulting in water stress in crops and crop loss/ low productivity

Impact on small ruminant Production

Availability of the water is the major constraint that affects the animal production due to depletion of feed/ fodder resources setting in migration process thereby putting pressure in limited resources available in adjacent area as well as chance of spread of diseases. This is more serious in arid/ semi-arid region where sheep and goat farmers are relatively resource poor. Further, depending on the duration and severity of drought, the production and reproduction performance of the small ruminants are compromised as prolonged drought puts these animals under thermal, nutritional and water stress as well as to move long distances for want of feed and water (walking stress) leading to the disruptions in maintaining homeothermy, endocrine systems etc.

- Thermal Stress leads to excessive heat dissipation through sweating and evaporative water loss, increases turnover of Na and K, elevated prolactin concentrations, lowered metabolic rate in chronic stress as evidenced by lower concentration of growth hormone, thyroxin and glucocorticoids in blood. Feed intake lowers as the environmental temperature reaches upper critical level.
- With reduction in feed resource availability sheep and goat goes for selective feeding thereby leading in depletion of nutritive herbs and shrubs with spreading of weeds and toxic plants. If drought is prolonged, animals are forced to feed on toxic plants which end up in nutritional/ mineral imbalances.
- 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. The sheep and goats decrease the nitrogen losses particularly when they are in low nitrogen intake regime conserving the Nitrogen through efficient recycling of urea in the gut.

- Further, if rainfall follows period of drought, there is chances of nitrite poisoning in small ruminants. The excessive intake of forages containing nitrates which is common leads to build up of nitrites in rumen which is absorbed into RBCs to form methaemoglobin thereby resulting in muscle tremors, staggering, rumen paralysis may occur, and animal eventually dies.

Mitigation Strategies

The objectives of drought mitigation strategies should be to ensure survival of livestock farm business with minimal loss of productivity as well as optimizing available resource utilization with minimal number of animals with no loss of reproductive efficiency and ability to recommence the production optimally after the end of the drought (Ramachandra, 2009). The important areas to be taken for preparedness to tackle drought includes stocking rate, fodder conservation, pasture development, improving water sources and irrigation, silvi-pasture development and feed bank development (Jakmola, 2010).

Feeding Management:

Feeding and nutrition are the primary constraints for optimum animal production in drylands.

- In the early stages of drought, there might availability of poor-quality pasture, hence, strategy should be to supplement the animal feed with limiting nutrients. Supplement the animal which requires most i.e., young ones, pregnant and lactating animals should be given preference.
- Allow the animals for grazing during early hours in morning and later hours of evening.
- Supplementation of copper, selenium, zinc, and phosphorus through mineral bricks in the shed prevents heat stress (Ramana 2014).
- Provision of cool, fresh and clean water is prerequisite as water intake may increase by 20 to 50% during heat stress conditions.
- Feed ingredients that have a high digestibility in the animal should be fed.
- Buffers (sodium bicarbonate and magnesium oxide) should be added to the ration which helps in maintaining a normal rumen environment (Pan, 2014).
- Electrolytes like Na, K, Mg should be supplemented. When no green fodder is available, addition of vitamin supplement in concentrate mixture helps in mitigating heat stress.
- Use of complete feed blocks in lean season and total mixed ration will improve dry matter intake in stressed animals.
- With the progress of drought, pastures deplete further. energy intake through grazing becomes less or negative as 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.

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.

1. **Revival of Pasture/ Common Property Resources**

Small ruminants largely sustain on the existing grazing resources and it is mainly dependant on availability of grazing resources from pastures and other grazing lands viz. forests, miscellaneous tree crops, cultivable waste lands and fallow lands commonly called common property resources. Since there is no control over the number of animals allowed to be grazed, CPRs got depleted of favourable herbaceous species in grazing lands thereby affecting the productivity of animals adversely. Mann and Singh, 1982 observed that protecting the rangeland from grazing during plant growth phase increased the yield up to 17.9 q/ha and forage yield increased 2 to 3 times when reseeded with perineal grasses (Mann and Mehta 1998). CPRs need to be reseeded with high producing legume and non-legume fodder varieties at every 2-3 years' intervals as a community activity and following rotational grazing would improve the carrying capacity of CPRs.

2. Promoting Short duration fodder production from tank beds
3. Integrated fodder production systems such as silvi-pastures and horti-pastures.
4. Fodder production systems in homesteads
5. Fodder production systems through alley cropping
6. Intensive irrigated fodder production systems: High yielding perennial (hybrid Napier varieties) and multi-cut fodders varieties could be choice of fodder crops under this system.
7. Fodder production through contingency plan:

Early season drought	Short to medium duration fodder crops which are ready for cutting by 50-60 days can be sown immediately after rains under rainfed conditions during kharif season.
Mid-season drought	Short to long duration fodder crops. Mid-season drought affects the growth but once rains received in later part of the season, the crop revives.
Late season drought	normal short duration fodder crops may be sown

8. Use of unconventional resources and agro industry wastes as feed to meet the nutritional requirements of animals.

Genetic Approach to mitigate Abiotic stress:

Many local breeds are having valuable adaptive traits that have developed over a long period of time which includes tolerance to extreme climates, diseases and adaptability to survive, regularly produce and reproduce in low input management conditions and feeding regimes. Hence, Genetic approach to mitigate the environmental stresses should include measures such as Identifying and strengthening the local genetic groups which are more tolerant to environmental extremes. Hence, it is always advisable to use the descript breed local to the region/ adjoining to the region for improving the non-descriptive animals of the region rather than introducing new genotype which brings into region issues of adaptability to environmental condition and disease resistance. Local climate resilient breeds of moderate productivity should be promoted over susceptible crossbreds. For example, Performance and survivability of goat breeds of North-western region deteriorate in hot and humid eastern and southern regions. Many goat breed (as a breeding farm) do not perform well under stall feeding farm however some breed do well such as Barbari, Black Bengal and some need open area for walk/grazing such as Beetal, Sirohi etc. Luckily, almost every region of the country is having its own sheep/ goat breed which can be used as improver breed.

State/ region	**Goat breeds available**	**Sheep Breeds available**
Gujarat	Surti, Zalawadi, Gohilwadi, Kuttchi, Mehsana and Kahmi	Panchali, Patanwadi
Rajasthan	Jakhrana, Sirohi and Marwari	Chokla, Jaisalmeri, Magra, Malpura, Nali, Marwari, Pugal and Sonadi
Maharastra	Sangamneri, Osmanabadi, Berari and Konkan Kanyal	Deccani
Andhra Pradesh		Deccani, Nellore
Tamil Nadu	Kodi-Adu, Kana-Adu and Salem-black	Tiruchi Black, Vembur, ChevaaduKatchaikatty Black, , Coimbatore, Kilakarsal, Mecheri, Nilgiri, Ramnad White and Madras Red
Uttar Pradesh	Jamunapari, Barbari and RohilKhandi	Muzzafarnagri, Jalauni
Madhya Pradesh	Jamunapari, Bundhelkhandi	Jalauni
Kerala	Malabari and Attapady Black	
Karnataka	Bidri and Nandi-Dugra	Bellary, Hassan, Kenguri, Mandya
Himachal Pradesh, J & K	Chegu, Changthangi, Gaddi and Bhakarwali	Bhakarwal, Changthangi, KarnahPoonchi, Rampur Bushair, Gurez and Gaddi
Punjab	Beetal	Kajali
Orissa	Ganjam	Balangir, Ganjam, Kendrapada
Uttrakhand	Pantja	Muzzafarnagri
West Bengal, Bihar, Jharkhand	Black Bengal	Chottnagpuri, Garole, Shahbadi
Assam	Assam Hill	
Nagaland	Sumi-Ne	
Sikkim	Bonpala	Tibetan
A & N Island	Teressa	

In case of non-availability of pure-bred and high potential females then purchase relatively high potential graded or non-descript females and do up-gradation of them through high potential bucks suitable for prevailing climatic conditions. Castrate crossbred male and sale them for meet or sacrifice purpose, however half-bred females should be regularly upgraded for 3-4 generation from pure-bred buck of choice. Take precaution that halfbred or females under process of upgradation should not be breed by their sire (avoid inbreeding). Rotate bucks after 2-3 seasons use and always select un-related buck to avoid inbreeding. One healthy buck is enough to breed 25 to 35 females. However, at beginning 10 to 15 females should be allotted a buck so that enough genetic variation could be created in farm.

Shelter Management to reduce environmental stress:

The basic requirement of good animal shelter is that

It should alter or modify the environment for the benefit of animals and protect from high and low ambient temperatures, environmental humidity, solar radiation, wind and rain. It should reduce environmental stress allowing optimal animal performance in terms of growth, health and reproduction.

1. Housing in tropical and semitropical regions should be kept to a minimum.
2. In the arid tropics, no protection other than natural shade is required as shades can cut the radiant heat load from the sun by as much as 40%. Shades with straw roofs are best because they have a high insulation value and a reflective surface.
3. Provision of trees at certain distance from the shed will provide shade to the animals.
4. Shifting the animals to cool shaded area during the hot climatic conditions.
5. Provision of vegetative cover over the surrounding area will reduce the radiative heat from the ground. The surface covered with green grass cover will reflect 5-11% of solar radiation as compared to 10-25% by dry bare ground and 18-30% by surface covered by dry sand adding to thermal stress.
6. In humid climates, a simple thatched shelter will provide shade and protection from excessive rain.
7. The orientation of the long axis of the shed should be in east west direction in plain region and should be north south in high altitude areas having high humidity.
8. Provision of elongated eaves or overhang will provide shade as well as prevent rain water from entering the sheds.
9. The house should be well ventilated and wind flow at a speed of 5 km/h is ideal.
10. Overcrowding in the animal sheds must be minimized
11. As sheep and goats do not tolerate mud well, yards and shelters should be built only on well-drained ground.
12. In areas of high rainfall it may be desirable to keep the animals off the ground. Elevated housing with slatted floor raised 1–1.5 metres above the ground, to facilitate cleaning and the collection of dung and urine.
13. Optimum floor space requirements* for different categories of goats

Sl. No	Age / Category of goats	Covered area (m^2/goat)	Open paddock (m^2/goat)
1.	0 - 3 months	0.2-0.25	0. 4 - 0.5
2.	3 - 6 months	0.5 - 0.75	1.0 – 1.5
3.	6 - 12 months	0.75 - 1.0	1.5 – 2.0
4.	Yearling goats (above 12 months)	1.00	2.00
5.	Adult goats	1.5	3.0
6.	Pregnant and lactating goats	1.5 - 2.0	3.0 - 4.0
7.	Bucks	1.5 - 2.0	3.0 - 4.0

* At any given time, 10 percent more animals can be accommodated without compromising the production, health and welfare of the animals

Health Management Strategies

Climate change is strongly associated with many emerging and re-emerging animal diseases (M C Sharma *et al.*, 2010), infections spreading to newer geographic area etc. Increased prevalence of endemic diseases due to aberrations in weather conditions is becoming a potential threat to the profitability of small ruminant farming

- Increasing mean temperatures leads to expansion of vector populations into cooler higher altitude systems causing tick borne protozoal diseases like babesiosis and theileriosis in animals at high altitudes.
- Increase in humidity along with temperature would result in more of internal worm burden, hence deworming should be planned accordingly.
- Increase in frequency and intensity of heat waves leads to morbidity and mortalities and in this situation, oral rehydration along with feeding gruel mixed with jaggery and salt is advocated.
- Variations in rainfall pattern may also lead to more vector population and outbreaks of diseases like blue tongue, the classic example being Blue Tongue outbreak in Tamil Nadu during monsoon of 1997-98 wherein three lakhs sheep and goats died (M C Sharma *et al.,* 2010).
- Preventive vaccination against endemic diseases especially PPR, FMD etc, deworming and dipping should be done to all small ruminants.

Deworming:

Deworming is usually done before and after rainy seasons. There is need to rotate the deworming drugs in order to prevent the problems of drug resistance

Dipping:

It is done to prevent infestations caused by ectoparasites. Usually done twice in a year before and after winter season.

Regular deworming, preventive vaccination against endemic diseases, dipping and control of intermediate hosts are critical for sustainability of small ruminant production system.

Vaccination Schedule:

Name of Disease	First Vaccination at age of**	Booster Dose	Repeat Vaccination after	Dose*	Route*
PPR	3 months	Not Required	3 years	1 ml	subcutaneous route
Goat Pox	3 months	1 month after first vaccination	1 year	1 ml	subcutaneous route
Foot and Mouth Disease (FMD)	3 months	3-4 weeks post first vaccination	6 months***	1 ml	subcutaneous route
Enterotoxaemia (ET)	3 months	3-4 weeks post first vaccination	6 months	2 ml	subcutaneous route
HemorrhagicSepticemia (HS)	3 months	3-4 weeks post first vaccination	6 months***	2 ml	subcutaneous route

*Dose & Route may vary manufacturer to manufacturer; **At the age of 3 months, any of the above may be given, ***May differ as per the adjuvant used in the vaccine

FODDER PRODUCTION MODELS FOR IMPROVED LIVESTOCK MANAGEMENT

V. Maruthi, K Srinivasa Reddy and Pushpanjali

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad

Introduction:

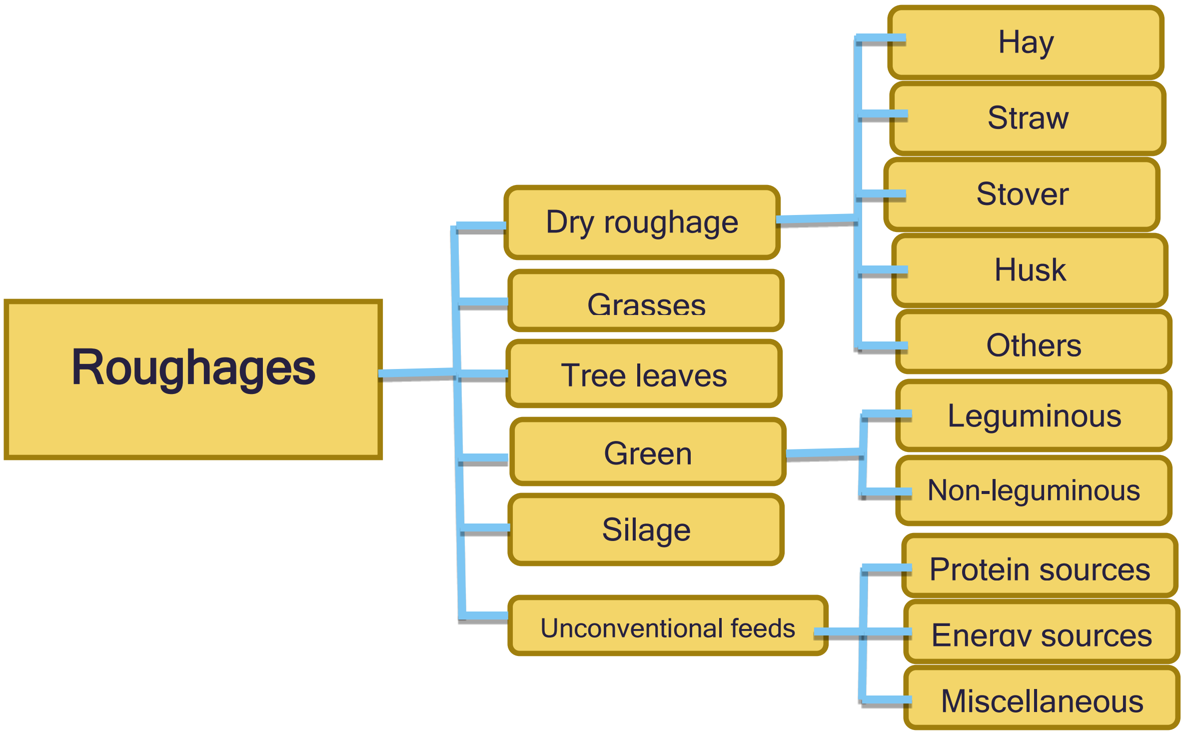
Presently, India is facing a net deficit of 61.1% green fodder, 21.9% dry crop residues and 64% concentrate feeds for feeding of 20% of the livestock population of the world covering 2.3% geographical area. Severe fodder crisis is witnessed during drought years due to lack of preparedness for forage and pasture management which leads to distress sale of valuable animals. Early dry spells reduce the area under fodder crops, whereas mid-dry spells impact fodder availability during lean period. Terminal dry periods has little effect on fodder production, however, seed availability for succeeding year is severely compromised. The condition is further aggravated by damaging of seed materials for subsequent years.

Mitigating scarcity of dry fodder and managing availability of green fodder round the year is a serious challenge for the livestock keepers as majority are marginal and small holders unable to produce and store livestock feed and forage and face acute shortage during certain periods. The current chapter have been framed to highlight fodder production practices, recent concepts and viable strategies to meet out the requirement by livestock in India.

Fodder production and range management: Usually two different types of fodder management system are prevalent in India:

1) Rainfed systems
    - a. Annuals i) Intercropping systems ii) Sole crops/Sequential Systems
    - b. Perennials i) Arable ii) Non arable (Silvi pasture) iii) Ley farming
2) Irrigated systems
    - a) Annuals (Single & multi cut types)
    - b) Perennials (round the year fodder production system)

Fodder can be classified as Cereal variety fodder (sorghum, maize, oat & millets); **legumes** (groundnut, berseem, lucerne, stylosanthes, cowpea); **perennial grasses** (hybrid napier, guinea grass, para grass); **annual grasses** (dinanath grass); **popular trees** (moringa, neem & babool); **leguminous trees** (subabul, khejri, sesban & gliricidia) and **newly identified fodder resources** (cactus, azolla and hydroponics).



Rainwater harvesting and efficient use of water in fodder units: The primary source of water in rainfed regions is rain, which is sporadic and uncertain in nature. In order to make maximum and best use of this water, several technologies can be implied in these regions in consultation with farmers themselves, which must not avert the traditional practices of water harvesting and utilization. Rainfed agriculture which builds on traditional means of water management practices can play a vital role in reviving the rural economy if supported and improved on scientific grounds. The productivity and sustainability of a dryland agro-ecosystem depends on the quality and reliability of water resources—which in turn depend on the health of its watersheds.

Basic package of practices for fodder production

a. **Climate and soil:** The grasses grow throughout the year; however, the optimum temperature is about 31°C. Light showers alternated with bright sunshine are very congenial to the crop. Total water requirement of the grass is 800-1000 mm. Hybrid Napier can grow on a variety of soils. Light loams and sandy soil are preferred to heavy soils. The soil has as to be wet at the root zone but should not be stagnated.

b. **Land preparation:** Clearing of undesirable bushes, thorns, weeds etc. are must be done at the beginning. Most of the fodder plants require a deep, thorough, weed free and compact seed bed. One disc ploughing may be followed by two or three fork ploughing, levelling and removal of clods. Basal application of farmyard manure is done before the preparation of ridges. Ridges are made across the slope far as possible at a spacing of 60 cm with a height of about 25 cm which enables irrigation uniform and easy.

c. **Manuring:** Farmyard manure should be spread at the rate of 3-5 MT/ Acre before ploughing. Apply fertilizer as per soil test recommendations. The standard recommendation for a barren land is N:P:K @ 8:10:5 kg/Acre as basal application. The above fertilizer recommendation can be given at the time of the first weeding, normally 30 days after planting.

d. **Spacing and seed rate:** The recommended spacing for Hybrid Napier sapling plantation is 1 m X 1 m, however, it varies from species to species. Thus, a total of 4000 saplings may be planted per acre.

e. **Planting:** Planting should be done with the onset of monsoon or any time, if irrigation facility is available. The grasses are planted by rooted slips or by stem cuttings. Cuttings with 2 nodes from the middle portion of moderately matured stems (3-4 months old) are preferred. The cuttings are planted at a slanting position at one side of the ridges with one node buried in the soil.

f. **Top dressing:** Application of Nitrogen @ 30 kg/acre after every harvest with gentle raking of the soil produces more tillers.

g. **Irrigation and drainage:** The field should be provided with good drainage during the rainy season as the crop cannot stand water stagnation. The first irrigation is done at the time of planting and the life irrigation on the 3^{rd} day after planting. Frequencies of subsequent irrigations depend upon the rainfall and weather conditions. The standard irrigation interval during summer is 3-4 days (depending upon the soil quality).

h. **Weed control:** Weeding should be done within 30 days of planting and second weeding is essential only if there is heavy weed growth.

i. **Harvesting:** The first cut is taken from 60 to 75 days after planting in case of Hybrid Napier grasses. Subsequent cuts are taken after 30-45 days or when the plants attain a height of 1½ m. Annually at least 6 to 8 cuts are possible. The fodder has to be cut closer to the ground level for more profuse tillering.

j. **Yield:** 100-150 MT/acre/year green fodder is obtained on an average if it is cultivated as a single crop. Hybrid Napier can be cultivated as a single crop or intercrop with other leguminous crops.Vegetative growth is reduced to dormant during winter.

Suitable fodder production system strategies for small and marginal farmers

Grazing conditions in the India have deteriorated partly due to the cyclic drought and due to the increasing pressure on the land by expanding population. This means that whenever a drought occurs, the existing grazing resources are depleted very fast leading to livestock mortality due to starvation and opportunistic diseases. Thus, in every drought, pastoral households lose their livestock particularly cattle and small ruminants.

A multi-pronged strategy is essential to meet the fodder requirement of the region,

- Production of Quality seeds (breeder and foundation seeds) of selected promising varieties/hybrids with participation of farmers.
- Organizing fodder production programme by promoting appropriate and region-specific varieties.
- Post-harvest management techniques like fodder block making units, chaff cutter for fodder processing and silage making.

Moreover, there is lot of culturable wasteland which can effectively be utilized for low resource need-based fodder crop cultivation. Following are some fodder production strategies which can mitigate fodder scarcity to some extent in rural areas are:

Intensive irrigated fodder production systems: High yielding perennial (hybrid Napier varieties like CO-3, CO-4, APBN-1 etc.,) and multi-cut 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.

Table. Intensive forage crop rotations for eastern part of India (adopted from Sunil *et al*., 2012)

S.No.	**Crop rotation/ Climate & soil**	**Green fodder yield (t/ha/yr)**
I	*Sub-humid, red acidic soil*	
1	Pearl millet + Cowpea – Maize + Cowpea – Oats	103
2	Maize + Cowpea – Sorghum + Cowpea – Berseem + Mustard	96
II.	*Sub-humid, Alluvial soil*	
1	Maize + Cowpea – Dinanath grass – Oats	131
2	Maize + Rice bean – Berseem + Mustard	112
III	*Humid, acidic soil*	
1	NB hybrid (Perennial)	106
2	Maize + Cowpea – Maize + Cowpea – Maize + Cowpea	85

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

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 fodder.

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 horti-pastoral and silvi-pastoral systems for fodder production.

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 (*Leucaenaleucocephala, 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.

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, Azadirachta indica, Ailanthus excelsa, Acacia nilotica* trees and modified plants of cactus are highly drought tolerant and produce top fodder. 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 these systems.

Fodder production systems at homesteads: *Azolla,* a blue green alga 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 considering unused space between two beds. It is more nutritious than the leguminous fodder crops like lucerne, cowpea, berseem etc and can be fed to cattle, buffalo, sheep, goat and poultry after mixing with concentrate mixture at the ratio of 1:1.1

Hydroponic Fodder Production Systems: Fodder can be produced in large quantities within 8 days from seed to grass for all livestock. These include barley, oat, 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.

Year-round forage production systems: Cultivation of a combination of suitable perennial and annual forages for year-round nutritious fodder supply for the livestock 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.

Table. Normal sowing window for different fodder crops in the region

Fodder crop	Normal sowing window
Sorghum (single cut)	June-July
Sorghum (multi-cut)	March-April
Pearl millet (single cut)	June-July
Pearl millet (multi cut)	March-April
Fodder maize (single cut)	March-April
Lucerne	September-October
Berseem	October
Cow pea (kharif crop)	June-July
Cow pea (Summer crop)	March-April

Other strategies are

1) **Common Interest Group (CIG) model for mitigating fodder scarcity:** Development of Institutions like Common Interest Group (CIG) will be able to mitigate fodder scarcity as membership of a co-operatives or commodity association increases access to productive resources such as seed, information and training. It also provides a ready market for milk, for instance, the group may hire transport and procure processing material and refrigeration. With an efficient market provided by dairy associations, it is expected that farmers will adopt new technologies quickly. If a farmer has been a member of dairy association for a long period, such a farmer is more likely to have received information on fodder trees for a longer time and the possibility of adoption would be higher. This will be especially important for small and marginal farmers.

   All dairy farmers/members of milk dairy cooperative society will be able to work in liaison with line department - village level to involve fodder requirement, cultivate improved fodder varieties either in leased land or common land, sale and market the surplus.

   Community level seed banks with buffer stock of seed material of diverse crops appropriate for the village/area need to be maintained. These seed banks should be considered as a necessary common infrastructure particularly for rainfed areas supported by government on a regular basis. Seed banks should be controlled and maintained by organized farmer groups. Presently, approximately 20,000 MT quality fodder seed is produced, which is enough to cover about 4 % of total cultivated area used under fodder crop. There is a need to target at least 10% of net cultivable land to meet the fodder shortages, for which quality fodder seeds requirement would be about 46,000 MT. Later, a revolving fund may also be developed for fodder development through CIG which will increase the risk bearing capacity of small and marginal farmers.

2) **Entrepreneurship model for imparting skills to SHG women:**
   - Production of quality seed by appropriate selection of promising varieties/hybrids.
   - Production, preservation and sale of urea molasses mineral bricks (UMMB) feed mixture blocks, selling of fine cut fodder and silage fodder for needy farmers.
   - Establishment and management of a feed mixture plant by women groups.
   - Motivate female farmers for Indigenous Technical Knowledge (ITKs)
   - Women headed households may respond less favourably to new technology than men because the traditional power structure and control over household productive resources are less favourable to women, i.e. negative effect on adoption. On the other hand, women may not have access to cash to purchase commercial feed concentrate for the livestock and therefore they may readily embrace fodder banks than men. In addition, fodder banks may be more attractive to women given that it provides other benefits such as fuelwood which will result in less labour inputs fire wood collection by women.
   - Motivate female farmers for Indigenous Technical Knowledge (ITKs) Shrubs and small trees (like Gliricidia, Desmanthus, Leucaena, Sesbania spp.) are very cheap source of protein and minerals and can be introduced between farm plots and have multipurpose utility.

3) **Forage seed distribution model:** Dairy farmers who have undertaken forage production are not able to optimise the yields and maximise the returns due to several reasons. These include poor quality soils, inadequate fertiliser application, moisture scarcity, improper timing of sowing and inadequate facilities to transport and store the forage, till it is fed to livestock. Selection of suitable forage crops to suit the local agro-climatic conditions, non-availability of good quality certified seeds, lack of knowledge about cultivation practices and lack of marketing opportunities to sell the surplus forage at remunerative prices are also important problems, contributing to the poor response to forage production. Except for a few crops like sorghum, maize, lucerne and berseem, which are cultivated in a few isolated pockets in different regions, most of the farmers are not aware of other forage crops, which have special advantages under adverse agro-climatic conditions.

   Resource-poor farmers often cultivate forage on low productive soils to make use of the idle land and do not apply the required quantity of nutrients. Such farmers have several options to boost crop yields by applying low cost inputs such as soil amendments, organic manure and bio-fertilisers. Unfortunately, most of them do not bother to apply bio-fertilisers and soil amendments due to their ignorance and difficulty in procuring them. This problem can be attributed to lack of an organised set up for extension, distribution of forage seeds and other inputs in the country. Serious thought should be given for developing a forage seed distribution network, at least in selected pockets where dairy husbandry has developed as an economic activity. There has also been a wide communication gap between the forage development programme and the livestock extension department. As a result, there is no free flow of information from either side. A well-established communication network would help the forage scientists to understand the problems of the dairy farmers and offer suitable interventions.

4) **Rotational grazing model for the village:** Implementation of rotational grazing plan for the village at CPRs and watershed

   - Continuous grazing of pastures leads to soil degradation and poor productivity of fodder.
   - Suitable varieties chosen for common pastures and adequate gap between grazing of herds and development of fodder provided for sustainable fodder supply on watershed basis.
   - Suitable varieties chosen for common pastures
   - Adequate gap between grazing of herds
   - Development of fodder provided for sustainable fodder supply on watershed basis.

5) **Range improvement:** Livestock grazing, and fodder production is the major land-use of drylands. Livestock is the major source of income for the people residing in the drylands. The rangelands in the arid and semi-arid belts have, however, insufficient carrying capacity for huge populations of livestock. Following are some of the techniques that could be applied to overcome water shortage for getting better results with the establishment of grasses, trees and shrubs.
   - Introduction of rotational grazing system and the concept of Social Fencing
   - Range stocking according to the carrying capacity of range
   - Silvo-pastoral systems with multi-purpose, fast growing fodder tree species (indigenous and exotic species)
   - Bund stabilization with multipurpose trees (with deep planting and soil amelioration techniques), shrubs (e.g. *Saccharum* sp.) and grasses (with tuft planting and sowing in seed beds)
   - Protection of soil and crops with shelterbelts and wind-breaks
   - Different range reseeding techniques
   - Even distribution of animals on rangelands through selecting locations of water ponds for animals.

6) **Unconventional feed usage:** Increase in livestock and human population and decrease in land under cultivation has resulted in acute shortage of feeds and fodder for livestock which further increases due to natural calamities like droughts and floods. The feeds which are traditionally not

used for feeding animals are called unconventional feeds. Their use in livestock ration is increasing day by day due to shortage of animal feeds. The main source of such feeds is agricultural and forest by-products. Such feeds are not used either because of traditional beliefs of livestock owners or due to less palatability and presence of incriminating factors in them. It also happens that certain un-conventional feeds are being traditionally fed to animals in particular region but the same may be neglected in other regions. Recent studies indicated that quite a large number of agricultural by-products and industrial waste materials could be used for livestock feeding.

7) **Fodder preservation techniques**: There are two popular methods for preserving or conserving the seasonal excess of green fodder, viz. hay making and silage making.

a. Ensiling / Silage Making: Green fodder can be preserved as silage stored for a long period. If green grasses are cut at the early flowering stage, they can be preserved as silage, then the grass will be more nutritious. Silage may be defined as the green succulent roughage preserved under controlled anaerobic fermentation in the absence of oxygen by compacting green chops in air and water tight receptacles. It can be prepared in silage bags also. Unlike hay making, which has seasonal constraints and heavy nutrient losses, silage on the other hand is superior and has better acceptability, digestibility and nutritive value.

It is possible to ensile almost any plant material and by-products, the most important crops for ensiling worldwide are whole-crop corn, alfalfa and various grasses. Other crops include whole-crop wheat, sorghum and various legumes. Harvesting the crop at 50% flowering to milk or dough stage can make good quality silage of crops like maize, sorghum and pearl millet. For NB hybrids 45-50 days after the previous harvest is recommended. For natural grasses and Cenchrus, they should be harvested at flowering stage.

Pit, trench, bunker and tower silos are used for silage making. Various types and sizes are used depending upon the availability of green fodder and the convenience of the farmer. The green fodder is filled in the silo either as such or after chopping and it is well packed to reduce air. The top must be covered with dry straw and then sealed with mud plaster or covered by polythene sheets. The silage will be ready after 4-6 weeks. A pit size of 20 x 20 x 20 feet is enough for 50-55 t of green fodder. One cubic foot of settled silage will weigh about 15 kg. The rate of utilization of the ensiled material also has a bearing on the size of the silo. Once is opened for feeding, then every day at least half a foot of the material must be removed to avoid spoilage if the silage.

b. Hay making: Hay is a stored forage that is essentially characterized by having low moisture content (less than 15 %) and is unharmed by fermentation and moulds. Hay making is the most common and easy method of preserving seasonal excess of green fodder and the only method of preserving farm by-products. The principle involved in hay making is to reduce the water content of the herbage so that it can safely be stored in mass without undergoing fermentation or becoming mouldy. Legume hay, non-legume hay and mixed hay are the major three types of common hays used in livestock feeding.

For hay making, the harvest must be taken up after the dew has dried. The harvested fodder must be allowed for curing in the field itself and must be turned after every 4-5 hours. By the evening the moisture content could have reduced from 75% to 40% and it must be loose heaped in windrows. Next day it requires 1 or 2 turnings. The moisture content by the second day afternoon could have reduced to 25% provided the sunshine is not interrupted and it is ready for storing as bales or for storing in tripod stand (pl provide pictures/photos).

At the end of curing the moisture content will be around 20% or less and it is ready for storing. Normally 70-75 sunshine hours are required for drying the grass in the-field method. For rainy season hay curing sheds are recommended. During the process of hay making some nutrients are lost in the curing process.

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SUSTAINABLE NUTRIENT MANAGEMENT IN LIVESTOCK UNDER CHANGING CLIMATIC CONDITIONS

Sanjay Kumar

Department of Animal Nutrition, Bihar Veterinary College, Bihar Animal Sciences University, Patna

Introduction

Droughts, scarcity and natural calamities, unfortunately, are part of India's rural scene, and their frequency and severity in the future are likely to be increased. However, livestock causalities are immense, making livestock farming, vulnerable in event of continuous scarcity, droughts and natural calamities- either directly through the improper supply of feed and water, or indirectly by reduced income both during and after adverse situations. Deterioration of pasture and soil erosion are less obvious costs, but important, particularly in the long-term sustainability of production from ruminants. India is short of feed resources. This shortage is consistently with us. Although the quantities of feed resources available were increased from 1954 to 1996 by about 70%, correspondingly, the animal population has also increased by 80%. The bovine population is increasing at an annual rate of 1.5% and the cross-bred cows are projected to increase to 12 million, requiring about 18MT of compound livestock feed. When rain occurs, there is a change in type of vegetation for grazing and few animals can not adjust and die (10% of the total number, Rathore, 2005).

The area under fodder production has decreased to 4.4%, the crop residues available has increased (500MT), and compound livestock feed production has also increased (8MT), of which CLEMA produces only about 3MT. But still as mentioned above, we are not able to meet the requirement. Annual availability of green fodder, dry fodder and concentrates for livestock feeding in India is about 573.50 MT, 387.86MT and 41.98 MT respectively while requirement is about 761.53MT, 650.70MT and 79.40MT respectively result in a huge deficit of 188.03MT (24.7%), 262.84MT (40.4%) and 37.42MT (47.1%) respectively. Similarly, the area under permanent pastures is approximately 13 million hectares only and the area under grazing is 2.1 crore hectares. All these resources are able to meet the forage requirements of the grazing animals only during the monsoon season. A gigantic gap (shortage of concentrates 47%, green fodders 24.7%, and dry roughages 40.4% exits between the demand and supply of animal feed resources in the country. Gujarat producing about 52.62 MT fodders and pastures resources around 4.5% of the national averages. To meet the availability and requirement feeding and management strategies of dairy animals during scarcity period is the demand of the time.

Strategy for probable monsoon scenarios in animal science

The normal and other four probable monsoon scenarios and strategy of programmes recommended to be implemented in case of Animal Science Sector are given in Table 1.

Table 1. The normal and other four probable monsoon scenarios and strategy of live stock management

Scenario	Strategy Program
Normal Monsoon	1. Ensuring feed and fodder availability 2. Ensuring drinking water 3. Livestock health management 4. Action plan to ensure strategy against sudden break of monsoon 5. Action plan against extended monsoon
Delayed monsoon Three weeks late	6. Ensuring quality feed & fodder availability during delayed monsoon arrival 7. Strategy of livestock management due to water scarcity, starvation, sickness & death
Timely onset Sudden break	8. Strategy of feeding green fodder due to timely onset of monsoon 9. Strategy as under program 6 & 7
Early with drought	10. As under 6,7,8 & 9
Extended monsoon	11. Strategy of feeding green fodder of high moisture content & spoilage due to mould development 12. Strategy of animal protein & mineral feeding 13. Strategy of antiparasitic, epidemics & other metabolic disease management 14. Strategy of conservation of excess fodder mass produced

The detailed solutions on the 14 strategies suggested above are given below.

- ❖ Feeding Technologies to be used during Drought Situation
- ❖ Livestock management practices
- ❖ Preventive Measures against Epidemics and Diseases
- ❖ Water Management
- ❖ Unconventional Feed Resources

Strategy of meeting feed shortages

Two feeding strategies**,** one relates with lack of fodder availability and the other with lack of feed quality. Under the above situation, three programmes need to be followed depending on the severity of the drought situation.

- Feeding strategy for maintenance of animals to ensure its survival
- Feeding strategy to maintain minimum level of production and growth
- Feeding strategy to maintain desired production by purchasing supplements from outside.

Critical body weight for survival will be upto 20% of body weight loss in case of cattle, while in case of desert animals (sheep and camel) it may be upto 30 to 40%. In case of milch and other producing animals, the only solution lies with supplementation because productivity loss cannot be recouped by any other means.

- Storage in fodder banks
- Urea treatment of straws
- Complete feed formulations
- Use of dry and fallen tree leaves

Feeding Technologies to be used during Drought Situation

Use of Sugarcane Bagasse as Animal Feed: Sugarcane is a major cash crop grown in many parts of the country. The sugarcane is popular with farmers in many regions for its ability to withstand extremes of environmental conditions and because of its assured market price. The crop is primarily for sugar, but sugarcane bagasse, cane tops and molasses form important byproducts. Sugarcane bagasse which is produced near the factory has industrial use like paper and board, creating a competing demand with its use as animal feed. Country is producing nearly 383 million tonnes of sugarcane bagasse. This is an important feed resource for ruminants. Cattle and buffaloes have the capacity to utilize sugarcane bagasse for production of milk

A variety of methods have been used to improve the nutritive value of sugarcane bagasse which is classified as poor-quality feeds. Urea when used for treatment of sugarcane bagasse enhances the nutritional quality of straw. In terms of increased nitrogen/protein content, increased palatability and improved digestibility of cell wall contents. Urea treatment of sugarcane bagasse is so far the only chemical treatment with practical potential under field conditions. Urea is readily available and safe chemical that is easy to store and also easy to dissolve in water. Sugarcane bagasse is commonly used as fuel in sugar factories. But it can be used as livestock feed during scarcity. It is not palatable as such but mixed ration containing 50% sugarcane bagasse, 17% groundnut cake, 4% wheat bran, 25% molasses, 1% urea, 1% salt and 2% mineral mixture is quite palatable to animals after adaptation and animals can be maintained on it. Growing animals can be raised on complete feed containing 30% sugarcane bagasse, 20% Prosopis juliflora pods, 7% mango seed kernel, 12% babul seed chuni, 8.5%maize gluten, 12% corn steep liquor, 8% molasses, 0.5% urea, 1% salt and 1% mineral mixture. Digestibility of sugarcane bagasse can be increased by steam treatment.

Sugarcane tops: Under global context wheat straw (25.3%) is the most abundant cropresidue followed by rice straw (22.8%), corn stover (15.8%), barley straw (8.3%), sugarcane tops (8.1%) andsugarcaneby products (6.3%) as reported by Han and Garett (1986). Cane tops contain less N than the concentration that is required for optimum fermentation in the rumen. It should be possible to augment the rumen fermentation of cane tops through judicious use of nitrogen rich supplements. Studies on urea supplementation of cane tops revealed that the digestibility of OM can be increased. Tree leaves from *Sesbania, Leucaena* or other crops that are often used as windbreak are a potential source of nitrogen and can be used as supplement for the tops.Cane tops are also a poor source of phosphorous (0.1 - 0.2%). This is perhaps a reason for the reported poor reproductive performance of animals fed large quantities of cane tops without supplementation. It contains 5.3% crude protein, 2.3% DCP and 49% TDN. It is being fed to animals in South Gujarat. It can be used for livestock feeding during scarcity. It should be fed along with calcium supplement as it contains oxalate which develops calcium deficiency in animals on long term feeding.

Straws and Gotars: Straws and Gotars are the byproducts of cereal and legume crops, respectively. They are used for feeding animals but in many parts they are not fed to the animals and burnt in the field. Rather they should be stored for feeding during scarcity. Urea treatment (4%) of straws improves its palatability, digestibility and nutritive value. If straws and gotars both are available, straws should be fed along with gotars as it improves its palatability and digestibility. Straws like rice, wheat, jowar, bajra, maize, etc. and gotarslike Groundnut, Mung, Gram, Tur, Urad, Cow pea, etc. can be used.

Cher leaves and fruits (*Avicennia officinalis*): Cher grows near the sea shore in stagnated sea water. During scarcity, cher leaves are available which can be used for feeding animals. Ripen cher fruits floating on water can also be used for animal feeding. It is the experience of livestock owners that cher leaves and fruits increase the milk fat content.

Tree leaves and vegetable leaves: Green fodder is not available during scarcity. But tree leaves are easily available. Leaves of neem, mango, banyan, pipal, babul, subabul, mahuva, etc. can be used as green fodder. Tree leaves are good source of protein, calcium, Vitamin A. They contain about 6 to 20% crude protein, and 0.5% to 2.5% calcium. Complete feed prepared using 50kg tree leaves, 5kg groundnut cake, 25kg vilayati babul pods (*Prosopis julifora* pods), 15kg molasses, 1kg urea and 2 kg mineral mixture is palatable to animals and it can form a good maintenance ration. The livestock owners of north Gujarat are traditionally using castor leaves for feeding their animals. The vegetable leaves and creepers like cabbage, cauliflower, potato can also be used as animal feed during scarcity.

Cactus: Cactus is primarily found in deserts hence it is easily available during scarcity also. As such it is not used for feeding animals but during scarcity it can be used. It contains 3.3% crude protein, 3.8% crude fat and 56% carbohydrates. It also provides water to animals. In Brazil, cactus is specially cultivated for feeding animals. The thorns should be removed/burnt before feeding cactus. 8 to 10kg cactus can be fed daily to an adult along with other roughages.

Agave (Ketki): Agave also grows in desert and semi desert areas and hence during scarcity also it is available. It is not being fed to animals routinely but during scarcity, it can be used. It contains 4.5% crude protein, 3.3% crude fat and 48% carbohydrates. Animals can be maintained on it along with other concentrates during scarcity.

Paper waste: Routinely also we are seeing stray cattle eating waste papers on road side. Paper waste contains about 70% cellulose and hence it helps satisfying the hunger of animals. Ground paper waste (6kg) supplemented with molasses (4kg), salt (50g), and mineral mixture (50g) per day is sufficient to maintain an adult animal. Complete feed containing 30% ground paper waste and other concentrates can be effectively used to maintain the animals during scarcity.

Saw dust: During scarcity when nothing is available, saw dust can also be fed to animals. Complete feed containing 30% saw dust, 32% maize bran, 31% molasses, 4% urea, 2% salt and 1% mineral mixture can be used as maintenance ration during scarcity.

Neem Seed Cake: Neem (*Azadirachta indica*) seed kernel cake (NSKC), a protein rich (34-40% CP) agro-industrial by-product, which, even under unorganized seed collection, is available to the tune of 0.7 million tons annually, is hitherto utilized as pesticide-cum-fertilizer, as it was found unsuitable for animal feeding due to the presence of bitter and toxic triterpenoids. The ensiling with 2.5% fertilizer grade urea for 5-6 days followed by sun drying and grinding resulted in improvement of cake. Such processed cake was found suitable in the feeding of buffalo calves for buffen, fattening lambs and kids, broiler poultry and rabbits without adversely affecting the growth, nutrient utilization, blood biochemical profile, rumen/caecal fermentation, physical and chemical characteristics of meat including organoleptic evaluation and gross and histo-pathology of vital organs. Thus, urea ammoniated neem seed kernel cake can be a wholesome protein substitute in the feeding of various farm livestock to spare costly and scarce vegetable protein sources, like groundnut cake, for human consumption.

Urea Ammoniation of straws: Urea treatment of straws is so far the only chemical treatment with practical potential under field conditions. Urea is readily available and is relatively safe chemical that is easy to store and also easy to dissolve in water. Urea-treated straw saves on concentrate feeding, increases milk yield by 1-2 litres/animals a day, offers better economic returns to the farmers and may help reducing land area required for green fodder production.

The process is very simple and involves spraying of urea solution uniformly over the straw and storing it for a specific time period. The process straw requires 1000 kg straw, 40 kg urea with a space requirement of 180 x 150 x 150 cm.

Silage technology for drought situation: The process is very simple and involves spraying of urea solution uniformly over the straw and storing it for a specific time period. The basic principle of silage making is to convert the sugars in the ensiled fodder into lactic acid; this reduces the pH of the silage to about 0.4 or lower depending on the type of process. In this way, the biology of activities responsible for spoilage is inhibited. To attain this, the early establishment and maintenance of oxygen free, i.e. anaerobic, micro-environment is essential.

- Crops and plant material rich in soluble sugars such as maize, sorghum, oats, sugarcane tops, hybrid Napier grass and other grasses are highly suitable for ensiling.
- The dry matter concentration of the forage at the time of ensiling should be around 15-30%, but higher is possible.
- Chaffing of the material for ensiling increases it compactness, thus eliminating the air space to the maximum extent.
- Green to semi-green forage, which may use the oxygen present for respiration, results in high quality silage.
- The silo should be air tight for filling.
- Fermentation starts within hours after closing the silo, and accelerates over the next 2 to 3 days. It terminates about three weeks. Organic acids, primarily lactic and acetic acid, ethanol and gases such as CO2, CH4, NO2 and NH3 are produced during the fermentation process.
- Due to the production of acid, the pH of the biomass is reduced to a level below 4, resulting in the termination of all biological activities, after which the material remains conserved under anaerobic conditions.

Silage from different forages: Maize, oats and sorghum are important fodder crops that are rich in carbohydrates. During periods of abundant green fodder availability, they can be chopped and ensiled to produce silage for feeding during scarcity periods. Sorghum and oats should be harvested at flowering stage when 50% ears have emerged, while maize should be harvested at its milk stage.

Silage from cultivated and forest grass: During the monsoon season, cultivated as well as forest grass grow luxuriantly, and there is abundant availability of green fodder. These grasses can be harvested at their pre-flowering or flowering stage when growth has leveled off while their feeding value is still high. If the weather is too humid for hay making, these grasses might be conserved in the form of silage for feeding during scarcity periods. The main stovers used for silage are from sorghum, though also crops like pearl millet and green maize can provide Stover for silage. The prussic acid which is present especially in younger sorghum plants or quick regrowth, and which is dangerous if fed to ruminants in larger quantities, is destroyed completely by ensiling.

Silage from water hyacinth: Water hyacinth is an aquatic weed, abundantly growing in Eastern India. In its fresh form it is not liked by ruminants. Its leaves are rich in protein, but the plant contains 90-94% water. In order to prepare silage from water hyacinth, it is necessary to reduce the water concentration to about 70%. As the leaves dry faster than the petiole and the stems, they drop down during the drying process, and the nutritive value is reduced.

Silage from Berseem: Berseem is an important green fodder legume in Northern India. It grows luxuriantly during March and April. However, it is not suitable for ensiling, due to its high moisture and protein concentrations 85-90% and 14-18% (on DM basis) respectively.

A mixture of berseem/paddy or berseem/wheat straw in a ratio of 4:1 can be suitable for ensiling. Addition of molasses (4% of total biomass) further improves the fermentation and quality of the silage. For the purpose, any other material such as crushed maize grain, spent barley from breweries, apple pomace or citrus pulp, can also be used instead of molasses.

Complete Feed for drought area

Completefeeds: imply a system of feeding all ingredients including roughages, processed and mixed uniformly, to be made available *ad libidum* to the animals (Sharma and Singhal, 1986). It can be in mash andpelleted form when this product is fed as sole source of nutrients. Pelleting feeds increases voluntary intake by 3-30% but adds to the processing cost by 57- 130% depending upon the type, percentage and original cost of roughages in the ration (Reddy, 1986). If baling of fibrous feeds is practiced, it can be useful to producecomplete feeds for use during droughts, i.e. to add some concentrate ingredients. Biologically, the use of complete feeds with an appropriate balance of roughage and concentrates may lead to better utilization of locally available crop residues, agricultural-byproducts and waste. Complete diets for livestock could benefit rural farmers during periods of feed shortage if the feed and transport costs can be kept low. Many complete feeds using locally available byproducts like bagasse, mixed with tree leaves and other unconventional byproducts have been developed.

Block (CBF's) Technology: The CFBs were found to be very nutritious, easily digestible and handy to transport. The blocks were made of proportionate mixture of wheat bran, rice, bran mustard, groundnut cakes, one percent urea, molasses, minerals and salt. The blocks have dimension of 0.5 cubic feet containing about 13% proteins and 50 to 55% total digestible nutrients. The nutritive value is 33% higher than common feed. This machine is being tested in five different locations. The CFBs can be used in famine and flood situations due to easy transport. The machine costs about 8.5 lakhs. Establishment of feed block production unit at farmers' level was found to be economic preposition (Rohilla *etal.*, 2004).

Low Density Block Technology: Chopped crop residue is mixed thoroughly with other concentrate ingredients. One of the ingredients should be molasses as it helps in better block making and also acts as a binder. Molasses could be avoided along with leguminous fodders, as these fodders have inherent qualities of blocking under pressure. Pressure application appeared to be most critical factor in process of block making. The block texture and compactness improved progressively on the application of increased pressure. A force of 15 to 20 tonnes (15 mpa) tonnes was considered satisfactory. The moisture content higher than 23% resulted into loose blocks. The alkali treated straw blocks were more compact (340-470 kg/M^3) than from untreated (280-370 kg/M^3) straw.

Various complete feeds based on crop residues and non-conventional feeds have been evaluated for growing lactating and adult cattle during last two five-year plans. The recommendations drawn from the experiments are as follows.

Complete feed for growing animals:

- Complete feed containing 30.0% ground wheat straw, 20.0% *Prosopis juliflora* pods, 6.5% rice polish, 5.0% wheat bran, 26.0% ground nut cake, 0.5% urea, 10.0% molasses, 1.0% salt and 2.0% mineral mixture can be used as ration of growing crossbred calves without any adverse effect on growth and health of animals. It provides 11.0% DCP and 56.0% TDN.
- Complete feed with 30.0% wheat straw, 18.0% ground nut cake(deoiled), 20.5% rice polish, 19.0% wheat bran, be used as ration of growing calves supporting the growth rate of 435 g/day. It provides 12.0% DCP and 56.0% TDN.
- Complete feed with 30.0% sugarcane bagasse, 8.5% maize gluten, 20.0% Prosopis juliflora pods, 12.0% corn steep liquor, chuni, 7.0% mango seed kernel, 12.0% corn steep liquor, 0.5% urea, 8.0% molasses, 1.0% salt and 1.0% mineral mixture supports the growth rate of 497 g/day of growing calves. It provides 12.0% DCP and 58.5%% TDN. It is 44% economical in terms of feed cost per kg gain than conventional system of feeding.
- Complete feed with 40.0% wheat straw, 19.5% deoiled groundnut cake, 8.0% wheat bran, 10.0% mango seed groundnut cake, 8.0% wheat bran, 10.0% mango seed seed keernel, 10.0% *Prosopis juliflora* pods, 0.5% urea, 1.0% salt, 1.0% mineral mixture and 10.0% molasses can be used as ration of growing calves without any adverse effects on growth rate and health of calves. It provides 11.0% DCP and 54.0% TDN and supports the growth rate of 450 to 500 g/day. The feed cost per day is Rs.15/animal.
- Complete feed based on 52.0% wheat straw, 23.0% deoiled groundnut cake, 9.0% *Prosopis juliflora* pods, 8.0% corn steep liquor, 5.0% molasses, 1.0% salt and 2.0% mineral mixture supports the growth rate of 468 g/day in growing calves.

Complete feed for milch animals: Complete feed with 30% wheat straw, 20% Prosopis juliflora pods, 6.5% rice bran, 5% wheat bran, 26% dioiled groundnut cake, 0.5% urea, 1% salt, 2% mineral mixture and 10% molasses can be used as ration and milk fat %.

Complete feed or total mixed ration with 45% wheat straw, 25% deoiled groundnut cake, 14% Prosopis juliflora pods, 3.5% babul seed chuni, 10% malasses, 1% salt, 1% mineral mixture and 0.5%

urea can be used as ration of lactating cows without any adverse effect on production performance of cows. Total mixed ration is 8.66% economical than complete feed in terms of feed cost per kg milk yield.

Complete feed based on 45% wheat straw and non-conventional feeds (Prosopis juliflora pods 14% and babul seed chuni 3.5%) with 25% deoiled groundnut cake, 10% malasses, 0.5% urea, 1% salt and 1% mineral mixture can form an efficient and economic ration for lactating cows without any adverse effects on the milk yield and composition. It decreases the feed cost per kg milk yield by 36.58% over conventional systems of feeding.

Creation of Feed & Fodder Bank: It is an important over delayed proposal to be implemented to meet the contingency needs of livestock during Drought & Floods. It has following; types of feeds & fodder to be stored for meeting the above emergencies.

- Feed Bank from Ingredients Not Fit for Human Consumption: All State & ICAR labs should test the feed ingredients, which become unfit for human consumption in FCI silos & stores. These tests are aflatoxin contents, pesticides & drug residues. Once they are declared suitable for use in ruminants or non-ruminants, they may be spared for livestock use & stored in feed banks. Such feeds will be useful for all class of livestock including birds.
- Fodder Banks: Grasses: Grasses from periphery of forest area wastelands & farmlands may be harvested & stored as hay in briquettes & high-density stacks.
- Fodder Bank: Crop Residues: The major cereals like rice & wheat straws are more important for this purpose. Next are coarse cereals, legumes, haulms left after removing grains from the crops. These may be stored in these banks.
- Fodder Bank: In Temperate & Alpine Areas: This practice is already followed in Ladakh, Himachal & Hill Hills of Uttaranchal Govt. should provide support to farmers for making stacks briquettes & bailing & storage by Mechanized, Bailing Machines, developed at IARI, GFRI, CIFE, BAIF & ANGRAU. This is a regular programme to meet the fodder needs during extreme winters and snow-covered seasons.
- Fodder Banks in Islands & Below the Sea Level Areas: This is a fodder bank to meet the feed requirements of livestock kept in areas involved in reclamation of land in coastal areas. Such farmers in their reclaimed land grow coastal rice, rice cum fish culture & rice cum prawn culture. These farmers need animal manure to be used for rice farming & culturing fish & prawn tanks & also to meet the need of milk, meat & egg for their own consumption. They also need the help of Govt. to store Crop residue, coconut by products & other brackish water vegetation, grasses. This programme is useful for the state of Kerala, Andaman & Nicobar & other below the sea level areas.

- Gramin Feed & Fodder Bhandaran Yojna: Ministry of Agriculture & Cooperation has a scheme with the name of Gramin Bhandaran Yojna. Similar Programmes may be proposal for feeds & fodder to encourage needy farmers having organized dairy & livestock enterprises.
- Training Programme To Meet emergencies of Drought & Flood: ICAR Institutes, KVKs, Regional Centres may organize training programmes on the above.

Water management: It is a most important commodity, whose availability is severely affected for the animals in drought condition. During summer large animal like buffalo/ cattle need 80-100 lts/day for drinking and same amount needed for cleaning and bathing etc. It is not available in required amount; for this precaution should be taken to avoid wastage of water. Further the salt intake of the animal should be restricted. The water should be mixed with 'Gur' as it quenches the thirst. The water should be provided to animals in small quantity and more frequently. Adequate water conservation means should be adopted during the rainy season, so that rainwater is not wasted and utilized during the drought period.

Water that has been utilized for external use for animal as well as human being should be recycled and treated before it reaches the main stream, so that it is again utilized and does not get wasted. This harvesting and recycling of water is already in practice in some areas and needs to be encouraged. Earlier as was the practice in villages that huge ponds were created which in rainy season got filled with the rainwater. This stored water was utilized during the lean period and throughout the year. This practice should be encouraged again at village level.

As drought and floods are a regular phenomenon in our country hence there is a need to have a mission mode project for water conservation, so that suitable means can be adopted for conservation and scientific utilization of water in drought hit areas.

Water Requirement: This depends upon environmental temperature and physiological needs of animals.

- Cattle above 27 deg centigrade atmospheric temperature requires 5.5 litres of water per day. Pregnant cattle require 9 litres of water per day. A milch cow needs 0.87 litres of water per litre of milk produced in addition to its requirement of 5.5.
- In case of sheep water requirement is 3 kg per day, 5 kg per day is needed for pregnant sheep & milk.
- A pig requires 2.1 litres of water per day, lactating sow requires 3.1 litres of water per day.
- For other animals, water requirement can be assessed based on above principles.

Use of sea water: Efforts should be put in to develop cheap method of desalination of seawater, so that it can be used for irrigation etc. In the drought hit region there should be a close coordination between the veterinarians, Veterinary scientists with the livestock owners of the area so that immediate remedial measures can be provided to them and the precious livestock of the poor landless farmer can be saved.

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PRECISION LIVESTOCK PRODUCTION: CLIMATE CHANGE PERSPECTIVE

Rana Ranjeet Singh

College of Veterinary Science & AH, Kamdhenu University, NAU campus, Navsari, Gujarat.

Primarily due to drivers of development change global demand for livestock products is expected to double by 2050. Meanwhile, climate change is a threat to livestock production because of its multidimensional impact. Together with climate change and drivers of development change will add up to a tough set of challenges for the livestock sector. Therefore, to maintain the quantity and quality of livestock products in the event of increase in global temperature role of precision dairy farming tools is of paramount importance. Precision dairy farming tools are used to measure physiological, behavioural and production indicators on individual animals to improve management strategies and physical resource variability to optimize economic, social benefits and minimize environmental impact. It applies sensors and information technology in dairy farming to identify individual animals, daily milk yield, milk components, step number, temperature, automatic estrus-detection and daily body weight & body condition score recording, disease and discomfort, stress etc. Some of these technologies already in vogue and in the future such technologies may change the way dairy herds are managed worldwide.

Precision livestock farming

Empirically, precision livestock farming (PLF) may be defined as a set of farming practices, which include use of advanced technologies, to deliver better results in livestock farming. These results may be quantitative, qualitative and the technologies involved include cameras, microphones, and other sensors for tracking livestock, as well as computer software. As per the concept given by Wathes (2007) precision livestock farming is the application of theprinciples and techniques of process engineering to livestock farming to monitor, model andmanage animal production. PLF encompasses collection of data from animals and their environment by innovative, simple and low-cost techniques, followed by evaluation of the data by using knowledge-based computer models. Under precision livestock farming, livestock is monitored by continuous automated real-time animal monitoring systems to improve production, health and welfare and environmental impact. Large animals are tracked "per animal", however other animals, such as poultry, are tracked "per flock".

Objectives: The basic objectives of PLF are to maximize individual animal potential, early detection of diseases and increase longevity, minimizing the use of medication through preventive health measures, supplements observation activities of skilled herd persons, reduction in number of farms labour required, optimize economic, social and environmental farm performance. Helps to make timely important decisions and informed decisions, resulting in better productivity and profitability.

Benefits of precision livestock farming: Traditionally, livestockowners have used experience and judgment to identify animals that were different from others. While this skill is invaluable and can never be fully replaced with automated technologies. However, this technique flawed by limitations of human perception. Many times, an animal exhibits signs of stress or illness, and it is too late to intervene, and these easily detectable clinical symptoms are naturallyfollowed by physiological responses not detected by human eye. Thus, by identifying changes in physiological parameters, a dairy manager may be able to intervene sooner. Technologies for physiological monitoring of dairy cows have great potential to supplement the observations of skilled farmers.

Benefits of PLF technologies include increased efficiency, reduced costs, improved product quality, minimized adverse environmental impacts and improved animal health and welfare. These technologies are supposed to have the greatest impact in the areas of health, reproduction, and quality control. As the herd size increases the anticipated benefits from summarizing data and reporting exceptions are likely to be higher because individual animal observations become more challenging and less likely to occur. As farming operations continue to increase in size, PLF technologies become more feasible because of increased reliance on less skilled labour and the ability to take advantage of economies of size related to adoption of technology. The most important aspect of the PLF technologies is that it utilises real time data to monitor animals and create exception reports to identify meaningful deviations from the normal pattern thus allows farmers to make more timely and informed decisions, resulting in improved productivity and profitability.

Current status of precision livestock/dairy farming

As it is a newer technological tool therefore the list of PLF technological options continues to grow. Some of the PLF tools are already in vogue: daily milk yield recording, milk component monitoring (e.g. fat, protein, and SCC), pedometers, automatic temperature recording devices, milk conductivity indicators, automatic oestrus detection monitors and daily body weight measurements.

Other PLF technologies which are at different level of developmental stages utilised to measure jaw movements, ruminal pH, reticular contractions, heart rate, animal positioning and activity, vaginal mucus electrical resistance, feeding behaviour, lying behaviour, odour, glucose, acoustics, progesterone, individual milk components, colour (as an indicator of cleanliness), and respiration rates. Many Precision Dairy Farming technologies measure variables that could be measured manually, while the remaining technologies measure variables that could not have been obtained previously.

Besides widespread availability, adoption of these PLF technologies has been relatively slow primarily due to perceived economic returns from investing in a new technology. Additional factors which affect adoption of these technologies includes degree of impact on resources used in the production process, level of management needed to implement the technology, risk associated with the technology, institutional constraints, producer goals and motivations, and having an interest in a specific technology. Adoption of PLF technologies in many developing countries including India is in its early stages.

Limitations and possible solutions: Generally, PLF technologies has slow adoption rate due to uncertain return on investment, high fixed costs of investment and information acquisition, and lack of demonstrated effects of these technologies on yields, input use, and environmental performance. Such technologies are adapted by younger and well-educated farmers who operate larger enterprises and gain higher profits. Information obtained from PLF technologies is only useful if it is interpreted and used effectively in decision making. Hence, concept of farm data sharing, and big data analytics will help in this aspect. Sometimes animal ID may show read errors, may be cases of equipment failure and data transfer errors while using these technologies hence improved equipment design cloud computing and further specialization may be helpful. These technologies are generally applicable to a restricted spatial area, thus wider applicability needs to be explored. Further, lack of validated research results concerning the effects of application, high capital input and high costs.

Climate change

Climate is defined as the long-term average condition of the meteorological variables in a given region. These meteorological variables influence an organism through the flow of energy to or from the organism. The world's climate is continuing to change at rates that are projected to be unprecedented in recent human history. The IPCC Fifth Assessment Report identified the ''likely range" of increase in global average surface temperature between 0.3^{o}C and 4.8^{o}Cby 2100.

Climate change is primarily caused by the emissions of greenhouse gases (GHG) which result in warming of the atmosphere that further leads to increase land degradation, air and water pollution, and declines in biodiversity. About 14.5% of global GHG emissions are from livestock sector. Climate change will affect livestock production through competition for natural resources, quantity and quality of feeds, diseases, heat stress at the same time demand for livestock products is expected to increase by 100% by mid of the 21st century. Therefore, the challenge is to maintain a balance between productivity, household food security, and environmental preservation. Figure1 shows impact of climate change on livestock in detail. Figure 2 shows various adaptation and mitigation strategies for livestock.

Figure 1: Impact of climate change on livestock (Source: Rojas-Downing et al.,2017)

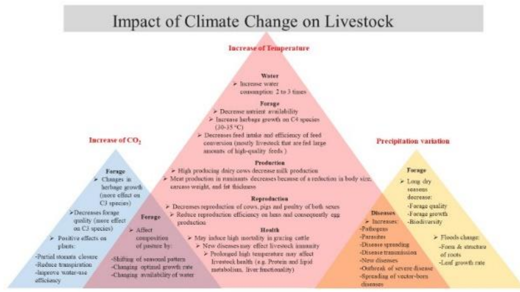
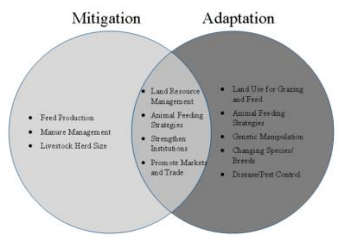


Figure 2: Strategies for Mitigation and Adaptation in Livestock Sector



Precision livestock farming technologies and livestock production under climate change scenario

There are several PLF technology options like electronic identification systems, sensors, automatic recording devices, automatic milking system, mastitis detection tools, automatic oestrus detection machine, methane detection machine, automatic feeders, pedometer, parturition sensors, Software, big data analytics, infrared thermography, expert systems, machine learning, deep learning tools, robotics, IoT, blockchain technologymay be used directly or indirectly in negating impact of climate change on livestock. We will discuss some of them in following paragraphs

1. Electronic (radio frequency) identification systems: National Livestock Identification Scheme (NLIS) made the use of radio-frequency identification (RFID) tags, these tags contain a microchip that can be read electronically in a fraction of a second by producers who have a suitable reader. Electronic identification systems provide accurate identification of cows and linked to pedigree, management events, treatment records, electronic milk meters, computer-controlled feeding, automatic sorting and weighing, etc.

2. Automatic body condition scoring: Automated Body Condition Scoring (BCS) through extraction of information from digital images has been demonstrated to be feasible; and commercial technologies are under development. Ferguson et al. assessed the ability to assign a BCS to a dairy cow directly from digital photographs.

3. Modern Sensor Technology: These sensors are categorised into two types.

a. Invasive sensor (External sensors): These are the sensors which may be immobile sensors located in the barn or mobile sensor boxes attached to the cows.

b. Non-invasive sensors (Internal sensors): These are the sensor Boxes Swallowed or Implanted in the animals. Ex.: PH meter and In-build thermometer.

4. Automatic recording devices (rumen temperature, pressure, pH)

a. **Rumen temperature**: Al-Zahal et al. (2008) reported that the relationship between rumen temperature and rumen pH may be an indicator in the diagnosis of SARA (Sub Acute Rumen Acidosis). A bolus containing a mote (temperature sensor, processor and radio) was placed in the rumen of a fistulated cow to monitor body temperature. Rumen temperature was measured every minute and stored in the internal buffer of the mote.

b. Rumen pressure: Rumen motility can be assessed by measuring changes in rumen pressure. Thus, rumen pressure can be used to determine bloat in ruminants. There is not a lot of rumen pressure data for cattle. Therefore, the boluses would be a very useful tool for assessing the relationship between rumen pressures on bloat in cattle.

c. Rumen pH: Several important factors such as average ruminal pH, the pattern of ruminal pH over time, duration of suboptimal ruminal pH and the variation in the pattern of ruminal pH can be processed by artificial intelligence or other advanced computational programs to evaluate the significance of ruminal acidosis in cattle performance as well as in defining the relations between intake and acidosis.

d. Monitoring ruminal fluid pH is a reliable method to determine acute acidosis or SARA. For research monitoring of rumen pH, a permanent device in the rumen is required to continuously monitor rumen pH remotely without interfering with the normal behaviour of the animal.

5. Robotics has been used successfully for milking, feeding and cleaning etc.

6. Automatic calf feeders consist of a self-contained unit that heats the water, dispenses a programmed amount of milk replacer, and mixes the milk replacer and water in a container from which the calf can suck it out via a nipple feeding station. Each calf as identified by their EID.

7. Automatic milking system: - In this system, detailed data is recorded by the machine which can be accessed remotely by computer or mobile device so farmers can check the health and performance of their herd from a distance. Labor on the AMS is 29 percent less than other methods. A Study in Spain reported production of 1537 kg milk from 53 cows producing 29 kg milk / day.

8. Mastitis Detection Tools: These tools may prevent the infection of udder from becoming chronic and reduce the losses associated with mastitis. Eq.: Milk Checker and Somatic cell count machine. There are various cell counters on the market that can monitor the somatic cell count and give farmers a daily update so that they can react in time.

9. Automatic oestrus detection machine (AED): These are the instruments used to detect heat symptoms and helpful in breeding management. The success of oestrus detection not only increase conception rate but also raises milk production for the herd. For example, Wireless Intravaginal Temperature Sensors and Pedometer (Pedometer readings for estrous detection and as predictor for time of ovulation in dairy cattle).

10. Methane detection machine: The equipment used is Laser Methane Detectors (LMD) measures methane (CH_4) and also monitor impacts of farm changes on greenhouse gas emissions.

11. Automatic feeders (ATM): Automatic feeders are used to eliminate the extra time spent mixing and feeding the animal. It works on the principle of body condition score and milking performance of cow.

12. Parturition sensors: Predicting the onset of parturition is an important requirement as it may enable the rescue of newborn calves and mothers in difficult birthing situations.

• Sensors fixed on pregnant animal - Vaginal temperatures (VT) of cows were collected by a data-logging apparatus with a thermocouple sensor.

• Sense the change in body temperature - useful to save work and trouble at perinatal parturition of cattle.

13. Software used in PDF: In India, a number of herd management software have emerged apart from android based individual animal-based information software. They are Herdman, Milking cloud, Farm ERP, etc.

14. Big data analytics: Modern dairy operation is full of data that complicates timely and precise decision making. These data are mainly used more for daily activities and leaving the vast majority of the data underutilized. Therefore, there is opportunity to use analytics to turn data into information for decision making.

15. Machine learning techniques for predicting heat stress: Becker et al. (2021) reported that both logistic regression and random forest were consistent in predicting scores for control, shade, and combined groups. The mean probability of predicting non-heat-stressed cows was highest for cows in the sprinkler group. Finally, the logistic regression method worked best for predicting heat-stressed cows in control, shade, and combined. The insights gained from these results could aid dairy producers to detect heat stress before it becomes severe, which could decrease the negative effects of heat stress, such as milk loss.

16. Heat Stress Management in cattle with IOT: Different sensors can be used for continuousreal time measurement of crucial parameters like body temperature, ambient temperature and humidity, rectal temperature, heart rate and heat index, and it can also send alert messages to the farm owner whenever counter measures are activated.

17. Infrared thermography: Infrared thermographic cameras are used to measure body temperature of animals and heat emissions are detected by the sensors of infraredcamera and image is displayedas a thermogram of pixels varying in colours/shades that indicate different infrared temperature.

18. Neck-mounted activity collars for heat stress detection: The accelerometer-based neck-mounted collars may be used to identify and quantify the time periodsthat dairy cattle exhibit signs of heat stress and may provide the basis for a fullyautomated system to quantify the effectiveness of strategies e.g., water sprinklers, fans, foggers, etc to provide effective relief to their cattle and improve animal welfare.

Conclusion: Precision Dairy Farming technologies provide tremendous opportunities for improvements in individual animal management on livestock farms. The anticipated adverse effects of climate change on animals could easily be guessed and suitable changes could be made in the daily farm management practiceswhich will lessen the risk of mistakes and will ultimately result in healthier animals& more profits.

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LIVESTOCK AND CLIMATE CHANGE - A GENDER PERSPECTIVE

G. Nirmala and Prabhat Kumar Pankaj

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad

Introduction

India is an agriculturally oriented country, and the livestock sector is an important part of it. Livestock is often regarded as a critical asset for rural livelihoods. Livestock production contributes to 6 percent of GDP in the country. Of the 600 million poor livestock keepers in the world, around two-thirds are women and most live in rural areas. In most communities, all members of the household have access to livestock and are active in both production and livestock management. There is special relationship between women and livestock. Poor women can own livestock when they are denied land, looking after livestock fits well with their work of running households and raising families. Hundreds of millions of women livestock farmers daily tend sheep goats and chickens, milch cows, buy and prepare food, plant and harvest crops, weed their plots besides household chores.

1.1 Strategic needs of women in livestock production

Women take part in livestock activities like cleaning of animals, cleaning of shed, watering of animals, making of dung cakes, and providing fodder to livestock in addition to house hold activities. Raising of poultry, goat and sheep is totally under the control of rural women and they need not to consult their male counterparts for decision making. Women spend 6 hours per day on livestock activities and men spend 3 hours on management of animals. Except for marketing, women are involved in all aspects of livestock production, and their roles appear to vary according to zone. Women in marginal rainfed areas have a greater responsibility for livestock production than their counterparts in favorable rainfed areas or irrigated areas. In marginal rainfed areas, women and girls are responsible for feeding, watering and cleaning sheep pens, while in irrigated zones, women and men share the responsibility in feeding animals (FAO, 1995).

In India, livestock production is largely in the hands of women. Women do most of animal agricultural tasks such as fodder collecting (88%), cleaning of animals and sheds (67%), feeding (79%), watering, and health care (67%), as well as management, milking (46%), and household-level processing, value addition, and selling of milk and by- products. Involvement of women in livestock management practices varied depending upon the type of management practices (Seema Mishra *et al*., 2018). Livestock provide income, create employment opportunities and provide food and nutrition security across different production systems and along different value chains. Moreover, vulnerable groups, particularly women and the landless, frequently engage in livestock production, thus highlighting the multifaceted virtues of livestock promotion as a pathway out of poverty.

1.2 Participation in Livestock activities: In a study in Pakistan had revealed that women participation in livestock production was medium in nature and reasons mentioned were that they had less opportunities in high paid jobs as they possessed low self-confidence levels, received less training and skills which makes women to resort to livestock activities as only livelihood option physical labour, as most of the livestock practices are labour intensive and involve drudgery and fatigue (Munawar *et al*., 2013)

1.3 Control and Access to Livestock: Majority of women involved in decision making related to taking loans (75 %), selection of type of livestock and breed (62.50%) and type of livestock to be sold and medical care, However, women in consultation with husband jointly made decision in respect of extent of investment in livestock production (25.00%), deciding the number of animals to be reared (52.50) and fixing the price of produce (69.16). Areas where decisions were left to husband in relation to livestock management were type of breeding method (AI/NB) (47.50%), growing of fodder (71.66%), purchase of feed/fodder (52.50%), medical care (59.16%) and place of marketing (14.16 %) (Reshma *et al*., 2014).

Gender is a key factor in impacts, adaptation, or mitigation in the voluminous literature on climate change. Men and women experience, understand, and adapt to climate change in different ways, and it is important to understand changes currently taking place, and likely to happen soon, from a gendered perspective. Climate change is likely to exacerbate gendered vulnerabilities and differential abilities to cope with changes on livelihoods in rural areas.

The Climate change induced socioeconomic and environmental problems that received attention for its impact on global food security has impacted women much more tending small animals and livelihoods than men. Women and men vary in holding ownership over livestock, expressing control and decision-making authority over different animal resources and women found to be more vulnerable to climate change. Climate-change related risks to agriculture and livestock-based livelihoods include decreases in crop yields and crop failure, livestock loss, increased water scarcity, and destruction of other productive assets (FAO, 2008). Climate change and gender perspective in relation to livestock production and management being discussed in this paper.

2. Consequences of climate change on women managing livestock

Evidences on impacts of climate change on livestock sector revealed that six major areas being effected in livestock management which are; increased disease pest infestation, depleting grass and feed level, decreasing milk production, death of animal, heat stress and appetite loss. Among those six issues increased disease and pest infestation found to be most important followed by appetite loss and decreased milk production.

2.1 Vulnerability and adaptation of livestock holders

The livestock mix tends toward more small ruminants and fewer cattle. Laws and rules governing diverse and access to land, as well as migration of men, has led to a feminization of livestock keeping. The author demonstrates that this feminization is reflected in changes in herd composition. Herds have shifted away from cattle towards small ruminants (goats and sheep) dominated flocks. The changes have a direct impact on land use patterns as cattle and small ruminants have different grazing behavior and affect vegetation differently. Cattle are also, well known to be more sensitive to drought and other climate impacts than small ruminants. Changing land use patterns and the differential sensitivity of cattle and small ruminants are decisive factors in planning ecosystem-based adaptation in the Sahelian country context (Turner, 1999).

Female livestock holders are found to be more vulnerable to climate change. Livestock holders adapt to climate change as most livestock live in semi-arid areas where climate change impacts are high. Women significantly stresses in livestock sale under stress. Some of the adaptation strategies are mobility, herd management strategies like de-stocking, splitting herds, recuperating herds after crisis through family loans, livelihood diversification, and settlement.

Table-1 A gendered approach to understanding how climate change is affecting dimensions of food security across a spectrum of livestock holding livelihood groups

Livelihood	**Gendered Pathways of climate change impact on Food Security**		
	Economic	Health	Nutrition
Pastoral	Time demand on women for collection of water and fuel	Risk of disease due to proximity of women's work to reservoirs of disease agents and biologic risk	Under nutrition due to availability of certain plant
	Time Demand on men to seek out water sources with herd	Vulnerability to maternal mortality due to fertility associated with sedentarisation	Undernutrition due to separation of family members from milk producing animals
	Productive and reproductive demands on women due to new	Mental and emotional health	Undernutrition due to unfavorable terms of

	coping mechanisms and livelihood modifications		trade between animal products and gains
	Financial autonomy of women due to probable liquidation of small animal assets		
Agro-Pastorals	Time demand on women due to migration of men for herding or wage labor	Vulnerability of newly sedentary households, particularly women	Risk of food insecurity due to production of livestock and process of grains and other foods, particularly in women and children
	Financial autonomy of women due to probable liquidation of small animal assets	Earlier weaning shortened birth intervals, andrisk of maternal depletion due to migration of men for herding or wage labor	Diets may become less varied and less nutritious
	Constraints on herd management due to shifts in households' herd management	Incidence of anemia and stunting in children	
Urban livestock holders	Vulnerability and poverty due to increased population growth and lack of employment opportunities	Access to clean water, adequate sanitation and sufficient living areas	Food insecurity due to higher food process and loss of income
	Susceptibility to market fluctuations based on animal food supply from pastoral/agropastoral communities	Child mortality of infectious diseases	Malnutrition, including overnutrition

	Access to inputs	Incidences of chronic diseases Incidence of infectious diseases	Shift towards unhealthier dietary patterns
	Urban nutrient cycling of food waste as to animal feed	Levels of stress and depression	Affordability, accessibility and availability of processed foods that are poor in nutrient value
			Transportation time may improve perishability and enhance food safety

(Adapted from Sarah L McKune *et al*., 2015)

Conclusion

Climate change increased workload for women as men migrate and burden of management of large animals fell on women and in turn women converted large animas to small animals. The higher workload and decreased access to assets and decision making on the newly acquired agricultural land increased women's vulnerability. Both men and women should be equally involved in disaster risk management of livestock. For women, purchase or receipt of a cow does not necessarily imply ownership. Analysis of the specific conditions of the project area and target households and monitoring of change are important to formulate and achieve realistic project goals.

Due to differences in the ways in which men and women use income, increases in men's earnings from livestock-related activities may not be necessarily translated into improved household nutrition, whereas women tend to prioritize household well-being. The division of work between men and women in processing and marketing needs to be analysed and project activities adapted accordingly. An agreement among men and women beneficiaries that protects women's position must be found.

The role of women and their empowerment in the local and regional livestock production system should receive special attention. The local practices at the basis of livestock production must inform all development initiatives, and proposed technologies should be economically feasible, socially accepted and low risk.

Although income is not the only factor that determines women’s socio-economic position, it greatly influences their status and living conditions. Increasing women's income by boosting livestock production therefore strengthens their position. As men may feel exposed by this process, projects must involve men and women in all negotiations to bring about equitable and sustainable changes. Efforts are needed to increase the capacity of women to negotiate with confidence and meet their strategic needs.

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CONTINGENCY PLAN FOR LIVESTOCK AND POULTRY IN INDIA

Prabhat Kumar Pankaj, DBV Ramana and R Nagarjuna Kumar

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad

Introduction

Poultry flocks are particularly vulnerable to climate change because birds can only tolerate narrow temperature ranges. The damages due to climatic extremes have gone up over the years. Poultry farmers need to consider making adaptations now to help reduce cost, risk and concern in the future. ICAR-Central Research Institute for Dryland Agriculture, Hyderabad has prepared contingency plan for different states under different extreme scenarios, like drought, flood, cyclones, cold and heat waves, etc. to be used as an advisory as and when need arises with the help of line department officials and universities.

The present chapter deals with the systematic contingency plan to maintain production level of livestock and poultry in India ultimately maintaining livelihood and nutritional security of farmers.

Systems of livestock farming in India

There are 3 systems of rearing livestock in India. They are, (i). Intensive, (ii). semi-intensive, and (iii). Extensive system. In view of prevailing climate change, the animals reared under extensive system are the most vulnerable due to more exposure and dependency on external environmental conditions.

In India, both intensive and traditional systems of poultry farming are followed, but intensive system is rapidly increasing due to increasing land and other input costs. In case of layers, the cage system is rapidly replacing the deep litter system. However, in broiler farming, the deep litter system is more prevalent. Poultry Production has three segments: i). Layers, ii). Broilers, iii). Backyard / family production and iv). Alternate poultry production.

Extreme events and its importance in livestock and poultry farming

Apart from affecting human beings, natural disasters cause tremendous sufferings for the livestock and poultry population. Poultry, being vulnerable to environmental factors like temperature, relative humidity, wind velocity, radiation, etc; they are severely affected by any of the climatic extreme events. Special forecast for following conditions will be helpful in effective preparedness practices. They are tropical storms (cyclones, hurricanes, typhoons, etc.) associated with high winds, flooding and storm surges, floods (other than those related to tropical storms) heavy rains due to monsoons, water logging and landslides, severe thunderstorms, hail storms, drought and heat waves, cold spells, low temperature, frost, snow, dust storms and sand storms, pest and diseases of crop and livestock. Prolonged flood can also cause death of livestock and birds through a number of direct and indirect mechanisms. During droughts, livestock are affected by water shortage and increased radiation and also lack of water increases their vulnerability to diseases. Since climate change would increase susceptibility to natural disasters, as mentioned in earlier sections, the anticipated toll on the livestock sector would be quite high. The sufferings of livestock in the coastal zone are much higher than in other parts of the country, however, livestock density is relatively low in the coastal areas, particularly in the southwestern parts of the country. Gradual increases in salinity also increase competition for freshwater resources, and the livestock suffer the brunt of such a calamity. Animals used to have the least access to freshwater sources during the dry season. Due to drinking of poor-quality water, these animals fall victim to diseases, which reduce their economic efficiency (growth rate, egg production, etc.). It may therefore be concluded that the livestock sector would also be vulnerable to the adverse impacts of climate change. The various contingency conditions can be categorized as,

i). Drought: In India, droughts are a regular occurrence every single year. Severe droughts in 2002, 2009, 2012 and 2014 impacted negatively the growth of agriculture sector, including field crops, horticulture, livestock, poultry, and fishery particularly in rainfed regions of the country. Drought results when the principal monsoons, namely, the South-West Monsoon and the North-East Monsoon, fail, or do not provide as much water as usual. The erratic behaviour of the monsoons causes periodical droughts in both low (less than 750 mm per year) and medium (750 mm to 1000 mm per year) rainfall regions, which constitute 68% of the total area of India. Monsoon failure results in crop failure, water scarcity and a shortage of food and fodder for humans and animals.

India has developed numerous strategies to cope with droughts, e.g. harnessing water through medium reservoirs, developing traditional systems of tanks, exploiting groundwater, etc. Current drought management practices include the operation of an early warning system: meteorological conditions, particularly the monsoon rains from June to September, and hydrological conditions, such as reservoir and groundwater levels, are closely monitored. Early warning means that better preparations can be made, which improves the effectiveness of drought mitigation strategies. Drought preparedness measures: this involves communities developing plans so that health care and veterinary care institutions, water resources and disaster assistance resources can expand their services in times of drought

At district level, a standard procedure for drought mitigation is in place, which, if implemented promptly, can substantially reduce the vulnerability of people and livestock. However, seasonal vulnerability to drought is a reality in India and the transfer of food, fodder and water resources to drought-affected areas is costly and may increase dependency and undermine the ability of local community systems to cope. Therefore, what is needed urgently is to strengthen the local system or the traditional household system and ensure that there is local community involvement in disaster mitigation strategies.

ii). Flood: Extreme hydrologic events are becoming more common with changing climate. Floods are characterized as any high stream flows which overlap natural or artificial banks of a river or a stream that leads to inundation. Sometimes copious monsoon rain combined with massive outflows from the rivers cause devastating flood. Flooding is caused by the inadequate capacity within the banks of the river to contain the high flows brought down from the upper catchment due to heavy rainfall. Floods have become a regular annual event in India, causing extensive damage to agricultural production, loss of property and livestock and loss of human life. In addition, in the aftermath of a flood, the environment, rivers and drinking water become contaminated. Animals in contaminated floodwater for long periods become susceptible to infections. In addition, the cuts acquired from disaster debris make animals more vulnerable to tetanus and toxins contained in the floodwater. Common animal illnesses caused by sewage-contaminated water include tetanus, salmonellosis and other important water borne diseases. In addition to this, pathogenic viruses, bacteria, and other organisms present in floodwater can enter the body through openings in the body.

iii). Cyclone: Due to the low-depth ocean bed topography and the coastal configuration, the Indian sub-continent is affected by cyclones more than any other area in the world. The Indian Ocean is one of the six major cyclone-prone regions of the world. The super cyclone in Orissa during October, 1989 killed more than 18 lakhs of poultry birds in 12 affected districts. The per day milk collection under the impact of the cyclone saw a 25% fall. The states most exposed to tropical cyclone surges are West Bengal, Orissa, Andhra Pradesh and Tamil Nadu along the Bay of Bengal, and Gujarat and Maharashtra along the Arabian Sea. The frequency of the tropical cyclones in the Bay of Bengal and the Arabian Sea is greater than anywhere else in the world: on average, about five cyclones occur there every year. They produce great disruption to normal life and business by causing damage to human and animal life and property, failure of power transmission and communication lines, and flooding of roads and residential areas. In the aftermath of the cyclone, feed and fodder were scarce and consequently many animals starved to death, veterinary dispensaries and livestock aid centres were in a dilapidated condition.

iv). Hailstorm: It produces heavy rain showers, lightning, thunder, hail-storms, dust-storms, surface wind squalls, down-bursts and tornadoes. Though hailstorm can occur in any part of the world, temperate zones are the most vulnerable. They damage the poultry industry due to direct mortality, effect on nutrient availability and changing pattern of diseases.

Building resilience in poultry production through disaster risk management

India is one of the top four most disaster-prone regions in the world. India, being a vast country with a tropical climate, experiences all types of natural disaster, except volcanic activity. The frequency of droughts, floods, earthquakes and cyclones is increasing every year. Based on disaster affinity, the country can be categorised into five sub-divisions, as follows:

i) Northern mountain region (including foothills): mainly prone to snow storms, leading to landslides and cold waves, heavy rainfall, and land and soil degradation. Massive snow avalanches occur in the Himalayan region, which have great destructive potential.

ii) Indo-Gangetic plains: floods are a common occurrence here.

iii) Deccan plateau: this area is prone to drought and has erratic rainfall. Earthquakes of varying intensities have also been reported in this area.

iv) Western desert: this area, known as the Thar Desert, has limited and unreliable rainfall and is prone to drought

v) Coastal areas: the coastal areas are vulnerable to sea erosion, cyclones, tsunami and tidal waves. Five to six tropical cyclones form in the Bay of Bengal and the Arabian Sea every year, two to three of these cyclones will be severe and will devastate the densely populated coastal areas of India, causing extensive damage.

Basic management options during emergencies

There are following management techniques need to be considered while facing any of the contingency conditions:

I. **Destocking Strategies:** The first, and arguably the easiest option for livestock and poultry producers during times of emergencies is to do nothing, i.e., continue to operate as if no such conditions are present. If the drought is short-term (e.g, one growing season) and the range resource was in good to excellent ecological condition when the drought began, this option may not result in adverse effects on the range resource. However, if the drought becomes severe or the range was in less than good condition during the drought year, this option could result in severe range degradation. Destocking is the option to balance the demand with feed supply and will generally be less financially detrimental to the livestock/poultry owners. In most cases, destocking and selling the livestock is advised rather than purchasing feed or sending the animals to non-drought areas.

II. Breeding Management: There is lack of good quality semen and frozen semen facilities in the country are available to a limited extent. Also, the conception rate of frozen semen is very poor. No definite breeding policy is there regarding use of frozen semen of different breeds in India is available. There is large scope of development of tolerant breeds with respect to environmental extremes using marker assisted selection and breeding. Indian breeds are hardy due to low susceptibility to diseases, can thrive under nutritional stress, etc. which need to be promoted during breeding programmes. There is need of complete stoppage of indiscriminate breeding.

III. **Feeding Management:** Feeding management is very important in drought/ flood/cyclone/ hailstorm affected area. Limited feed resources that too of poor quality need to be processed or enriched before use. Generally, byproducts of crops like maize, jowar, bajra, wheat, etc. and broken grains are fed to livestock. The total digestible nutrients are also very low (40-50%) in these diets. Animals kept on such feed are affected by mal-nutrition. Opportunities for supplemental feeds include many of the by-product feeds, or residues from the cereal grain and oilseed milling and processing industry. Examples of by-product feeds include wheat middling's (produced dueing wheat flour milling), soybean hulls (soybean oil extraction), distiller's grains (ethanol production) and corn gluten feed (high fructose corn syrup production). By-product feeds are characterized by moderate to high energy values, medium to high protein, and relatively high fiber content.

Heat stress could induce the unfavourable changes in intestinal bacterial microflora. The supplementation of probiotic *Lactobacillus* strains may enrich the diversity of *Lactobacillus* flora in chicken jejunum and caecum, and therefore restoring the microbial balance and maintaining the natural stability of jejunal and caecal microflora of broiler chicken after heat stress. Dietary supplementation of chromium (120 ppb) and Zinc (4.5 mg/kg) is favourable to the performance of heat-stressed broiler chickens, by increasing feed intake and body weight, improving feed efficiency, and facilitating carcass characteristics. Moreover, there is a combination of zinc and Vitamin A effect in preventing heat-stress-related depression in performance of broiler chickens.

IV. **Water Management:** During periods of high temperature, the flock has higher demand for drinking water. The water to feed ratio is normally 2:1 at 21ºC (70ºF) but increases to 4:1 at 40ºC (105ºF). For floor raised flocks, providing additional drinkers can help to fulfill the increased requirement.

The presence of blue-green algae (*Cyanobacteria*) in the farm ponds, where the water becomes stagnant due to drought condition results in poisoning. As the water level in a pond drops, less oxygen is available, resulting in death of algae cells. The organisms concentrate downwind to form "scum" on or just below the pond surface. If an animal drinks in this scum it may die immediately or succumb hours or days later. To prevent blue-green algae poisoning, the farmer should monitor farm ponds for algae blooms, especially during hot weather. Drinking water stored in overhead water tanks can get very hot. These tanks should be painted with white colour, to reflect the solar radiation and avoid direct sunlight.

V. **Shelter management:** The provision of sprinklers, anti-reflective coatings on roof may help to fight against heat wave, however, covering with gunny bag and provision of bulb will help in protection from cold waves. During floods, high raised platforms may be of help both for keeping animals as well as feed. Housing systems need to be managed to maintain optimal seasonal temperatures and reduce the risk of heat stress.

VI. **Control of Parasites and vaccination:** Control of both internal and external parasites is very important during climatic extremes. Deworming should be done regularly once in three months. To control external parasites like ticks, mice, lice etc. periodical spraying of insecticide is necessary.

Implementation of District Agriculture Contingency Plans

Contingency plans are the best strategy for risk reduction and building resilience at farmer's level through preparing them with alternative plans to withstand climate variabilities. In general, the district plans focus more at macro level changes at the district level and does not catch the micro-level changes. The issues and vulnerabilities at micro-level may vary especially weather variations at the block level.

Contingency measures for tackling extreme events

Environmental extremes/ Series of events		**Contingency measures to be adopted**
1. Drought	Before	• Weather forecasting and early warning systems • Prepare contingency plan for local needs • Constituting efficient team of workers to act as a Rapid Action Force during emergencies. Collaboration of the district veterinary officials to handle endemic animal diseases. • Culling of unproductive animals for efficient utilization of feed • Storage of household grains like broken rice, maize, pulses, oilseeds etc. • Preserving water in tank, adoption of various water conservation methods at village level to improve the ground water level for adequate water supply. • Culling of weak and sick animals • Timely deworming • Vaccination against endemic diseases • Provision for balanced feeding of productive animals • Veterinary preparedness • Mass awareness programme on management of animals during drought • Popularizing livestock insurance and its implementation.
	During	• Constitute technical groups at state, zone, district and block levels • Offering stored feed and use of non-conventional source of feed like broken grains, brewery wastes, etc. • Supplementation only for productive birds with house hold grains • Immediate marketing of the meat type animals • Arrangement of good quality feed • Judicious use of stored water • Immediate segregation of disease affected and suspicious animals from the flock • Immediate treatment of the sick animals • Conducting animal health camps during the period

		• Maintenance of proper hygiene and sanitation in the commercial farms • Regular cleaning of animal houses to minimize disease incidence • Restriction against needless movement of individuals in the farm premises • Restricted feeding • Restriction against needless movement of individuals in the farm premises • Use of fly proof netting in sheds to prevent arthropod borne diseases. • Use of foot baths at the farm entrance to minimize disease transmission.
	After	• Regular operations for the remaining stock and restocking of the new one • Culling unproductive animals • Providing of good quality feed to obtain optimum growth • Developing drinking water storage facilities • Availing insurance wherever required • Maintenance of proper hygiene and sanitation in the sheds • Disposal of dead animals by burning or by deep burial with lime powder in pits of optimum sizes • Timely vaccination of all the animals
2. Flood	Before	• weather forecasting and early warning systems • Prepare contingency plan for local needs • Constituting efficient team of workers to act as a Rapid Action Force during emergencies. Collaboration of the district veterinary officials to handle endemic animal diseases. • In case of early forewarning of floods, shift the animalss to safer and higher place which has to be identified before • Procurement and storage of sufficient good quality feed ingredients in flood prone areas and storing of house hold feeds like broken rice, pulse, oil seeds, etc. • Preserving water in tank • Popularizing sheds on raised bamboo/ pucca structures to protect them from flood water, occurrence of diseases and storage of feed

		• Identification of sites/areas not prone to inundation during floods for erecting sheds and feeds storage units • Add antibiotic powder in drinking water to prevent any disease outbreak • Vaccination against endemic diseases • Stocking of emergency medicine for prevalent diseases • Mass awareness programme on management of poultryanimals and zoonotic diseases. • Popularizing the concept of animal insurance and its implementation • Training and awareness
	During	• Constitute technical groups at state, zone, district and block levels. • Rescue and help • Flood Action Plan prepared and mobilize the team to meet up the urgency • Arrangement of safe drinking/ medicated water from outside • Shifting of animals and feed to raised sheds and storage units • Conducting animal health camps during the period • Immediate segregation of disease affected and suspicious animals from the flock and treatment of the sick animals • Prevent water logging surrounding the sheds through proper drainage facility • Assure supply of electricity by generator or solar energy or biogas • Sprinkle lime powder to prevent ammonia accumulation due to dampness • Maintenance of proper hygiene and sanitation in the commercial farms • Restricting trade of milk, meat and eggs during outbreak of a disease having potential to take an epidemic form. • Erect pens to protect the stock • Water treatment to minimize ecto-parasite infestation
	After	• Compensation • Re-establishment of normal managemental conditions • Culling unproductive animals • Use of good quality feed to obtain optimum growth • Treating drinking water • Sterilization of vacant sheds before bringing back the batch of animals

		• Disposal of manure to prevent protozoal problem • Vaccination • Maintenance of proper hygiene and sanitation in the shed • Disposal of dead animals by burning or by deep burial with lime in pits at proper depth • Timely marketing of meat type poultry and poultry eggs to minimize losses due to mortality
3.Cold/ Heat wave/ Frost	Before	• Prepare contingency plan for local needs • Popularizing the concept of animal insurance and its implementation • Multiple use, reuse and integration of poultry/animals with other farming systems • Arrangement of adequate water and feed • Prepare shelter shed with all precautionary measure at village level • Prepare medicine and vaccines etc. at village veterinary sub-center/ dispensary • Construction of wind breaks, fixing of sprinklers on the roofs, provide thatch on the roof, optimize stocking density, decrease litter depth. • Construction of wind breaks keep curtains ready and arrange for heating devices • Adopting measures for maintaining the in-house temperature at or near to physiological optimum temperature • Nutritional manipulation like use of fats/edible oil in the ration, extra supplementation of methionine, biotin, choline chloride and vitamin C etc.
	During	• Constitute technical groups at state, zone, district and block levels. • Shift the animals to the sheltered areas • Organize health camp with the help of line department officials • Modulate energy content and increase protein content in feed, add anti stress factors, provide cool drinking water.
	After	• Prepare scientific housing with locally available materials • Organize health camp with the help of line department officials • Re-establishment of normal managemental conditions

4. Hailstorm	Before	• Prepare contingency plan for local needs • Listen to local weather forecasts and stay aware of weather changes • Popularizing the concept of animal insurance and its implementation • Ensure enough water quantity in the water bodies • Constituting efficient team of workers to act as a Rapid Action Force during emergencies. Collaboration of the district veterinary officials to handle endemic animal diseases. • Procurement and storage of enough good quality feed ingredients and storing of house hold feeds like broken rice, pulse, oil seeds, etc.
	During	• Constitute technical groups at state, zone, district and block levels. • Use of unconventional and locally available cheap feed ingredients for feeding of animals and birds • Avoid soaked and mould infected feeds • Provide clean drinking water • Treatment of diseased one, proper litter management and spraying of fly repellents in the sheds
	After	• Follow up surveillance and monitoring • Insurance claim • Compensatory stocking of seed • Repair of sheds and restocking • Cleaning and disinfection of the shed • Bleach (0.1%) drinking water / water sources • Disposal of manure to prevent protozoal problem • Supplementation of coccidiostats in feed • Vaccination
5. Cyclone/ Tsunami	Before	• Forewarning systems to be installed • Prepare contingency plan for local needs • In case of early forewarning of floods, shift the animals and birds to safer and higher place which has to be identified before • Popularizing the concept of animal insurance and its implementation

		• Constituting efficient team of workers to act as a Rapid Action Force during emergencies. Collaboration of the district veterinary officials to handle endemic animal diseases. • Store sufficient feed for the transportation to the flood affected villages • Keep stock of bleaching powder and lime • Treatment of animals for both external and internal parasites • Keep stock of sufficient medicines like anthelmentics, anticoccidials and antimicrobials. • Add antibiotic powder (Terramycin/Ampicilline/Ampiclox etc., 10g in one litre) in drinking water to prevent any disease outbreak • Don't allow scavenging of animals and birds
	During	• Constitute technical groups at state, zone, district and block levels. • Safety return back to the shore/ stay at home/ move to safe places • Protect from thunder storms • Proper hygiene and sanitation of the poultry shed • In severe storms, let loose the animals and poultry in a safer enclosure • Use of unconventional and locally available cheap feed ingredients for feeding of animals and poultry • Avoid soaked and mould infected feeds to animals and poultry • Provide clean drinking water • Vaccination and treatment of diseased one, proper litter management and spraying of fly repellents in the sheds • In case of uncontrollable condition, it is advisable to sell of the flock at the earliest (All in all out policy) - more relevant for poultry
	After	• Cyclone/ tsunami shelter rehabilitation of affected area • Compensatory stocking • Repair of sheds and restocking • Cleaning and disinfection of the shed • Bleach (0.1%) drinking water / water sources • Disposal of manure to prevent protozoal problem • Vaccination

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DIETARY MODULATIONS FOR AMELIORATION OF HEAT STRESS IN POULTRY

S V Rama Rao, M V L N Raju, B Prakash and U Rajkumar

Directorate of Poultry Research, Hyderabad

Animals are subject to stress from a number of sources including management, husbandry practices, nutritional variations and environment fluctuations. Environmental variables include high temperature, humidity, ventilation, etc. High temperature coupled with humidity, which is more common in larger part our country across the seasons is more stressful to chicken. Environmental temperature is one of the major stressors in our country because the temperature ranges from -5 up to 40-45°C for prolonged periods with variations in the temperature range. The ideal temperature for broilers is 10-22°C for optimum body weight and l5-27°C for feed efficiency. However, layers will produce eggs in the temperature range of 10-30 °C. Above the ideal temperature zone, performance will be depressed in terms of growth, feed intake, egg production, egg size and eggshell quality. Sub-optimal nutritional (excess or deficiency of nutrients, mycotoxins, pesticide residues, chemical toxins, phyto chemicals, etc.) profile further aggravate stress condition in chicken. Routine management practices, e.g. medication, vaccination, beak-trimming etc, also add to the stress.

Higher environmental temperature reduces feed intake, body weight gain (growth) and egg production in poultry. Since chicken has no sweat glands and body covered with feathers metabolic heat produced is exhaled through increased respiration (panting) and proportionate increase in heart rate. During this phase bird undergo several physiological and hormonal changes, which result in increased stress, reduced immune competence and in extreme case severe mortality is also not uncommon.

Both nutritional and management corrections to make changes to the feed modulations and feeding practices may help in minimising the adverse effects of heat stress in broilers and laying hens. Several nutritional strategies were studied and few of the nutritional modulations were found effective in minimizing the ill effects of heat stress in poultry. In the present article few practical approaches are discussed to reduce the adverse effects of heat stress in poultry.

1. Energy

Energy intake is the most important nutrient limiting bird performance at high temperatures. The energy requirement for maintenance decreases by about 30 kcal/day with increase in environmental temperature above 21°C. Although the energy requirement for maintenance is lower at higher environmental temperatures (heat stress), most of the energy is wasted in heat dissipation (increased activity) so the energy requirement is not affected by heat stress.

The feed energy concentration should be adjusted to allow for the reduction in feed intake at higher temperatures. Feed intake changes about l.72% for every l ^{o}C variation in ambient temperature between 18 and 32^{o}C. However, the decline is much faster (5% for each 1^{0}C) when the temperature rises to 32-38^{0}C. Measures to increase feed intake include the inclusion of fat / oil in the diet. Dietary supplementation of oil during heat stress is beneficial due to 1. Increase the palatability of feed, 2. Increase the density of diet, and 3. Fat / oil has less heat increment (metabolic heat production) and energy through fat minimizes heat production in chicken. Feed consumption increased up to 17% by 5% fat supplementation in heat-stressed birds. In addition, fat offers an extra-calorific value by decreasing the rate of passage of digesta, thereby increasing the utilisation of nutrients. Fats or oils with more saturated fatty acids are preferred in hot-humid climates. The concentration of energy should be increased by 10% during heat stress, whilst the concentration of other nutrients (more particularly anti-oxidant vitamins and trace minerals) should be increased by 25%.

2. Protein

The requirements for protein and amino acids are independent of environmental temperature so heat stress does not affect bird performance as long as the protein requirement is met. However, heat stress reduces feed intake and the levels of protein / amino acids need to be increased with the environmental temperature up to 30 ^{o}C. At even higher temperatures, heat stress has a direct effect on production and there is no benefit in raising the protein level.

Dietary imbalance or deficiency of amino acids leads to fat accumulation in liver and abdominal area, which further aggravate heat stress. Balanced feeding of amino acids minimises fat deposition in the liver, thereby increasing the survival of birds under heat stress. So, a low-protein diet with balanced critical amino acids (methionine, lysine, threonine, tryptophan, valine, etc.) is more beneficial than a diet high in total protein during hot conditions. Further, the excess unutilized amino acids undergo oxidation which generates metabolic heat, which further tax the bird under heat stress.

3. Calcium and phosphorus

Heat stress reduces calcium intake and conversion of vitamin D3 to its metabolically active form (1, 25$(OH)_2$ cholicalciferol), which is essential for the absorption and utilisation of calcium. The calcium requirement of layers particularly older birds is increased at high environmental temperatures due to reduced feed intake and reduced utilization of Ca owing to impaired vitamin D3 metabolism due to heat stress. To overcome this effect, extra Ca should be provided at the rate of l g /bird during summer months in the form of oyster shell grit or limestone. Supplementation should be made over and above the standard dietary Ca recommendations (3.75g/bird/d) for layers.

However, excessive levels of Ca reduce feed intake due to the physiological limit of Ca appetite and also reduced palatability. Instead of increasing the diet specification, the Ca should be offered separately as a choice feed. Better results are obtained by offering the Ca source in the afternoon. The optimum particle size is the one that supplies the required Ca at the time of shell formation. The minimum size to improve gizzard retention is about l mm.

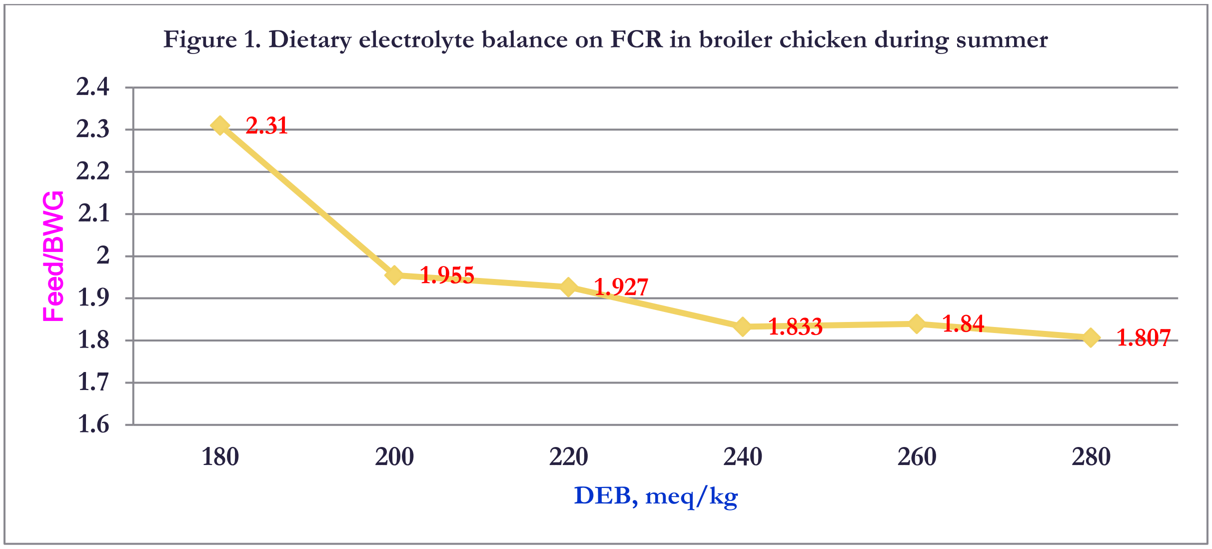
The phosphorus level in diet must not be forgotten as excessive phosphorus inhibits the release of bone calcium and the formation of calcium carbonate in shell gland, thereby reducing the shell quality. An ideal ratio of 2:1 Ca : nonphytate phosphorus give better results in chick and broilers. Excess phosphorus also detrimental for breeders and layers during heat stress, which may reduce shell quality and leads to cage layer fatigue. Therefore, optimum concentrations of Ca and available P are important for poultry during heat stress.

4. **Electrolytes/buffering agents**

Supplementing the diet with 0.5% sodium bicarbonate or 0.3-1.0% ammonium chloride or sodium zeolite can alleviate the alkalosis caused by heat stress. Sodium bicarbonate stimulates feed and water intake at high environmental temperature. The body weight gain can be increased up to 9% by addition of these chemicals in the feed of heat-stressed broilers.

The excretion of potassium through urine is significantly higher at 35 ^{o}C than at 24^{o}C. The potassium requirement increases from 0.4- 0.6% with a rise in temperature from 25 to 38 ^{o}C. A daily potassium intake of 1.8 -2.3 g potassium is needed by each bird for maximum weight gain under hot conditions.

To compensate for the reduced feed intake under heat stress, dietary allowances for electrolytes (sodium, potassium and chloride) may be increased by 1.5% for each 1^{o}C rise in temperature above 20^{o}C. Electrolytes are also present in the drinking water and these levels need to be taken into consideration. Excess intake of electrolytes can lead to wet droppings. Potassium chloride can be added to the drinking water (to give 0.24-0.30 % K) but care must be taken to avoid imbalances. Excess chloride is known to decrease the blood bicarbonate concentration. Dietary electrolyte balance should be in the range of 240 to 280 meq/kg during summer season (Figure 1).



During heat stress, the bird tries to maintain its body temperature by increased respiration, i.e. evaporation of metabolic water, which may considerably increase the water requirement. The addition of electrolytes (and/or vitamin C) to cold water helps to increasing feed intake by heat stressed birds.

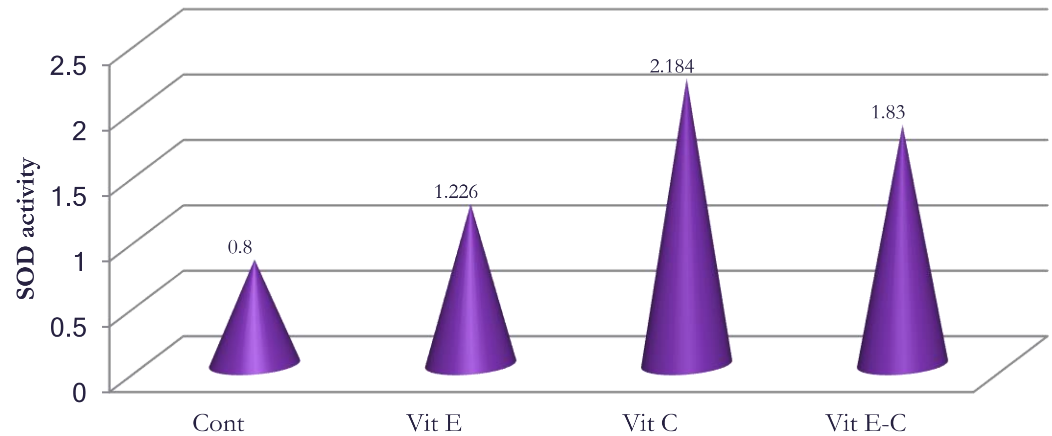
5. Vitamins

Additional allowances of ascorbic acid (vitamin C), vitamin A, E, and D3 and thiamine can improve bird performance at higher temperatures. However, the loss of vitamin activity either in premix or in feed during storage particularly at elevated environmental temperature is a prime concern and probably explains the conflicting results on the effects of vitamin supplementation during heat stress. High temperature, moisture, rancid fats, trace minerals and choline speed up the denaturation / oxidation of vitamins. Vitamin activity in feeds can be maintained by using feed antioxidants, gelatine-encapsulated vitamins, appropriate storing conditions and adding choline and trace minerals separately from other vitamins.

Ascorbic acid synthesis is decreased at elevated environmental temperature, making it an essential dietary supplement during the summer. The vitamin helps to control the increase in body temperature and plasma corticosterone concentration. It also improves eggshell quality via its role in the formation of the shell's organic matrix. Furthermore, it protects the immune system and reduces mortality in growing birds infected with infectious bursal disease (IBD) in a hot environment by protecting the lymphoid organs and thyroid activity. Supplementation of ascorbic acid (200-600 mg/kg diet) improves growth, egg production, number of hatching eggs, feed efficiency, egg weight, shell quality and liveability during heat stress.

Vitamin E protects the cell membrane and boosts the immune system so additional dietary supplementation may be advantageous during hot weather. Mortality due to E. coli infection reduced significantly by supplementation of vitamin E in diet. Supplementation of 100 mg/kg each of vitamins E and C in diets of commercial broilers improved the activity of anti-oxidant enzyme i.e. super oxide dismutase (SOD) during summer (Figure 2)

Figure 2. Effect of supplementing vitamin E and C on activity of SOD in broiler chicken



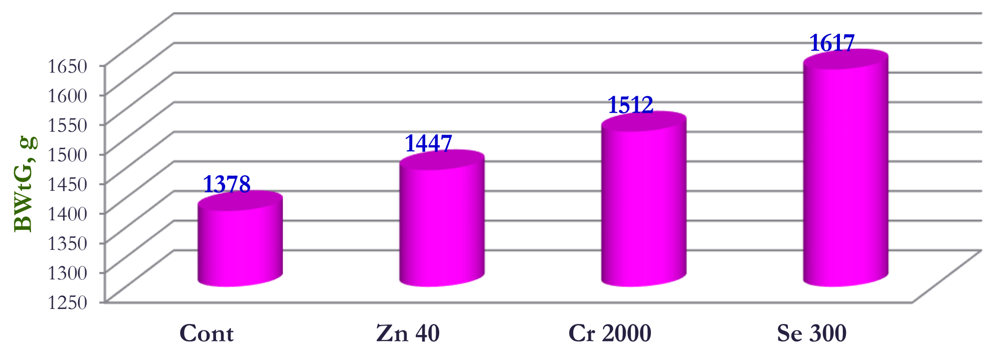
The absorption of vitamin A declines at high temperatures. In broiler breeders, a three-fold increase in supplementation has been found to be beneficial.

Heat stress is known to interfere with the conversion of vitamin D3 to its metabolically active form, i.e. 1,25 $(OH)_2D3$, so higher dietary levels may be justified during periods of high temperature. The active form of vitamin D3 is involved in the synthesis of calcium binding protein, essential for calcium and phosphorus homeostasis. Similarly, the requirement for thiamine is double at above 32^{o}C compared to those reared at 21^{o}C.

6. Organic trace minerals

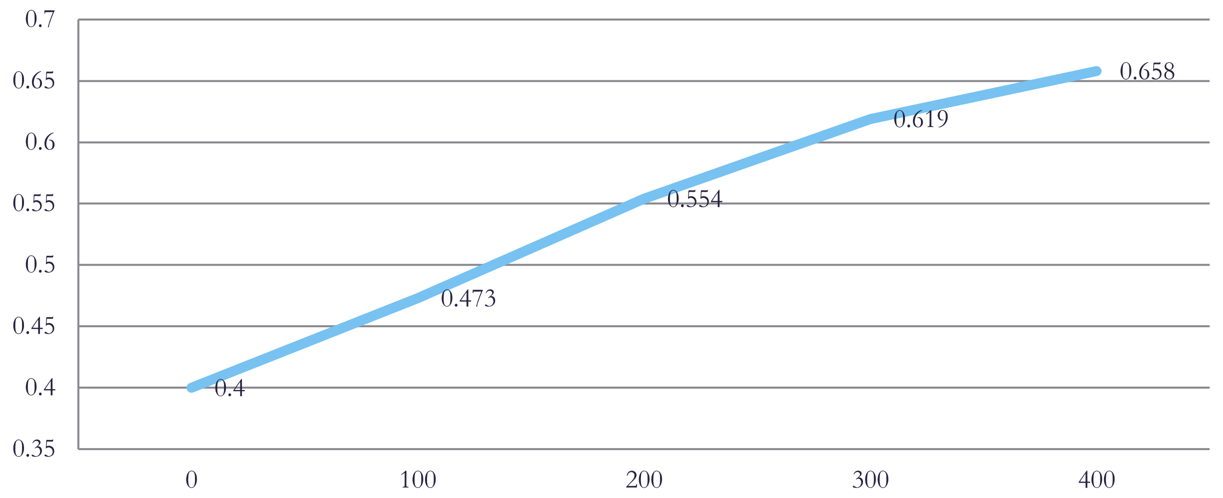
Organic trace minerals are preferred over inorganic source due to several obvious reasons like higher bioavailability, non-toxic, non corrosive, etc. However, the cost of organic TM is higher than inorganic trace minerals, which limits the use of OTM in poultry diets. Strategic supplementation of TM whose requirement is small (Se and Cr) but has a significant impact on performance and health of the bird is another approach to minimize the cost of mineral supplementation. Minerals like selenium and chromium are supplemented in micro gram per kg diet, but they play a significant role in broiler nutrition. The second school of thought is super dosing of these OTM in diets containing adequate levels of inorganic TM. Several experiments were conducted at the authors' laboratory to study the benefits of super dosing organic Se, organic Cr and organic Zn independently or in combination on performance, immune responses, slaughter variables and anti-oxidant responses in commercial broilers fed diets containing recommended levels of inorganic TM. The results demonstrated that supplementation of organic form of Zn (40 mg/kg), Se (0.30 mg/kg) or Cr (2 mg/kg) significantly increased body weight gain and feed efficiency (Figure 3) reared during tropical summer (30.2 to 43°C). Activity of superoxide dismutase in serum of broiler fed organic Zn, Se or Cr was significantly higher than those fed the ITM control diets. Supplementation of organic Se or Cr at graded concentrations (100, 200, 300 or 400 µg/kg diets) linearly increased the antioxidant status and cell mediated immune response in commercial broilers. Supplementation of organic Cr at graded concentrations (100, 200, 300 or 400 µg/kg diets) in broiler diets non-linearly increased cell mediated immunity, antioxidant enzyme activity and relative breast mass and decreased lipid peroxidation (stress) and pre-slaughter holding losses. The data of the four experiments envisages that super dosing of Se, Cr or Zn in diets containing 100% ITM significantly increased the performance of broilers during summer besides reducing oxidative stress and enhancing cell mediated immune response in commercial broilers. Pre-slaughter holding losses were reduced by supplementing organic form of Cr in broiler diets.

Figure 3. Supplementation of organic Zn, Se, Cr on body weight gain in broilers during tropical summer



Similarly, supplementation of organic chromium at graded concentrations (0 to 400 mcg/kg diet) progressively and significantly improved the cell mediated immune response (CMI) to phyto haemogglutining phosphate inoculation to toe web in commercial broilers reared under tropical summer (Figure 4).

Figgure 4. Effect of super dosing organic Cr on CMI response in broilers



7. Chemical agents

Few compounds are effective in reducing the ill effects associated with hyperthermia, but their use in poultry production is limited due to their prohibitively expensive. Antipyretic compounds, e.g. salicylic acid and aspirin, minimise the levels of catecholamines in the blood during heat stress. The performance of heat-stressed birds can be increased with magnesium aspartate, zinc sulphate, diazepam, metyrapone or clonidine in the feed. Aceryl salicylic acid (3% of the diet) increased the weight gain and shell quality in some reports but the dose recommended is higher impractical. Resinpine, an alkaloid from the Rawolfia plant is known to prevent the loss of carbon dioxide from birds subjected to high environmental temperature, thus stabilising the blood acid-base balance. The anticoccidial compound, nicarbazine (at the standard dose of 125mg/kg), has increased the mortality of broilers to up to 90% during heat stress. Adding potassium chloride in drinking water can ameliorate the toxic effects of nicabozine.

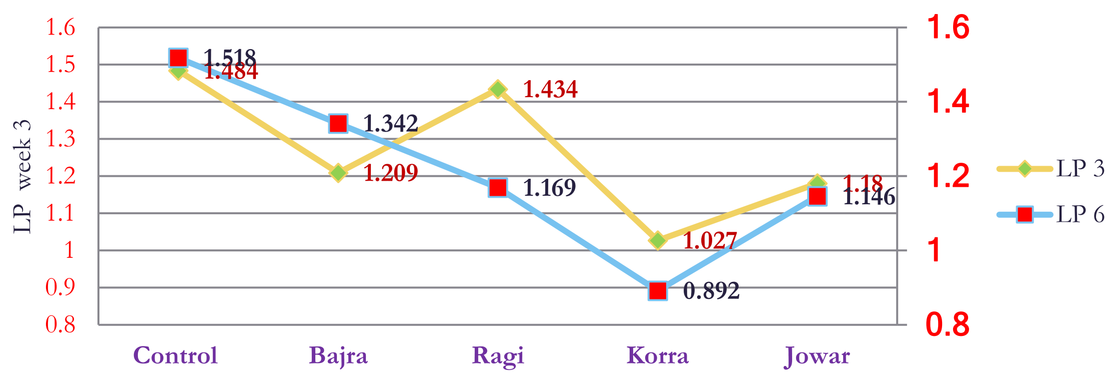
8. Change in feeding practices

Feed should be prepared fresh during hot season. Under hot and humid conditions, feed should not be stored for more than a week.

The bird's body temperature increases after feed ingestion (about 3) due to the thermogenic processes of digestion and metabolism. With routine morning feeding (7-8 am), the thermogenic effect coincides with the rising environmental temperature, aggravating heat stress. The thermogenic effect lasts for 3-10 hours at 35 ^{o}C, compared to just 2 hours at 20 ^{o}C. Metabolic heat production is 20-70% less in starved birds than in fed birds. Therefore, during hot weather, birds should be deprived of feed while the temperature is reaching and at its peak. Feeding during early and late hours of the day will help to minimise growth checks and mortality in broilers. Intermittent feeding, i.e. providing the light for 30 minutes followed by 3 hours dark, may also reduce the activity (heat production) of the bird but 20-30% more feeder and waterer space will be required. For layers, feeding during later part of the day will ensure sufficient calcium is available for optimum shell calcification.

Supplementation of sprouts (5% of expected feed intake) of millets (finger millet, foxtail millet, pearl millet, sorghum) or pulses (green gram, black gram or small gram) reduce the ill effects of heat stress in broiler chicken. Apart from enhancing weight gain, sprouts of some millets reduced axidative stress (lipid peroxidation) in broilers (Figure 5).

Figure 5. Sprouts Millets reduced lipid peroxidation in commercial broilers



Low feed intake is the main factor limiting the performance of chicken at high ambient temperature. The following practices can help to increase feed consumption and may be worthwhile considering reducing the ill effects of heats tress in poultry.

- wet mash feeding
- pellet or crumble form of feeding
- low-calcium diets with choice feeding of calcium sources
- frequent feeding and stirring of feed in the feeder
- addition of fat or molasses so to increase feed palatability

Conclusion

Typically, commercial chicken farming is in open sided poultry house. Environmental fluctuations in temperature and humidity severely impact the bird performance and health and in extreme circumstances severe mortality is more common. Reducing the house ambient temperature and humidity is the most effective way to sustain the bird performance. Certain dietary modulations as listed below can reduce the ill effects of heat stress on poultry performance and health.

- Increase energy content of the diet to compensate the reduction in feed intake. Energy from supplemental oil is beneficial.
- Reduce crude protein content in diet and meet the requirement for critical amino acids like lysine, methionine, theonine, tryptophan, valine, etc.

- Increase Ca supply to laying hen @ 1g additional Ca/b/day through choice feeding of shell / stone grit. Reduce dietary phosphorus by 0.1% during heat stress.
- Maintain optimum electrolyte balance in diet (240 to 280 meq/kg, DEB) by using sodium bicarbonate and potassium chloride.
- Supplementation of natural osmolyes (betaine anhydrous) or plant extracts from *tulasi*, *ashwagandha*, *amla*, *moringa* leaf or pomegranate peel powder may also support the bird during heat stress.
- Supplementation of vitamin C (100 mg/kg), vitamin E (50 mg) and or vitamin D3 (4000 icu/kg diet) may help to improve bird performance and health during summer stress.
- On top supplementation of organic trace minerals like Cr (400 mcg/kg), Se (0.30 mg/kg) or Zn (40 mg/kg) will improve the bird performance besides improving the anti-oxidant capacity of birds during heat stress.
- Supplementation of poultry diet with any-pyretics (acetyle salysilate, aspertate, ZnSO4, diazepam, etc.) reduces the bird body temperature and minimizes ill effects of summer.
- Enhance the feed intake (wet mash feeding, pellet or crumble form of feed, low-calcium diets with choice feeding of calcium sources, frequent feeding and stirring of feed, addition of fat or molasses).
- Feed only during cooler part of the day (early in the morning and late in the evening).
- Supplementation of sprouts of millets or pulses (5% of the feed intake) will improve the bird performance and also reduce stress indices in chicken.

IMPACT OF CLIMATE CHANGE ON DAIRY PRODUCTION

Mukesh Bhakat, S. Maiti, T.K. Mohanty, G. Mondal and R.K. Baithalu

Artificial Breeding Research Centre, ICAR- National Dairy Research Institute, Karnal

Introduction

The demand for livestock products in developing countries has increased ~3times in the last three decades. Globally 39% protein and 18% energy source are of the animal origin (FAO, 2018). The increasing production demand of the livestock sector globally to achieve nutritional security creates avenues for the farmers and the challenges under changing climate scenarios. The contribution of the livestock sector in food security is immense at all levels starting from the household, community, and global level in providing cheap, affordable and safe nutrition, employment and income generation to all strata of people (FAO, 2018).

India is an agrarian country and farmers are economically dependent on agriculture and livestock husbandry, which is playing an essential role in the country's nutritional security. However, the sustainability of the livestock husbandry and dairy industry is facing major challenges under changing climate scenarios. During 1901-2018 in India, an increase of 0.7^0C average temperature was recorded and speculated 4.4^0C rise by 2100, the intensity of heavy rainfall increased about 75 percent during 1950-2015 (Krishnan *et al*., 2020). The increase in temperature and rainfall will increase heat stress problems in dairy animals due to an increase in Temperature Humidity Index (THI). THI is a well-accepted model worldwide, but it includes only temperature and humidity, whereas other environmental factors like dew point temperature, wind speed, and solar radiation also affect dairy animals (Hahn *et al*., 2003). Researchers (Silva *et al*., 2015; Pantoja *et al*., 2018) are exploring newer concept to understand the climatic stress in animals; including other climatic variables (temperature, humidity, wind speed, dew point temperature and solar radiation) and physiological parameters (rectal temperature, pulse rate, respiration rate and body surface temperature). During heat stress increase in rectal temperature (RT), respiration rate (RR) and pulse rate (PR), body surface temperature was clearly observed (IPCC, 2007). Researchers have recorded adverse effects of these variables on dairy animals' productivity, reproductive performance and health status (Sere *et al.*, 2008). Disease incidence increased with increasing heat stress. Researchers documented a decrease in female fertility (De Rensis and Scaramuzzi, 2003; Dash *et al.*, 2016) to the extent of 20 to 30% in terms of conception rate (Schuller *et al.*, 2014) and pregnancy rate (Khan *et al.*, 2013) in hot climatic condition. The decrease in milk production, lactation length and increase in ectoparasite incidence, metabolic diseases, and vector-borne disease were also evident in heat stress conditions. Singh *et al.* (2012) reported a decline of 58.3% production and 63.3% reproduction level in dairy animals directly due to climate change. The effect of heat stress on production and reproduction is more severe in crossbred animals, followed by buffalo and indigenous cattle. However, environmental temperatures above 25-37°C in tropical climates induce heat stress as heat loss is less than heat gain (Vale, 2007; Kumar *et al.*, 2011), but the responses of crossbred; buffalo and indigenous cows are different. The effect of heat stress is direct and indirect in dairy animals, i.e., reduction in productivity due to higher utilization of energy for homeostasis (Upadhaya *et al.*, 2009) and compromise in welfare (Morignat *et al.*, 2014), whereas the quality of forage compromised due to variation of water-soluble carbohydrates and nitrogen (Kumar *et al.*, 2015). Scarcity in feed and fodder resources, higher lignifications, poor degradation, and digestibility of roughages are also associated with heat stress.

The challenge of the livestock sector is more due to the increasing scarcity of land and water (Weindl *et al.*, 2015), although their resilience is higher than the crop sector (Prasad and Sejian, 2015). Therefore, understanding the effect of climate change on dairy production systems or for specific livestock sectors (Seo *et al.*, 2009; Thornton and Gerber, 2010) in terms of vulnerability, sensitivity, and resilience capacity can help formulate better policy and ameliorative strategies. However, the various livestock production system in the developing countries (Thornton *et al.*, 2009) and climate change in local conditions further create complexities in better strategy formulations (FAO, 2007). A single approach to overcome the climatic stress on crossbred, buffalo, and indigenous cows under various livestock production systems will not work efficiently in India. Therefore, region-specific studies with various dairy animals need to be undertaken to formulate cumulative strategies to cope with heat stress. As a wholesome approach, comfortable housing, efficient cooling mechanism, and nutritional manipulation can help to improve dairy animals' production, reproduction, health, and overall farm profitability.

Observed and projected change in climate over Indian region

Climate change is globally due to anthropogenically derived greenhouse gas (GHG) emissions, aerosols, and land-use patterns. In the last 150 years, there is an increase in 1°C temperature of the earth and a projected rise of 5°C by 2100. India Meteorological Department concluded in its "Statement on Climate of India during 2018" that the rate of increase in temperature over the Indian region is almost like the global average. Annual maximum, minimum and mean temperature as well as annual rainfall over Indian region during last 100 years (1901-2019) has been plotted in the Fig. 1 and 2, respectively. It is observed an increasing trend in all three temperature-related parameters while the decreasing trend in annual rainfall. Krishnan *et al*. (2020) reported an average temperature rise around 0.7^0C during 1901-2018 and a projected rise of ~ 4.4^0C by 2100 relative to the recent past. Monsoon rainfall has also declined around 6 percent from 1951-2015, with a notable decrease over the Indian-Gangetic plains and the Western Ghats. In central India, the intensity of heavy rainfall increased about 75 percent during 1950-2015. Both the frequency and spatial extent of droughts have increased significantly during 1951–2016. Areas over central India, southwest coast, southern peninsula, and north-eastern India have experienced more than two droughts per decade, on average, during this period. The area affected by drought has also increased by 1.3% per decade over the same period. Though the number of tropical cyclones has decreased during 1951-2018; however, the frequency and intensity of very severe cyclonic storms have increased during 2000-2018 on the east coast of India than the west coast. Different climate models also projected that the intensity of tropical cyclones would be increased over the Indian ocean in the coming decades.

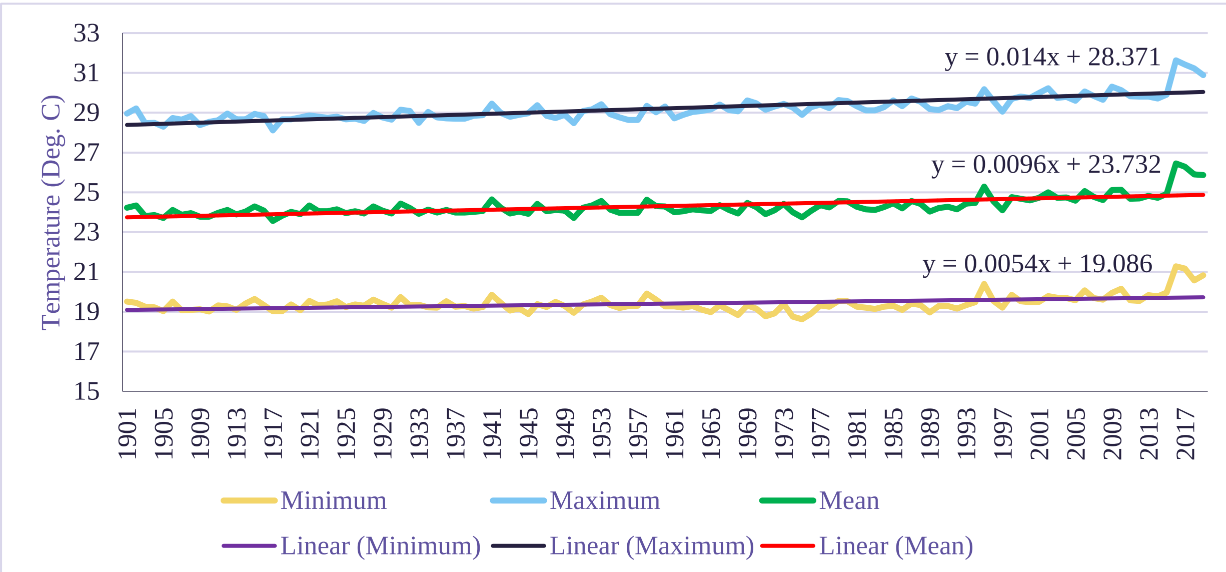


Fig.1: Trend of annual average maximum, minimum and mean temperature over Indian region in degree Celsius (1901-2019) (Data source: IMD, Pune)

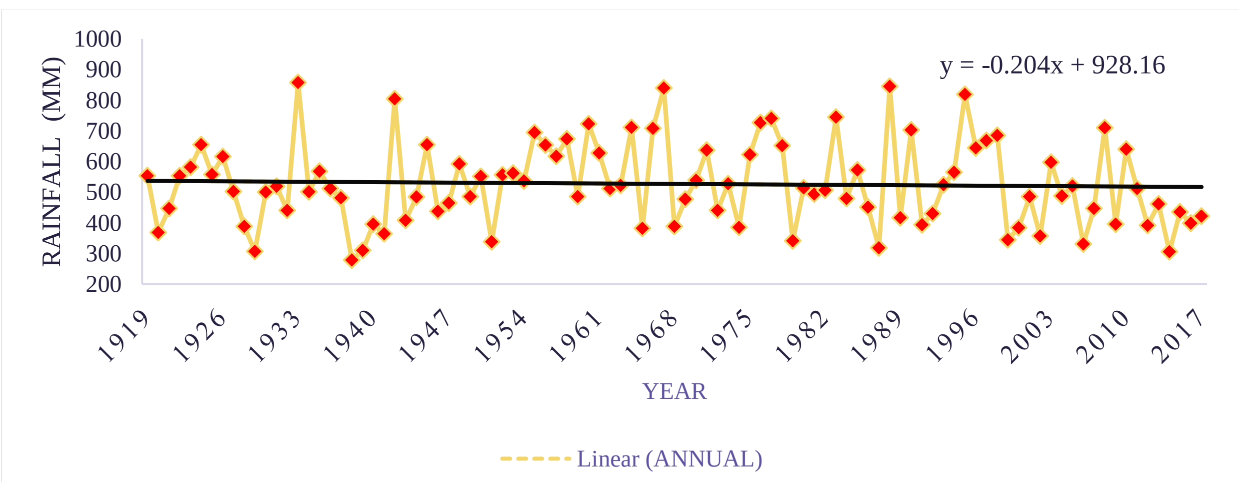


Fig. 2: Trend of annual average rainfall over Indian region in mm (1919-2017) (Data source: IMD, Pune)

Temperature Humidity Index:

A temperature-humidity index (THI) is a single value representing the combined effects of air temperature and humidity associated with the level of thermal stress. This index is considered as the indicator of the thermal stress of the dairy animal. THI has been categorized as, i. comfortable less than 72, mild heat stress 73 to 78 (increase in rectal temperature and respiration rate), ii. moderate heat stress 79 to 88 (more rectal temperature and respiration rate, decreased dry matter intake), iii. severe heat stress 89-98 (excessive painting and restlessness) and iv. danger >98 (extreme heat stress and death occurs) (Armstrong, 1994). Index value beyond 78 expressed as the severe threat of heat stress to the dairy animal and cause of significant reduction in milk production. The production and reproduction of dairy animals are negatively correlated with THI (Shinde *et al.*, 1990; Mandal *et al.*, 2002). In India, the duration of the heat stress period varies in different parts of the country due to wide variation in agro-climatic zones. Dutta *et al*. (2020) and Maiti *et al*. (2021) studied the trend of the Temperature-Humidity Index from 1958 through 2017 of the Sundarban region of West Bengal and Rohtak district of Haryana, respectively. They also reported that the heat stress season of the Sundarban region was more than eight months (March to mid of November). In contrast, the dairy animal of the Rohtak faced heat stress from the middle of April to the middle of October (Fig. 3). However, dairy animals of both regions were exposed to severe heat stress from June to September, and an increasing trend was observed in THI levels of these months during 1958-2017 (Fig. 4).

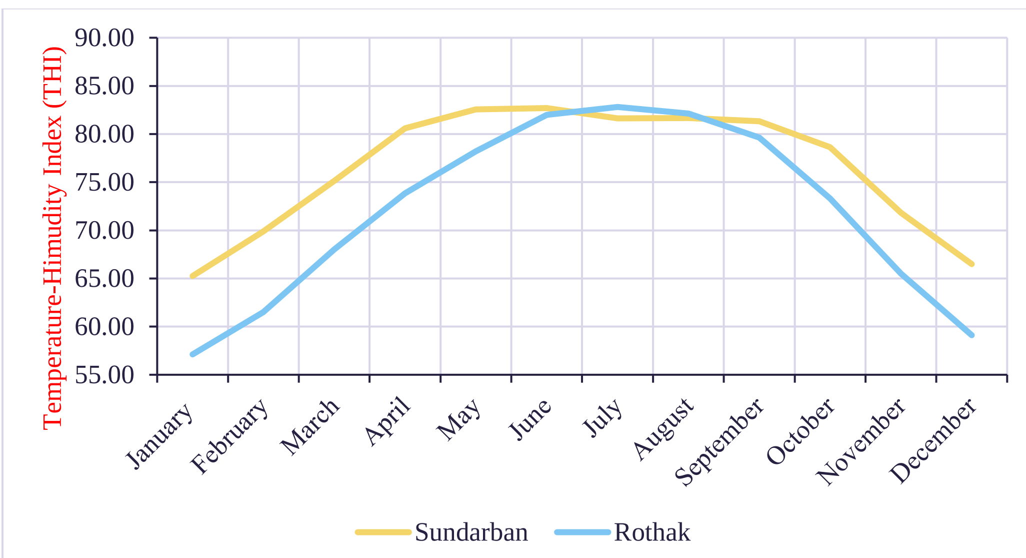


Fig. 3: Monthly average THI of Sundarban region and Rothak during 1958-2017 (Data source: http://www.climatologylab.org/ terraclimate.html)

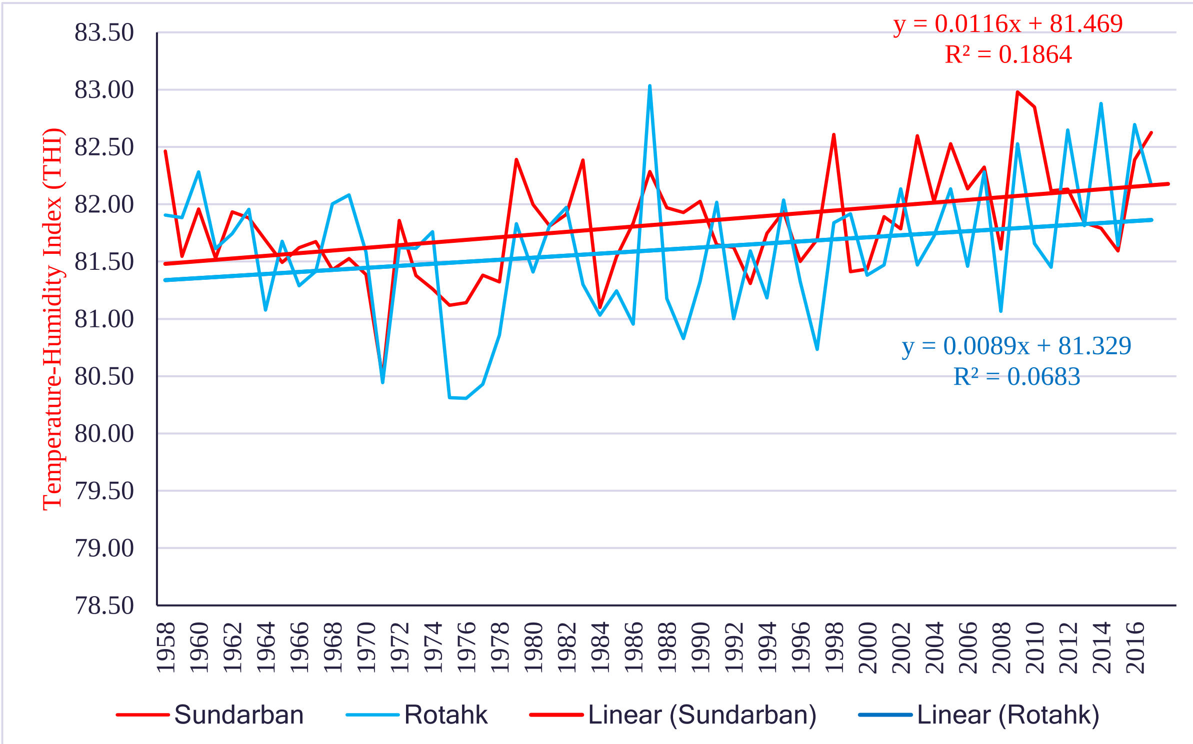


Fig. 4: Trend of average THI during June–September of the period 1958-2017 at the Sundarban region and Rothak (Data source: http://www.climatologylab.org/ terraclimate.html)

Effect of heat stress:

Heat stress in animals affects daily weight gain, feed conversion efficiency (Hristov *et al.*,2017), growth performance (Baumgard *et al.*, 2012), milk production (Das *et al.*, 2016), reproductive performance (Rhoads *et al.*, 2009, Dash *et al.*, 2016), meat production (Archana *et al.*, 2018), disease incidences (Rojas-Downing *et al.*, 2017), lactation length, infertility and external parasite load (Dhakal *et al.*, 2013).

Effect of climate change on production performance of Dairy animals

It is well documented in the literature that yield and composition of the milk get affected due to climate change, especially in high yielding dairy animals (Wheelock *et al.*, 2010; Upadhyay *et al.*, 2009) due to a reduction in dry matter intake, feed efficiency and alteration in physiological response during high THI level (West *et al.*, 2003; Wilson *et al.*, 1998). A negative relationship of THI with dry matter intake, milk production and reproduction, as well as rectal temperature and milk yield (Zimbelman *et al.*, 2009) was recorded by various researchers. In a semi-arid grazing system, the animal got affected by multiple stress factors, i.e., heat stress, feed and fodder scarcity and quality, water scarcity, higher walking distance for grazing, high lignifications of forage due to high temperature (Rojas-Downing *et al.,* 2017; Giridharand Samireddypalle, 2015; Sejian *et al.,*2013) leading to milk production, body weight and body condition score loss.

During heat stress, the physiological changes associated with an increase in body temperature (>102.5 ºF), respiration rates (> 70-80/minute) and blood flow (Pereira *et al.,* 2008) leads to sodium and potassium ion imbalance towards alkalosis and 20-30% increase in maintenance energy requirement. The susceptibility of high-yielding dairy animals is higher than low-yielders and beef breeds to heat stress, which may be associated with high metabolic heat production (Das *et al*., 2016). Decrease in 9.6% dry matter intake, 21% milk yield (Spiers *et al.,* 2004; Bouraoui *et al.,* 2002) and 36% milk yield (West, 2003; Rhoads *et al.*, 2009) was recorded with an increase in THI level. Further, decrease in the dry matter intake by 0.85 kg per cow with an increase in 1°C temperature, milk yield by 1.8 kg/d per cow in case of 0.55 °C rectal temperature increases from 38.6 °C (Johnson *et al.*, 1963) and 0.7 kg/day per cow in case of 0.6°C increase from 39.1°C (Igono *et al.,* 1985). Ravagnolo and Misztal (2000) reported a 0.2 kg decrease in milk yield in every unit increase in THI above 72. The early and late stages of lactation are affected more due to heat stress than mid-lactation. During heat stress in first parity buffaloes, milk yield declined 10-30%, and second and third parity 5-20% (Upadhaya *et al.,* 2007). During heat stress, deterioration of milk quality in terms of casein, lactalbumin, IgG and IgA was also recorded.

Effect of heat stress on animal reproduction

Reproduction of cattle and buffaloes also gets affected due to increased temperature and humidity (THI) during the heat stress period (Dash *et al.,* 2015). Reproductive hormonal changes associated with heat stress triggered the release of ACTH from the anterior pituitary and stimulates cortisol and glucocorticoid release from the adrenal cortex and further inhibits the release of luteinizing hormone. FSH and LH release also get affected at the hypophyseal level due to hyperprolactinemia during thermal stress (Singh *et al.,* 2013). The decrease in conception rate is recorded clearly in case of increased THI above 72-73 in cattle (Morton *et al.,* 2007; Schuller *et al.,* 2014) and 75 in buffalo (Dash, 2013). Heat stress in farm animals associated with the aberrant gametogenesis, folliculogenesis and ovulation, decreased male and female sexual behaviour, poor conception rates, early embryonic mortality, abortion, delayed post-partum recovery, reduced oocyte development by affecting its growth and maturation, increased calving intervals and perinatal mortality (Ghosh *et al.*, 2015; Singh *et al.,* 2013), lower heat detection efficiency (Rutledge, 2001) and less fertilization capability of heat-stressed spermatozoa (Rahman *et al.,* 2013). Gwazdauskas *et al.* (1973) reported a 12.8% decrease in conception rate with a 0.5° C increase in uterine temperature. Heat stress is also associated with a decrease in length and intensity of estrus due to low estradiol level on the day of estrus (Thornton *et al.,* 2009) and increase in the incidence of anestrous and silent heat

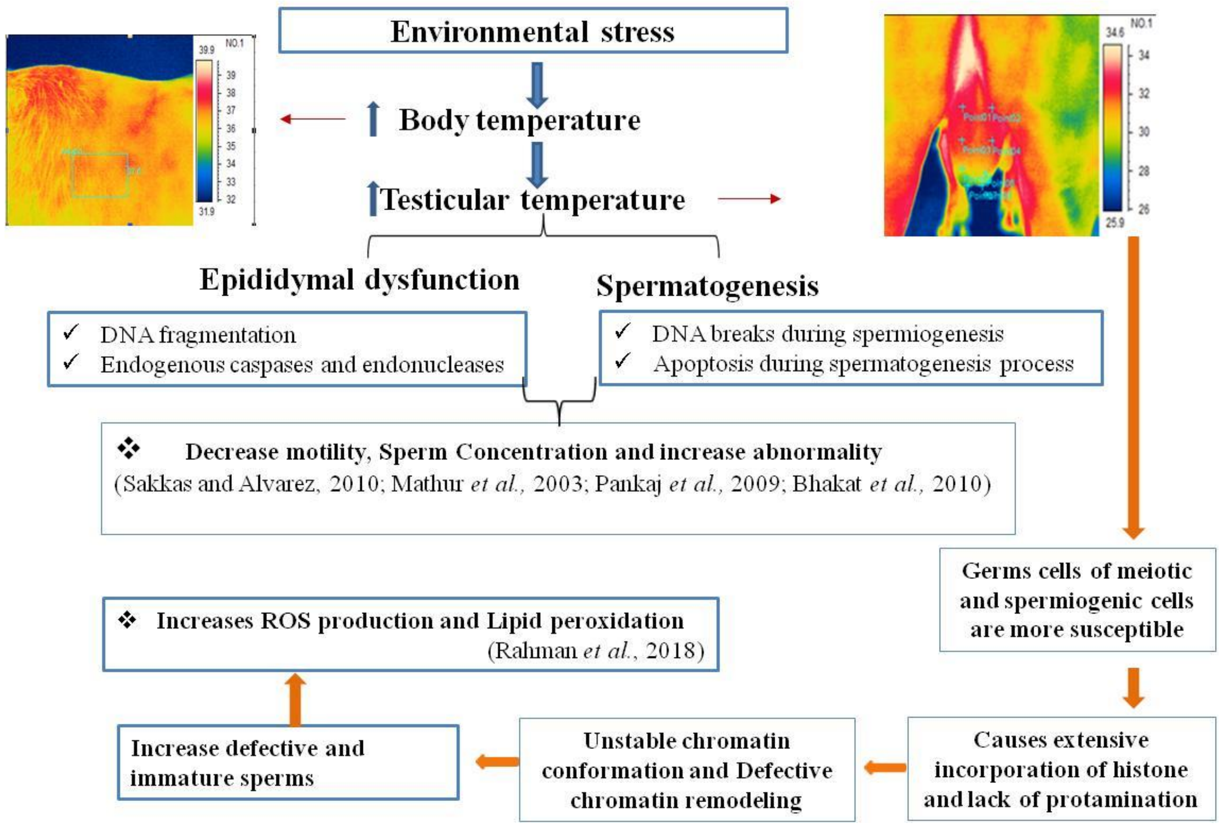
(Kadokawa *et al.*, 2012; Singh *et al.*, 2013), infertility was also observed due to higher circulating prolactin level in heat-stressed animal (Alamer, 2011).

Effects of heat stress on health of dairy animals

Heat stress is also associated with health problems in dairy animals due to alterations in metabolic, physiological, hormonal, and immunity levels. The metabolic changes may be due to decreased thyroid activity, which further decreases metabolic heat production (Helal *et al.,* 2010). Physiological changes lead to a decrease in rumen motility and rumination (Nardone *et al.*, 2010; Soriani *et al.*, 2013). A decrease in feed utilization efficiency and voluntary feed intake was also observed (Baile and Forbes, 1974). In temperate climatic conditions, a decrease in feed intake was recorded above 25-26°C and the decline was more above 40°C and it was 40% in cattle, 8-10% in buffalo heifer and 22-35% in goats (Hooda *et al.*, 2010; Rhoads *et al.*, 2013; Hamzaoui *et al.,* 2012). Heat stress affects the health of the animals in two ways, directly or indirectly. Direct impacts are higher prevalence and exposure of infectious and compromised immunity level (Bett *et al.*, 2017). At the same time, indirect impacts are persistence and abundance of disease vectors and parasites, host resistance, and changes in the severity of zoonotic diseases (Gethings *et al.*, 2015). In heat stress conditions increase in helminthological and nematode infections (Van Dijk *et al.* 2010; Verschave *et al.* 2016), mastitis (West, 2003), Foot and Mouth disease (FMD) in cattle (Ramarao 1988) and infestation of cattle ticks like *Boophilus microplus, Haemaphysalis bispinosa* and *Hyalomma anatolicum* (Basu and Bandhyopadhyay, 2004; Kumar *et al.*, 2004) has been recorded. Seasonal changes in mastitis and lameness were also documented by various authors (Dohoo and Meek, 1982; Elvinger *et al.,* 1991) and an increase in incidence rate has also been recorded during heat stress (Cook *et al.,* 2007) as compared to cold stress (Sanders *et al.*, 2009).

Effect of heat stress on male reproduction

The climatic stress is transient in males, but the impact might be long-term in terms of sperm fertility is considered. Seasonal stress is mainly associated with scorching weather and increased body temperature followed by testicular temperature, which results in changes in cellular metabolism, leading to testicular degeneration and decreasing the life span of the sperms. The elevated testicular temperatures impaired the spermatogenesis process, testicular degeneration and epididymal dysfunction. Epididymis acts as store houses of the sperms and they gain their fertilization potential and motility during the transit through the body of the epididymis. Therefore, the elevated temperature may cause potential damage during transit and affect sperm motility and fertilization potential. In the buffalo majority, i.e. 64.99% of the sperms are stored in the cauda epididymis (Sharma and Gupta, 1978). The increase in temperature is also associated with abnormal and dead spermatozoa increase in the storage site, and the dead and abnormal spermatozoa are engulfed due to phagocytic activities, which leads to a reduction in sperm concentration. The epididymal dysfunction associated with the release of endogenous caspases and endonucleases due to an increase in testicular temperature leads to sperm DNA nicks and fragmentation. The testicular degeneration and impairment of spermatogenesis lead to apoptosis and DNA breaks, an increase in sperm abnormalities and a decrease in sperm motility (Sakkas and Alvarez, 2010). Germs cells of meiotic and spermatogenic stage during the spermatogenesis process is highly sensitive to increase in temperature as in this stage in the chromosomes of sperm cells, extensive incorporation of histone and protamination occurs and the high rise of temperature lead to unstable chromatin conformation and defective chromatin remodeling which leads to increase in production of defective and immature sperms. These sperm further contribute to higher ROS production besides that mitochondria and LPO of the sperm plasma membrane of the average sperm also contribute to lipid peroxidation (Rahman *et al.,* 2018).



THI with semen quality

The semen quality of breeding bulls gets deteriorated with increasing THI due to reduced heat transfer efficiency between the testis' arterial and venous blood (Brito *et al.,* 2012). Previous studies reported that the higher THI have an adverse effect on the scrotal thermal profile, which affects the semen quality of bulls (Ahirwar *et al*., 2018; Menaagassi *et al*., 2014). THI values above 80.88 are critical for semen quality in Murrah buffalo bulls as the scrotal temperature remains negatively correlated with volume (r= -0.40) and progressive motility (r = -0.29) and positively with total sperm abnormalities (r = 0.11) (Ahirwar *et al*., 2018). Sharma *et al*. (2017) reported an adverse effect of the hot-humid season with higher THI on semen quality in buffalo bulls and a significant (P<0.05) effect on percent live sperm and sperm concentration was recorded. The effect of THI on the semen quality of different cattle and buffalo breeds has been presented below.

Table 1: Effect of THI on semen quality of different breeds of cattle and buffalo

Breed/Spp.	Study Area	Effect of season on semen quality	References
Bradford bulls	Brazil	THI> 83.8 is critical for semen quality	Menagassi *et al.*, 2014
Bradford and Nellore bulls	Brazil	THI was higher during summer (91) in comparison to other season and thermal gradient decreased (2.1) in summer more and was negatively correlated with spermiogenesis (18days) and epididymal transit (12 d) period	Menagassi *et al.*, 2016
Crossbred bull	Pantnagar, India	Hot humid season with higher THI (78-84) adversely affected seminal quality	Sharma *et al.*, 2017
Murrah, buffalo	Bengaluru, India	THI> 80.88 is critical for semen quality	Ahirwar *et al.*, 2018
Water buffalo	Brazil	THI positively correlated with spermatic cord, scrotal and epididymal temperature	Silva *et al.*, 2018
Murrah, buffalo	Karnal, India	Higher THI significantly (P< 0.01) is associated with higher sperm abnormalities, lower sperm individual motility, livability, concentration, intact acrosome and membrane integrity.	Ranjana, 2018

Change of thermal profile in livestock under different environmental conditions

IRT is a valuable tool for determining physiological changes in animals, making it useful for diagnosis, pain and thermal stress assessment (Nahm, 2013). Thermographic images can reveal changes in blood flow due to elevated body temperature in a specific area due to stressful environmental and disease conditions. Infrared thermography is used to obtain the temperature of specific regions such as the muzzle, eye, thigh, belly, neck, rump, flank, rib, shin, and foot for predicting physiological events and stress in farm animals (Weschenfelder *et al*., 2014 and Soerensen *et al*., 2014). In lambs, Paim *et al*. (2012) stated that the IR temperatures of the muzzle, neck, and rump are better indicators of seasonal and thermal comfort conditions. The distal part of the hindquarter and facial temperature is the most suitable body parts thermography to indirectly determine feed efficiency in cattle (Montanholi *et al*., 2009). Therefore, the body surface area temperature showed a temperature trend during thermal comfort situations. It has been observed that rectal temperature is strongly correlated with IRT forehead temperature and THI with forehead, right and left flank temperatures, so these body surface temperature monitoring may help monitor thermoregulation and body heat production. Various authors listed significant changes in temperature of different anatomical regions such as eye, foot region, flank and ocular region across different species (Holstein Friesian, Dairy cows, Horse, Pig, Hens) in case of stress listed below:

Table 2: Change of thermal profile in livestock under different environmental conditions and seasons:

Breed/species	**Evaluation**	**Findings**	**References**
Holstein Friesian	Thermal stress	0.6 to 0.66°C increase in eye temperature	Stewart *et al.*, 2008
Dairy cows	Heat stress	Temperature difference of flank and foot region are 0.1°C and 2.7°C	Montanholi *et al.*, 2008
Horse	Stress	0.55 to 0.98°C change in eye temperature	Valera *et al.*, 2012
Horses	Stress	1 to 1.5°C change in eye temperature	Bartolomé*et al.*, 2013
Pigs	Physiological stress	3.9°C change in temperature of ocular regions	Weschenfelder *et al.*, 2013
Pig	Stress	Increases in temperature of eye 1.5°C to 2.5°C	Soerensen *et al.*, 2014

Strategies to ameliorate heat stress

In dairy animals, heat stress is a crucial event that significantly affects production, reproduction, and health, and its economic impact is enormous. Therefore, a multidisciplinary approach should be implemented to formulate ameliorative strategies for heat stress involving shelter management, microclimatic modification, feeding and nutrient management and genetic selection of animals for improvement. In social science-based studies, the farmers' reported coping strategies against heat stress were feeding fresh fodder and clean water, feeding and milking in cool hours, offering extra concentrate, providing shade (tree or housing), bathing of the animals and improving living space by a decrease in herd size. Identification of genotype adapted to climatic stress and formulation of region-specific climate-resilient breeding strategies of livestock to select heat-tolerant livestock (Rashamol and Sejian, 2018; Angel *et al.*, 2018). Screening the suitability of the indigenous breed for their thermotolerance capacity in a different agro-climatic zone that needs to be studied (Hoffmann 2010), which is very challenging. Further, climate-resilient bovine herd management practices are a big challenge for balancing production by maintaining fertility and metabolic diseases without compromising welfare.

Modification of micro environment

During the heat stress period, the dairy animals can be cooled in two ways, either by improving the heat dissipation mechanism or by cooling the nearby environment of the animal through micro-climatic modification. The common ameliorative strategies are shed modification to provide a comfortable environment to cow and improve environment cooling by using an evaporative cooling system, i.e., fogging, misting or sprinkling with fan or without fan depending on the season (Atrian and Shahryar, 2012). Kadokawa *et al.* (2012) reported improvement in reproductive performance of dairy animals during heat stress periods by using an evaporative cooling system and tunnel ventilation.

Nutritional management

During heat stress, the major challenge for dairy animals is the insufficiency of nutrient supply and the reduced dry matter intake as a coping mechanism to reduce the heat increment. West (1999) reported lower nutrient utilization efficiency during hot weather due to lower DMI and nutrient availability for absorption. Therefore, nutrient-enriched feed in the form of good quality green fodder, concentrate, bypass fat, and protein should be supplemented to improve dairy animals' production and reproduction performance during hot weather conditions. El-Tarabany and Nasr (2015) reported improved fertility and reduced heat stress in case of niacin and antioxidant supplementation in buffaloes. Vitamin C and Vitamin E effectively reduce heat stress-mediated oxidative stress (Seyrek *et al.*, 2004).

Genetic modification

Identification and selection of heat-tolerant high-producing breeds and further use for breeding can help to cope up with heat stress even in crossbreeding (Kimothi and Ghosh, 2005). Therefore, in the base population, genetic diversity needs to be maintained. Coat colour and hair traits are also important from a better adaptability point of view. Under hot environment conditions, cattle with darker coat color and long hair are less adaptable than light coat color, small hair, thin skin, fewer hair follicles per unit area, and higher hair coat diameter (Bernabucci *et al.*, 2010; Hoffmann, 2010). McManus *et al.* (2009) reported that animals have light-/white coloured coats that reflect 50 to 60 percent of direct solar radiation compared with dark-colored animals. One of the good examples is Tharparkar cattle. Uttarani *et al.* (2014) reported highly pigmented skin blocks the penetration of direct UV radiation. The change in genetic biodiversity under changing climate scenario is unnoticed at farmers' level and needs attention (FAO, 2008).

General tips for heat stress management in dairy animals:

- Farmers can quickly identify the animal is in heat stress or not by simply monitoring respiration rate. If the respiration rate is more than 80 breaths per minute, heat stress is a clear indication.

- The easier way to understand when heat stress started is that if human being starts feeling the stress as for animals, it already started.
- Adequate space should be provided during the heat stress period to the dairy animals for effective heat dissipation, especially tie stalls, which are commonly observed at farmers' doorsteps and present-day small commercial dairy farms.
- Shades must be provided, especially during the summer months, to reduce the heat load from radiation. The roof should be reflective. Roof painted with white paint and insulated with puff or straw and covered with seasonal vegetable plants like bottle gourd, pumpkin and ridge gourd grown on earth is quite effective in reducing the inside temperature of the shed.
- The fresh and cool drinking water facility under shaded areas should be ensured for effective heat stress management.
- Holding and milking areas must have adequate ventilation, air circulation, and cooling facilities as less attention has been given to Indian conditions.
- In hot-dry weather, misting is quite effective in cooling the environment, which further helps cool the animals. Fogging is very effective but under closed conditions and when the temperature is high, and humidity is low. In fogging, desalinated water is generally recommended; otherwise, nozzle blocking is a common problem.
- In hot-humid conditions, sprinkling for a limited period along with fanning is quite effective. In closed housing for such a cooling system, proper ventilation must be ensured to reduce the humidity buildup.
- Wallowing is very effective for buffaloes due to their black skin colour and fewer sweat glands. Natural ponds are very common in the village area and quite effective amelioration of heat through wallowing. Artificially build 50 ft. wide X 100 ft. long and 4 to 6 ft. depth wallowing pond is suitable for 100 animals.
- Using geothermal energy can be an alternative for cooling closed sheds of the dairy farm by using the earth's temperature at a depth of 15 to 20ft through pipelines for reducing the temperature by 8-10^{O}C.
- In the heat stress period, four to five days of adequate cooling, especially around breeding, can enhance the fertility of dairy animals.
- Optimum body condition score maintenance in different stages of physiological state and especially the animals are going to calve in heat stress period can be an effective strategy.

Conclusion:

The climate change scenario at the global level and in India is well documented and perceived due to an increase in earth temperature and heavy rainfall. The dairy industry is experiencing the impact of climate change mainly in the form of heat stress, which affects milk production, milk quality, colostrums quality, reproduction, growth of young calves and health of dairy animals, and further economic loss. Milk production and fertility decreased more in high-yielding dairy animals as compared to low-yielders. During hot-humid conditions, buffalo gets affected less than cattle if a proper shade and wallowing facility is available. To cope with heat stress, ameliorative strategies in the form of environmental enrichment and cooling mechanism depending on the weather condition, nutritional manipulation, stress-relieving supplements i.e., antioxidants, yeast, buffer, vitamins and minerals, and hormonal treatment for reproductive management is quite effective. The adoption of the scientific management intervention suited to local conditions to cope with the heat stress issue depends on the farmers' awareness, social, economic, biophysical, and decision-making ability. Therefore, the systematic study of the impact of climate change on various livestock species, i.e., cattle, buffalo, sheep, goat and poultry, needs to be carried out to formulate better coping mechanisms and policy, as the livelihood of the many farmers depends on these sectors. Integrated crop and livestock production system heat tolerant and disease resistant native breeds (cattle, buffalo, sheep, goat, poultry, and pig) can be studied in depth under changing climate scenarios for better resilience. The growing human population and ever-increasing demand for livestock products need rationalization by formulating suitable strategies; although complex, environmental standards, greenhouse gas emissions, and livestock production systems should also be considered.

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ADAPTATION STRATEGIES FOR SMALLHOLDER LIVESTOCK PRODUCTION SYSTEM

Biswajit Roy[1] and Prabhat Kumar Pankaj[2]

[1]*Department of Livestock Production and Management, College of Veterinary Science and AH., NDVSU, Jabalpur*

[2] *ICAR-Central Research Institute for Dryland Agriculture, Hyderabad*

Introduction

Livestock play a key role in the livelihoods of many households where they contribute to informal household insurance and financing, soil fertility, and household nutrition. Livestock provide the social, cultural, and economic backbone to the landless and marginal farmers. In the world, livestock are the source of 33% of the protein in human diets and, especially in developing countries, livestock provide many other services such as draft power, manure, risk management, and regular income. At the same time, about 30% of the global land area is used for livestock rearing.

Livestock is the most critical asset for many rural poor; however, the current climate crisis is affecting widely to the livestock farmers. Traditional farming is highly labour-intensive, and it is the family labor that has been mainly involved various agriculture and animal husbandry related activates. About 5.50 per cent of total working population of India is engaged in animal husbandry sector (Sharma and Tiwari, 2011). The sector provides large self-employment to millions of households in rural areas, employed about 11.44 million in as a principal status and 11.01 million in subsidiary status, which does not include persons employed in sale, re-processing and transport of animal products at secondary market level. The landless, marginal and small farmers hold about 82 per cent of dairy animals and contribute about 70 per cent of milk production in India.

Climate change has been described as the "long-term change of the earth's climate including changes in temperature, precipitation, and wind patterns over a period of several decades or longer" (Leiserowitz *et al*., 2014). The International Fund for Agricultural Development (IFAD, 2014) has predicted an increased occurrence of extreme weather events with extensive destruction of agricultural lands. This will have major implications for those whose livelihoods are dependent on farming. Alternative options is to keep livestock for their livelihood as it reduces the risk arising from extreme climate conditions like floods, droughts, rising temperature etc. Interestingly, livestock such as cattle, buffalo, sheep and goat per holding have increased at a tremendous rate for the small and marginal, medium and semi-medium farm household categories (Mahajan *et al*., 2014).

Effect of climate change on livestock

Global livestock production is now under immense pressure. In the recent decade, demand for various livestock-based products has increased significantly due to increase in per capita income, urbanization, taste preference and increased awareness about food nutrition. Livestock sector is likely to emerge as an engine for agricultural growth in the coming decades. It is also considered as a potential sector for export earnings. Livestock helps to improve food and nutritional security by providing nutrient-rich food products, generate employment and act as a cushion against crop failure, provide draught power and manure inputs to the crop subsector.

The impacts of climate change on livestock systems have not received as much attention as those of crops. The impacts of climate change are not uniform and vary considerably across and within continents. Livestock production systems function under a wide range of environmental conditions, causing production to be increasingly affected by climate change (Jacquelyn *et al*., 2018).

The climate change adversely affects the livestock directly as well as indirectly. Directly, due to increased heat stress, physiological (rectal temperature, respiration rate, dry matter intake etc.) as well as production functions (milk production, meat production etc.) will be impaired (Davison *et al*., 1996). Indirectly, climate change affects the livestock by altering natural resources availability such as reduced water availability, feed and fodder shortages, reducing biodiversity and increasing the incidences of vector-borne livestock diseases (Thornton *et al*., 2007).

The profound impacts of climate change perceived by smallholder livestock farmers in the study area were decreased livestock growth rate, decreased livestock weight, decreased milk production, increase reproduction inefficiencies, increased pest and disease occurrences, increased poor vegetation and limited grazing land, scarcity of water resources, increased livestock deaths, and loss of farm income earnings. There are strong reasons to believe that certain pests/ macro-parasites and vector-borne diseases will be capable of invading new regions which will increasingly become extremely challenging for efficient and profitable livestock production.

Adaptation strategies

Adaptation is the process of adjusting to real climate and its effects. Adaptation to climate change is a process that initially requires farmers to perceive that the climate has changed and then identify the necessary adaptations to be implemented. Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes to moderate potential damage), to take advantage of opportunities, or to cope with the consequences. In India, adaptation of the livestock sector to the changing climate is important for ensuring livelihoods of the poor farmers.

Adaptation is essential to reduce the damages and take advantage of new opportunities in the light of the rapid climate change already occurring and expected future impacts. FAO (2006) grouped the strategies for adaptation strategies used to cope with climate change by smallholders into traditional strategies, government-supported strategies, alternative and innovative automatic adaptation strategies, and technology-driven strategies. Deressa et al. (2010) categorized the adaptation strategies as household, public, and government driven, while Kuwornu et al. (2013) grouped the strategies into indigenous and introduced adaptation strategies. Recently, Jack et al. (2021) categorized the adaptation strategies as production system strategies and management system strategies, which cover the entire adaptation process in comprehensive manner.

Production system strategies

Intensification of livestock

Intensification of livestock production can eliminate the direct effect of the changing climate. With intensification, the animals will be properly provided for nutrition and health, among others. For instance, during period of climatic stress, intensively reared ruminants could be optimally fed with sufficient energy supply but extensively reared ruminants are completely dependent on pasture and suffer production loses as a result of limited feed and water intake, especially in nonclimate-resilient ruminants found in dryer areas (Shilja *et al*., 2016).

Integrated system

Integration in the production system reduces the risk of production to a greater extent. Smallholder farmers should combine two or more other components vital to the sustenance of productivity. Farmers have to integrate crop production into livestock, pasture production and/or management, and agro-forestry.

Alternative livestock production

With the ever-increasing demand of milk, productivity of large ruminants improved due to better management of animals. However, large ruminants require a lot of resources for use, such as land, water, and grains which are scarce resources and affected by climate change. With the limited availability of natural scarce resources, small holder faces difficulties to maintain productivity of the animals.

Small ruminants like sheep and goats can tolerate the changing climate because they are efficient desert dwellers, and they have high digestive efficiency for survival in harsh climatic conditions. Methane emission form these species also low in comparison to the cattle. Buffaloes are efficient utilizers of poor-quality forages and crop residues and at present they contribute almost 50% of the milk produced in our country. They are reared in stall fed condition using crop residue. They have more fibrolytic bacterial population and a higher N-recycling capacity and are for meat and milk production. Therefore, sheep and goats, and buffaloes are alternative livestock that can be raised as a means of adaptation to replace cattle in a changing climate.

Nutrition

Low feed efficiency is one of the major problems affecting ruminant productivity. Animals exposed to higher environmental temperature take more water, less feed, and reduced duration and rumination frequency to reduce heat load. To improve the feed intake and feed utilization efficiency, balanced diet formulation and feed supplements can be offered. Supplements like betaine, antioxidants, vitamins, and electrolytes have beneficial effect in reducing heat stress in ruminants and improved performance. Night feeding and allowing the animals to graze early in the morning, evening are the best measures to combat the heat stress.

Strategic mobility

Animals can be moved to drier zones during the rainy season and returned to the cropped areas to graze the crop field after harvest. The fields of resident farmers would be fertilized through manure deposition by ruminants. For farmers in arid and semiarid zones, pastoralism through strategic mobility is their only adaptation option. Pastoralism provides food security across drylands. In search of pasture, they exercise transhumance grazing movements between lowlands and marshes and mountains during wet and dry seasons, respectively.

For this to be successful, pastoralist/farmers need to be provided good access to market and government security to their grazing lands. Also, the distance traveled after grazing should be reduced as much as possible to reduce energy expenditure for more efficient production.

Selection and breeding

Genetic makeup of the animals to adapt to extreme environment reflects in its productive and reproductive performances. Breeding animals with particular morphometric features or traits such as color, body size, feed efficiency, disease resistance, and heat tolerance and adaptation to poor-quality diet (Hoffmann, 2013) should be considered in this era of changing climate. This is achievable by locally identifying and selecting animals with the required traits and multiplying same or crossbreeding local breeds with desired traits. Breeding small body–sized animals, even in cattle, could help survive harsh ambient conditions, because the small body–sized animals have lower water and feed requirements (Jack *et al*., 2021). Other breeding strategies like adoption of drought-tolerant crops and animals that can adapt to the seasonal scarcity of fodder.

Diversification/multispecies composition of herds or flocks

Instead of concentrating on a particular species, livestock farmer should focus on diversification i.e., rearing more than one species. Keeping a number of different local species that are resilient to local environmental conditions will reduce the impact of changing climate (FAO 2012).

Management system strategies

Reducing livestock numbers

Management of scarce natural resources is the key factor for the overall productivity of the farm. Inadequate nutrient availability to the animals is one of the key attributes of animal production system. However, as the demand of livestock products are increasing due to various socioeconomic factors, livestock farmers have resorted to a continuous increase in animal population despite limited natural resources. High stocking density adversely affects the overall productivity of the animals especially in case of resource poor farmer. Therefore, regular destocking will reduce the number of less productive animals leading to more efficient production. Destocking of ruminants can also be done in the form of culling of weaklings from the herd or flock during periods of extreme climatic conditions.

Ideal shed requirements

Good management includes the modification of the surrounding environment to reduce the impact of the environment and/or to promote heat loss from the animals. It is suggested that a well-designed shade structure should reduce the total heat load by 30–50 %. Trees around the sheds are effective at blocking incoming solar radiation, and moisture evaporating from their leaves helps cool surrounding air. Locally available materials should be used to prepare cost effective housing. Providing adequate and improved housing facilities reduces the impact of heat stress and ultimately improves the animal's productivity.

Water resource management

Water scarcity has become globally significant over the last 40 years or so and is an accelerating condition for one to two billion people worldwide as well as livestock (MEA, 2005). Limitations in feed and water availability will require species that are tolerant of the conditions and more efficient in the use of the limited resources to be combined by smallholder farmers. Indigenous water harvesting techniques such as the use of tanks linked to the roofs of houses through channels, small superficial and underground dams, etc. for irrigation with associated accessories to collect and store rainwater (IFAD 2009) will be useful in conserving water for use by smallholder farmers. These waters harvesting and conservation systems will strengthen smallholder farmers mainly dependent on rain-fed farming systems to adapt to stress caused by drought (Boko *et al*., 2007).

Alteration in herd/flock composition

In the draught prone area, the choice of species should be sheep and goat as they are more tolerant of extreme climatic conditions and easy to survive due to their requirements of less input compared to cattle. Therefore, small holder farmer should manage the herd/flock composition based on the availability of natural resources and/or suitability of species for local condition.

Conclusion:

Adaptation requires involvement of multiple stakeholders, including policymakers, extension personnel, NGOs, researchers, and farmers. Climate change adaptation is mostly location-specific, and its effectiveness depends on local institutions and socioeconomic condition to the particular area. Adaptation can manage the impacts but cannot by itself solve the problem of climate change. Even with adaptation, there will be residual costs. Smallholder farmers, for instance, can switch to more adapted livestock breeds, but they may have lower productivity.

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GHG EMISSION FROM LIVESTOCK SECTOR AND MITIGATION STRATEGIES

Goutam Mondal, Rashika Srivastava & Madhu Mohini Datta

Animal Nutrition Division, ICAR- National Dairy Research Institute, Karnal- 132001

Introduction

Inadequate vegetation and drying of water resources stress every species on the earth during summer and prolonged period of summer severely impacts health and productivity, growth and reproductive capacity. Increased number of stress days due to climate change is likely to impact livestock body weight gain, productivity and other physiological functions. Assessment report 6 of IPCC (first prepared in 09-08-2021), indicated that there will be more extreme events in weather and Indian sub continent is more prone to the climate change effects than developed countries. However, Indian native breeds of livestock have inherent adaptive capacity to the extremely harsh environmental conditions, and resistance to various kinds of tropical diseases. Nevertheless, a small population of animals dies each year because of severe climatic conditions in winter and summer. More than 3600 cattle died due to floods during 2002 and from 1953 to 2002 deaths were more than 91 thousand in cattle indicating substantial annual losses to farmers on account of floods alone. Death of livestock also occurs during natural disasters like the summer drought, floods, and strong dust storms. The pastoralists and animal herders are vulnerable to a myriad of such extreme climate-induced events. Among all of these natural disasters, flood and drought are the riskiest to livestock production because the damages due to these are incomparably higher than others causes. Therefore, vulnerability of livestock to extreme events due to climate changes particularly drought and floods is high. Hot and hot-humid conditions that prevail from April to October in most agroclimatic zones of India impact livestock productivity due to direct and indirect effects. High producing cows, pregnant cows, working bullocks and growing animals due to higher metabolic activity are more vulnerable to rise in temperatures. A rise in ambient temperature of 2-4.5 °C due to climate change will make summer more intense and highest temperature will exceed maximum tolerable limits for some livestock species. The impact on milk production of European cattle, crossbreds and buffaloes maintained for milk production will be alarming. Further, non-availability and shortage of water will make animal production system more vulnerable to greater production losses. April to July after harvesting of wheat in Northern India either hay or straws of crops is available for animal feeding and greens are scantily available only to high producing animals. During this period of the year due to low body conditions and depressed immune status many bacterial, viral and parasitic diseases affect livestock and their production performance.

Impact of climate change

The rise in temperature in different agro-ecological areas will have different impacts in relation to rainfall and ground water availability thus affecting sustenance of livestock production and livelihood of farmers under different farming systems in different agro-climatic conditions. These all climatic events are caused due to increased global temperature of anthropogenic origin and is now irreversible. The major anthropogenic GHGs are carbon dioxide, methane, nitrous oxide and chlorofluorocarbons. Agriculture sector is the second largest contributor of anthropogenic greenhouse gas (GHG) emissions after the energy sector. The increases in methane and nitrous oxide concentrations in the atmosphere may largely be due to agriculture, while those of carbon dioxide are mostly due to fossil fuel use and land use change.

Increasing concentration of Green House Gases (GHG) in the atmosphere has contributed to an increase in the earth atmospheric temperature, an occurrence known as global warming. As per the estimates the GHG emissions from the agriculture sector account for about 25.5% of total global emission and over 60% of anthropogenic sources. Livestock agriculture accounts 35-40% of CH_4 emission and nearly 70% of N2O worldwide. Emission of CH_4 is responsible for nearly as much irradiative effect as all other non-CO_2 GHG gases combined. While atmospheric concentrations of GHGs have risen by about 39% since pre-industrial era, CH_4 concentration has more than doubled during this period. Much of the global GHG emissions currently arise from enteric fermentation and manure from ruminants. The development of management strategies to mitigate CH4 emission from ruminant livestock is possible and desirable. Efficient utilization of dietary carbohydrate and nitrogen enhance feed efficiency and animal productivity, along with reducing global warming effects of emitted gases.

Global warming through enteric fermentation in the rumen

The rumen provides a moist, anaerobic, well buffered environment that has a relatively constant influx of substrates and efflux of products. These conditions provide an ideal habitat for the proliferation of anaerobic microorganisms. The ruminal microflora consists of bacteria, bacteriophages, protozoa, fungi and methanogenic archaea. Carbon dioxide is a byproduct of the reactions that generate the volatile fatty acids. Ruminal methanogens utilize the CO_2 and H_2 produced by the protozoa and bacteria from the catabolism of hexoses to produce CH_4 and generate ATP, which benefits the donors by providing an electron sink for reducing equivalents to minimize the partial pressure of H_2.

Method of estimation

There are many methods prevailing in estimation of methane emission from the livestock and each method has its own merits and demerits. In vitro method is useful when availability of animal and precious instruments is the constraints. SF_6 tracer technique, is widely accepted in measuring the enteric methane emission but requires fine instruments, labourers and its time consuming. Douglas bag method is also a good option for researchers for estimating methane emitted from enteric fermentation, but requires complete infrastructure set in the lab. By estimating the methane meission factor for a particular stage of the animals/ species, is multiplied by 365 to get the annual emission from any particular species or year. Thus, GHG inventory is prepared for submission to MoEF&CC, GoI and subsequently to UNFCCC. Following steps are taken for accurate estimation method and activity data is most important factor.

- Population is taken from Indian Livestock census, GoI
- Body weights of the animals are taken as per the breeds available in various states
- DMI is taken per100 kg body wt compiled for ICAR (2013) feeding standards.

Emission from dung:

- Digestibility of the ration is considered, based on the literature values
- Quantity of dung is estimated based on the digestibility of the ration
- Dung disposal was estimated based on the season and methods used like: cake making, disposed on pasture or on roads etc. and stored as heaps

India's contribution

India's GHG emissions in 1994 were 1228 million-ton (Mt) CO_2 equivalent, which is below 3% of global GHG emissions. In per-capita terms, it is 23 per cent of the global average and 4 per cent of USA, 8 per cent of Germany, 9 per cent of UK and 10 per cent of Japan, per capita emissions in 1994. In terms of the GHG intensity of the economy, in Purchasing Power Parity terms, India emitted a little above 0.4 ton CO_2 equivalent per 1000 US dollars in 2002, which is lower than the global average. In terms of primary energy use, India's share of renewable energy (being a non GHG emitting energy form) at 36 per cent is far higher than industrialized countries can hope to reach in many decades.

	2008	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Crossbred Cattle	1.17	1.54	1.64	1.73	1.83	1.92	2.02
Indigenous Cattle	3.90	3.78	3.76	3.74	3.75	3.75	3.77
Buffalo	4.55	4.77	4.82	4.88	4.94	5.01	5.08
Goat	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Crossbred Sheep	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Indigenous Sheep	0.19	0.18	0.17	0.17	0.17	0.17	0.16
Other animals	0.9833	0.8341	0.798	0.7904	0.8073	0.8304	0.8575
GRAND TOTAL	10.09	10.55	10.68	10.81	10.97	11.14	11.32

Since GHG emissions are directly linked to economic activity, India's economic growth will necessarily involve increase in GHG emissions from the current extremely low levels. Any constraints on the emissions of GHG by India, whether direct, by way of emissions targets, or indirect, will reduce growth rates. In 2017, 266.10 million tonnes of CO_2 equivalent is produced from livestock sector, however, tier I and II methodology of estimation may cause this huge difference in quantitative terms.

MITIGATION STRATEGIES

Genetic improvement

By this way to increase livestock productivity is to bring genetic traits into the herd that enhances desirable characteristics. If heritable traits can be identified and enhanced to increase the level of production in animals, then overall methane emissions will decrease. Feed conversion efficiency and high growth rate are examples of an inherited trait that can lead to lower methane emissions. Genetic traits can be bred into animals that allow them to convert grains and roughage into meat, milk, and other products more efficiently. Recent publication indicated that heritability of methane emission is about 0.4, which indicated selection methodology have the edge to get all good animal in the herd.

Management practices

Better waste management

Improving the management of animal waste products through different mechanisms such as the use of covered storage facilities is also important. The level of GHG emissions from manure depends on the temperature and duration of storage. Long-term storage at high temperatures results in higher GHG emissions. In the case of ruminants, pasture grazing is an efficient way to reduce CH_4 emission from manure because no storage is necessary. Under Indian condition, contribution of nitrous oxide its very less as protein diet in the dairy ration less, manure application in agrcuture field may have chance to increase the emission.

Grazing management

One of the major GHG emission contributions from livestock production is from forage or feed crop production and related land use. Proper pasture management through rotational grazing would be the most cost-effective way to mitigate GHG emissions from feed crop production. Animal grazing on pasture also helps reduce emissions attributable to animal manure storage. Introducing grass species and legumes into grazing lands can enhance carbon storage in soils.

Lowering livestock population

Lowering the consumption of meat and milk in areas with a high standard of living is a short-term response to GHG mitigation. Decreasing the number of animals will definitely decrease the emission from livestock sector, but it will affect the livelihood of millions of people living in rural area and sub urban areas. Instead, increasing the productivity by efficient animal or selection of low methane emitting animals will be more practical approach to minimise GHG emission from livestock.

Methane oxidation and methane oxidizing microbes in the rumen

Methane oxidation occurs in both anaerobic and aerobic environments; however, these are completely different processes involving different groups of microbiomes. The microbial anaerobic oxidation of methane is proposed to be a reversed methanogenesis coupled to the reduction of sulfate involving methanotrophic archaea and sulfate-reducing bacteria. Aerobic methane oxidation is carried out by aerobic methanotrophs which are a unique group of alpha and gamma proteobacteria that utilize methane as a sole carbon and energy source. Since the first description of methane-oxidizing bacteria during 1900 to 1910, various investigators have reported studies dealing with microbial oxidation of methane and other gaseous hydrocarbons. It has been estimated that as much as 20% of net global methane flux is oxidised before it can enter the atmosphere and while methanogenesis would appear to be a strictly anaerobic process. Methane oxidation has been reported in paddy field, sediments from lake, river and ocean environments. The rumen is often considered to be an anaerobic environment; however significant amounts of oxygen can enter with engulfed feed and water and by diffusion across the rumen wall. The large number of evidences about methane production in the rumen is available; whereas few information about methane utilization, which would be mainly caused by methane oxidation in the rumen. The study on artificial rumen indicated that only 0.3% of methane flux is oxidized; while approximately 20% of the net global methane flux is oxidized before it can enter the atmosphere. Anaerobic methane oxidation must be coupled to an electron sink reaction other than oxygen.

Feeding fats and oilseeds

Adding fats to the diet reduces CH_4 emissions by decreasing organic matter fermentation in the rumen, reducing the activity of methanogens and protozoal numbers, and for lipids rich in unsaturated fatty acids, through hydrogenation of fatty acids. The effect of the fat was dependent on its composition, with medium chain fatty acids more effective (eg. coconut oil, 7.3% less CH4 per % of added fat), than linoleic acid (soyabean and sunflower, 4.1%) and linolenic acid (linseed, 4.8%) and monounsaturated fatty acids such as oleic acid (rapeseed, 2.5%) and saturated fats (tallow, 3.5%). Feeding the omega-3 fatty acids, eicosapentaenoic acid and docosahexaenoic acid resulted in strong CH_4-supressing effects when tested *in vitro*. Assuming that most forage has some fat content and that DMI may be suppressed at fat intakes above 6%–7%, CH_4 abatements of 10%–25% are possible with the addition of dietary oils to the diets of ruminants. There are five possible mechanisms by which lipid supplementation reduces CH_4: by reducing fibre digestion (mainly long-chain fatty acids); by lowering DMI (if total dietary fat exceeds 6%– 7%); the suppression of methanogens (mainly medium-chain fatty acids); the suppression of rumen protozoa; and to a limited extent, through bio-hydrogenation.

Feeding higher concentrate diets

Increasing the grain content of total mixed rations lowers the proportion of feed energy converted to CH_4 by decreasing the acetate:propionate ratio in the rumen fluid. Furthermore, methanogens are susceptible to the low pH conditions in the rumen that result from feeding high grain diets. However, the potential of using concentrates to lower CH_4 emissions from the dairy sector is limited because the increased incidence of clinical/sub clinical rumen acidosis jeopardizes cow health and reduces milk fat content. Increased concentrate-to-forage ratio decreased enteric methane emission and augmented the growth performance of A x B goat kids. Therefore, diets with low forage: concentrate ratio may be adopted as a feeding strategy for mitigating enteric methane emission and boosting the overall profitability of crossbred goats.

Replacing barley grain with corn grain

Selection of grain is also important factor for reducing methane meission from ruminants. In addition to feeding more grain, CH_4 emissions are also lowered by feeding corn rather than barley grain. This difference is due to a partial shift in the site of digestion from the rumen to the intestines, as corn is typically less extensively digested in the rumen than is barley. Of course, the method used to process the grain is also an important consideration; high moisture grains, steam flaking of corn, and fine grinding increase ruminal digestion compared with dry rolling, steam rolling and coarse grinding.

Dietary supplements

Dicarboxylic acids, like fumarate, malate, and acrylate, are precursors of propionate production in the rumen and can act as an alternative H_2 sink, restricting methanogenesis. Studies showed 0%– 75% reductions in CH_4 achieved by feeding fumaric acid. However, at the relatively high doses required, dicarboxylic acids are prohibitively expensive as an abatement strategy. Nitrate can also replace CO_2 as an electron acceptor, forming ammonia as an alternative H_2 sink in the rumen. Saponins have been shown *in vitro* to inhibit protozoa, as well as limit hydrogen availability for methanogensis. Essential oils have antimicrobial activities that act in a similar way to monensin by inhibiting gram-positive bacteria.

Ionophores

Monensin is a polyether ionophore antibiotic that reduces the acetate-to-propionate ratio in the rumen, effectively reducing CH_4 production. The effect of monensin on lowering CH_4 production appears to be dose dependent, with lower doses (10-15 ppm) producing a profitable milk response but showing no effect on CH_4, whereas higher doses (24-35 ppm) reduce CH_4 production by up to 10% (g/kg DMI). However, there are questions over the persistence of CH_4 suppression, and the future use of antibiotics in animal production systems is controversial. Results of our study showed that dietary concentrate proportion has significant effect on manure composition and greenhouse gas fluxes. Higher concentrate proportion increased CH_4 and N_2O fluxes from stored manure, but the emissions were very low. Thus, more research is needed for accurate quantification of manure GHG emissions under different feeding and management systems in India for its mitigation and inventory preparation.

Condensed tannin extracts

Condensed tannins are phenolic compounds extracted from the bark of black wattle trees (*Acacia mearnsi*) and Quebracho-Colorado trees. Adding *Acacia* tannin extract powder to the diet of sheep at a rate of 2.5% of DMI decreased enteric CH_4 by about 12% with only a marginal decrease in fibre digestion. However, Australian researchers used this same source of tannin extract in a dairy cow study and observed negative effects on milk production. Condensed tannins are thought to directly inhibit methanogens, as well as indirectly limit methanogenesis through a reduction in hydrogen availability. Condensed tannin containing *Lespedeza cuneata* was fed to goats *ad libitum* and found to reduce methane 57%in terms of g/kg DMI, compared to goats fed a mixture of *Digitaria ischaemum* and *Festuca arundinacea*. Tree leaves viz., moringa and others have different bioactive molecules and, in our experiments,, showed that supplementation of leaf powder decreases the methane emission from rumen and improves growth performance in kids and quality of milk in cows.

Defaunation

Treatments that have been used include copper sulphate, acids, surface-active chemicals, triazine, lipids, tannins, ionophores, and saponins. It has been suggested that the effect of defaunation on methane output is diet dependent. Researchers found that defaunation reduced methane output 13%, but the magnitude of reduction varied with diet. The greatest reduction in methane production with defaunation was measured on a high-concentrate diet, likely because protozoa are the predominant source of hydrogen for methanogenesis on starch-based diets. Defaunation is also not advisable due to health impact of dairy animals.

Conclusion

IPCC in its 6^{th} assessment report (published 9^{th} August, 2021) accepted that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. Rise in temperature due to climate change will definitely impact livestock production and livestock health. In India, almost 11 Tg methane and nitrous oxide or 266 million tonnes of CO2 equivalents are produced by livestock and due to poor productivity, its always blame comes from other developed nations on methane emitted per unit of milk or meat. Though, methodology of the GHG estimation factor affects the actual emission and this sector producing almost 10 percent of total emission.

There are many methods/ techniques to mitigate the emission from ruminants viz., culling/ slaughtering low producing animals and / or selecting germplasm for milk / meat production, utilizing best FCR animals, adding additives/ tree leaves and other methane mitigating components in the diet of ruminants. Subsequently, policy should be to incorporate proven methane mitigating items approved by government agency and implementation of the rules strictly may reduce climate catastrophe.

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ICAR-Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad
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National Institute of Agricultural Extension Management, Hyderabad