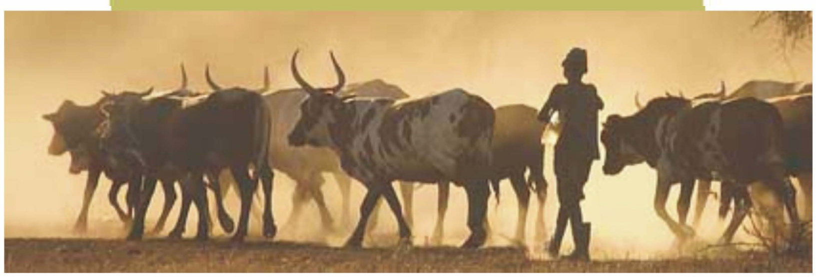
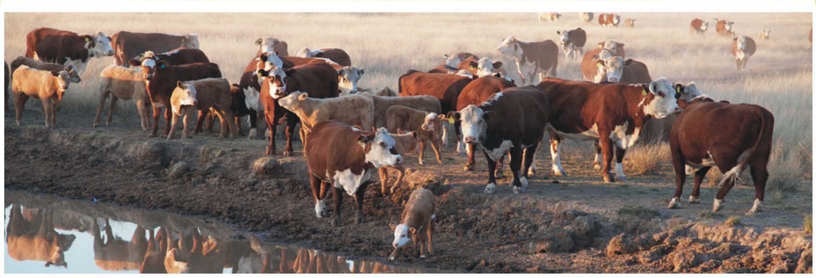
Directorate of Entrepreneurship, KVASU,
CAADECCS & MANAGE, Hyderabad

Climate Smart Dairying in the Context of Global Warming





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Dr. Aziz Zarina

2021

Directorate of Entrepreneurship, KVASU,
CAADECCS& MANAGE, Hyderabad

Climate Smart Dairying in the Context of Global Warming

Programme Coordination

Kerala Veterinary and Animal Sciences University (KVASU)
Centre for Animal Adaptation to Environment and Climate Change Studies (CAADECCS)
Mannuthy, Thrissur, Kerala

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Climate Smart Dairying in the Context of Global Warming

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This e-book is a compilation of resource text obtained from various subject experts for Collaborative Online Training Programme of KVASU-CAADECCS, Kerala & MANAGE, Hyderabad, Telangana on Climate Smart Dairying in the Context of Global Warming conducted from 04-07 May, 2021. This e-book is designed to educate extension workers, students, and research scholars, academicians related to veterinary science and animal husbandry about Climate Smart Dairying in the Context of Global Warming. 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.

KERALA VETERINARY & ANIMAL SCIENCES UNIVERSITY

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MESSAGE

Climate change has become a buzz word in recent times. The livestock sector, being the engine of agricultural growth, acts as the major source of income for the poor and marginal farmers of developed as well as emerging nations. Indeed, the sector is unique in that it contributes to climate change besides being affected by the same. The surging levels of greenhouse gases provide the arena for the phenomena called global warming, placing livestock production at stake. There is evidence of an increased concentration of greenhouse gases over the last century. These effects are of serious concern on account of their projected impact on the dairy sector, the major livelihood of the resource deprived and underprivileged farmers. The present scenario of global warming is expected to affect the breed composition, nutritional security, emergence and re-emergence of pests and zoonotic diseases as well.

Given the significance to sustain dairy farming in the context of prevailing climate change, it is therefore imperative to have productive discussions involving potential researchers who have vast knowledge in their disciplines of climate change and livestock production. The national training program "Climate Smart Dairying in Context of Global Warming", is one of such initiatives taken up by the Centre for Animal Adaptation to Environment and Climate Change Studies(CAADECCS), Kerala Veterinary and Animal Sciences University (KVASU) in collaboration with MANAGE, Hyderabad for dissemination of knowledge on this subject of importance by bringing together eminent personalities from different animal science institutes all over India.

I would like to take this opportunity to appreciate the Directorate of Entrepreneurship and CAADECCS, KVASU for initiating the efforts to collaborate with an esteemed institute like MANAGE for fulfilling the social commitment of the University. Being the youngest wing of KVASU, the initiatives taken by CAADECCS to conduct this training program in online mode amidst the COVID-19 pandemic is noteworthy. I am sure that the training will offer a great opportunity for researchers and students of different institutes and state veterinary and agricultural universities to gain knowledge from the experience of the learned experts and wish all success to this programme.

29/04/2021

Prof. (Dr.) M.R. Saseendranath
Vice-Chancellor.

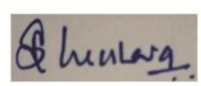
Message

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, called 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, who having expertise and facilities to organize technical training program for extension functionaries of state department.

Agricultural farming, which is the backbone of Indian economy is an imperative source of Greenhouse Gases (GHGs) emission worldwide. Dairy farming is a familial tradition in Indian agricultural activities; it is also a chief source of GHGs. Different studies have been conducted in different perspectives to assess the impact of climate change on production and productivity of dairy animals. Climate smart agricultural (CSA) practices help the world agriculture in keeping aim to meet our future food requirements without further increase in emissions. Climate smart dairy farming is most important to fight against negative impacts of changing climate. All the climate smart dairy farming practices are not suitable for every region as it largely depends on various contexts including particular location. However, climate smart dairy farming needs to be put into practice with paid attention so that in this changing climate scenario small holder farming can sustain with sufficient food security.

It is a pleasure to note that, Centre for Animal Adaptation to Environment and Climate Change Studies (CAADECCS), Directorate of Entrepreneurship, Kerala Veterinary and Animal Sciences University (KVASU), Mannuthy, Thrissur, Kerala and MANAGE, Hyderabad is organizing a collaborative training program on **"Climate Smart Dairying in the Context of Global Warming"** during 04-07 May, 2021 and coming up a joint publication as e-book on **"Climate Smart Dairying in the Context of Global Warming"** 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 Kerala Veterinary and Animal Sciences University (KVASU) many more glorious years in service of Indian agriculture and allied sector ultimately benefitting the farmers. I would like to compliment the efforts of course directors for this valuable publication.



(P. Chandra Shekara)
Director General, MANAGE

Prof. (Dr.) M. K. Narayanan
Director Entrepreneurship
Kerala Veterinary and Animal Sciences University

MESSAGE

Agriculture and animal husbandry are strongly influenced by weather and climate in terms of high degree of adaptation to local climatic patterns, farming and animal husbandry practices. The shift in climate due to man-made reasons had made an impact on farming systems and livestock rearing patterns and to human life. As rising temperatures alter the ecosystems and biodiversity, the distribution of plants and animal species will continue to change with a greater impact of availability of natural resources. Hence long term sustainable plans to protect our biodiversity need new generation researchers and scientists to work on combination of multiple fields to find a solution.

Climate Smart Dairying is a relevant topic taking into account the problems faced by the livestock farming community in the scenario of the recent floods and disasters. It is in this context the national training program "Climate Smart Dairying in Context of Global Warming", is planned by the Centre for Animal Adaptation to Environment and Climate Change Studies (CAADECCS) of Kerala Veterinary and Animal Sciences University (KVASU) in collaboration with MANAGE, Hyderabad for fruitful deliberations.

I am obliged to organise the programme in collaboration with MANAGE, Hyderabad which will put forth an effective platform for the researchers and students of various participating institutions to come together to discuss the topic.

Best wishes for the training programme.

Dr. M. K. Narayanan

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Centre for Animal Adaptation to Environment and Climate Change Studies(CAADECCS) - objectives and achievements

V. Beena[1,*]., S. Harikumar[1]., A. Afsal[1]., Divya Sasi[2]., M.R. Reshma Nair[1]

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Background (CAADECCS)

Climate models indicate that the global warming is real and rise in temperature is likely to be around 2-3^{o}Cby the end of the century with the regional uncertainties in rainfall. Monsoon aberrations have become more frequent over Kerala, popularly known as the Gateway of Monsoon. Decline in rainfall and increase in temperature is observed in the last 50-60 years across the state of Kerala. The livestock production is an integral part of mixed farming systems practised in the entire length and breadth of Kerala. Climate change affects livestock both directly as well as indirectly. It has been cited that the direct effects from the air temperature, humidity, wind speed and other factors influence the livestock production viz., growth, reproduction, milk production and occurrence of animal diseases. The impact of climate change on animal production can be categorized as (a) availability of feed, (b) pasture and forage crop production and quality, (c) health, growth and reproduction: diseases and their spread. Animal health may be affected by climate change in four ways viz., (1)heat related diseases and spread; (2)extreme weather events, adaptation of animal production system in new environment (3)emergence or re-emergence of infectious diseases; and (4) especially vector borne diseases which are critically dependent on environment and climatic factors.

The most significant direct impact of climate change on livestock production comes from heat stress. Heat stress imposes financial burden on livestock farmers through the decrease in the quality and quantity of milk production, meat production, reproduction efficiency and animal health. Most of the production losses are incurred via., indirect impacts through reduction or non-availability of feed and water resources. Climate change has the potential to impact the quality, quantity and reliability of fodder, their water demand as well as large-scale rangeland vegetation patterns. With the likely emerging severe loss that are already evident from the impacts of climate change effects, the livestock production systems are likely to face more negative than positive impacts.

Farmers in Kerala are encountering challenges in terms of shortage of livestock workers, rise in production costs, uncertain markets and more recently, increased weather / climate risks. Climate change related issues over Kerala are decline in land and ocean biodiversity and wetlands, increase in sea level, increase in landslides, groundwater depletion and saline water intrusion, decline in forest area and frequent forest fires and rate of increase in temperature across the High Ranges are likely to be immediate threat to several thermo-sensitive animal species. Life cycles of animals, reptiles and birds are likely to be adversely affected due to rising mercury in addition to mortality due to heat stress. Animal raids in farmsteads and attacks in peripherals have not become uncommon due to deforestation. Climate change also influences animal diseases and their dynamics. Alterations in the life cycle pattern of insect pests would cause changes in the occurrence of vector bourn parasitic diseases. Changing climate may also result in emergence of new pathogens and may also the pattern and intensity of pathogenesis.

The existing knowledge gaps on climatic trends and its physiological impacts on different livestock species make the dissemination of information from the scientific community on possible alleviation strategies to be adopted by the farmers difficult and that again aggravates the issues faced by the livestock sector of the state. Lack of thorough understanding on the impacts in quantifiable terms makes the adoption of optimum and adequate remedial measures impossible. It was therefore the need of the hour to undertake the research, teaching and extension activities so as to explore newer horizons in these fields to counteract the issues faced by the livestock farmers in the changing climatic scenario. With this perspective in mindthe Kerala Veterinary & Animal Sciences University (KVASU) has established the "Centre for Animal Adaptation to Environment and Climate Change Studies (CAADECCS)" to excel in climate change education, research and extension in the field of Animal Agricultural under the Directorate of Academics and Research as per the University Proceedings No. KVASU/DAR/R2/3579/2011 (1) Pookode dated 27.04.2012 with ICAR special grant during X1 Plan.

The CAADECCS serves as the nodal agencywith research and capacity building on all the aspects of climate risk management in relation to animal agriculture including weather insurance and provide information to the planners/ policy makers for implementing strategies to mitigate the ill effects of climate change/variability so as to sustain and enhance the rural livelihoods through livestock production and management.

The centre aims to have Livestock Advisory Field Units (LAFUs) at livestock farms to cater to the location specific issues on climate change adaptation and mitigation and prepare Livestock Advisory based on medium Range Weather Forecasting for the benefit of livestock farmers. The outcomes of the Centre are having local and regional as well as national and global relevance on climate change adaptation and mitigation strategies in the field of Animal Agriculture under the Humid Tropics.

Educational Programmes

Two P.G. Diploma Programs in Climate Services and Ph.D. programme in Climate Change and Animal Agriculturehave been launched in CAADECCS since the academic Year 2014-15 onwards. Besides CAADECCS is offering courses to the students of B.Sc.-M.Sc. (Integrated) Climate Change Adaptation of Academy of Climate Change Education and Research (ACCER) of KAU who have taken Veterinary Science as their elective subject.

One Ph.D. student has completed the research work in climate change and animal agriculture. Eleven students of ACCER, KAU were enrolled in CAADECCS for a six months elective course, out of which eight students completed research work from ICAR-NIANP in collaboration with CAADECCS. Four among them are placed in different universities in Australia for pursuing PhD. One student from ACCER completed the master’s research from CAADECCS. Apart from this CAADECCS is also providing infrastructure facilities for all the climate related researches of different disciplines of KVASU and also weather data for research projects of the University.

Research activities

CAADECCS has already signed MoU with UWA and NIANP and with IMD is in the process. Various collaborative research projects have been submitted to external funding agencies like DST, Animal Husbandry Department andKerala State Council for Science, Technology and Environment (KSCSTE). An RKVY- RAFTAR research project entitled "Strengthening of CAADECCS for thermal stress assessment in dairy cattle" for the year 19-20 has been sanctioned to CAADECCS with a financial outlay of 170 lakhs. The implementation of this project is in progress and as it gets completed; CAADECCS will become one among the pioneer institutes in India with climate-controlled research facility of global standards for thermal stress assessment in small and larger animals. Apart from this, state plan projects are being implemented every year. The preliminary research projects are focussed on the assessment of thermal stress in Animals. The members of CAADECCS have published articles in various national and international journals. Five text books on various aspects of livestock meteorology have already been published from this institute. An Automatic weather station had installed near CAADECCS in the year 2013. Every year a book on Automatic Weather Station-Hourly Weather Data and THI is also getting published from CAADECCS.

Meteorological Observatory in CAADECCS

CAADECCS has established a meteorological observatory with the equipments and technical expertise of IMD, Pune in the year 2018. The daily weather data is recorded and documented and which is used for climate related researches of the University. Observatory has the necessary instruments such as maximum and minimum thermometers, dry and wet bulb thermometers, sunshine recorder, wind vane, anemometer, soil thermometers and rain gauges.

Automatic weather station in CAADECCS

CAADECCS is having an automatic weather station (AWS) which records the hourly data of different weather variables.

Extension Activities:

CAADECCS has successfully completed nine years since its foundation and has achieved excellence in serving the needs of farmers, extension workers, policy makers and professionals associated with livestock production. During this journey, CAADECCS has emerged as the nodal agency for conducting several training programs and seminars. In the year 2013, CAADECCS organized a DST-SERB training programme on “Fundamentals of Livestock Meteorology” from 2-12-2013 to 22-12-2013. A total of 18 scientists from different parts of India participated in the training programme. Eminent resource persons from all leading institutes across the country and outside handled guest lectures /classes in connection with the training. Prof. Shane K Maloney of the University of Western Australia, Prof. GSLHV.Prasada Rao, Dr.V.Sejian, Principal Scientist, NIANP, Bangalore, Dr. Mahesh

Chander, Principal Investigator, IVRI, Dr.V.U.M. Rao, Project Co-ordinator, CRIDA, Dr.V.P.Maurya, PrincipalScientist, IVRI, Dr.N.H. Mohan, Principal Scientist, National

ബാങ്ക് ഓഫ് ഇന്ത്യ പരിയാരം ശാഖയുടെയും തുമ്പൂർമുഴി കാറ്റിൽ ബ്രീഡിങ് ഫാമിന്റെയും കേരള വെറ്ററിനറി സർവകലാശാലയുടെയും കാലാവസ്ഥാ വ്യതിയാന പഠനകേന്ദ്രത്തിന്റെയും നേതൃത്വത്തിൽ നടത്തിയ കർഷക ദിനാഘോഷവും സെമിനാറും പഞ്ചായത്ത് പ്രസിഡന്റ് ജനീഷ് പി. ജോസ് ഉദ്ഘാടനം ചെയ്യുന്നു.

കർഷക ദിനാഘോഷവും സെമിനാറും നടത്തി

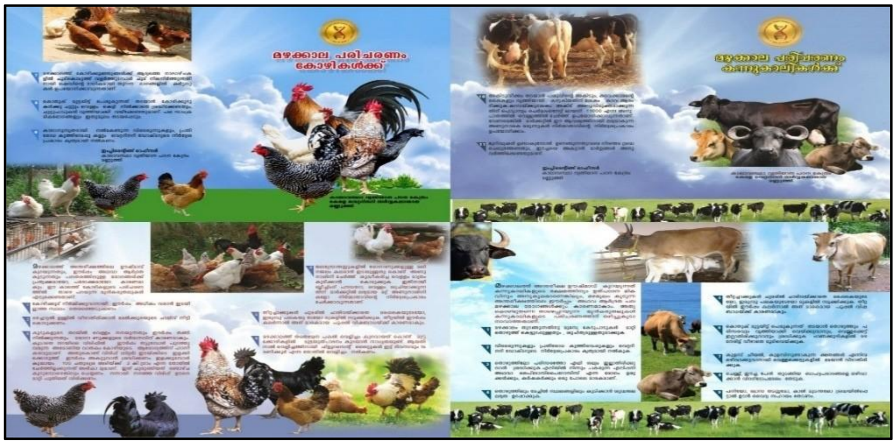
ചാലക്കുടി • ബാങ്ക് ഓഫ് ഇന്ത്യ പരിയാരം ശാഖയുടെയും തുമ്പൂർമുഴി കേറ്റിൽ ബ്രീഡിങ് ഫാമിന്റെയും കേരള വെറ്ററിനറി സർവകലാശാലയുടെയും കാലാവസ്ഥ വ്യതിയാന പഠനകേന്ദ്രത്തിന്റെയും നേതൃത്വത്തിൽ നടത്തിയ കർഷക ദിനാഘോഷവും സെമിനാറും പഞ്ചായത്ത് പ്രസിഡന്റ് ജനീഷ് പി.ജോസ് ഉദ്ഘാടനം ചെയ്തു. ബാങ്ക് ഓഫ് ഇന്ത്യ ശാഖ മാനേജർ സൗമ്യ ജോർജ് അധ്യക്ഷത വഹിച്ചു.

കെ.ആർ.സജീവ്, ഡോ. സിസിലായാമ്മ ജോർജ്, ടി.രവീന്ദ്രൻ, മനീഷ ജോബി, ഡോ. എ.പ്രസാദ്, ഡോ. കെ.പി.ശ്രീകുമാർ, ഷാജി ജോസഫ്, ഡോ. ദീപക് മാത്യു, ഡോ. പ്രസാദ് റാവു എന്നിവർ പ്രസംഗിച്ചു. മുഖാമുഖം പരിപാടിയിൽ ഡോ. വി.ബീന, ഡോ. കെ.കാർത്യായനി എന്നിവർ നേതൃത്വം നൽകി.

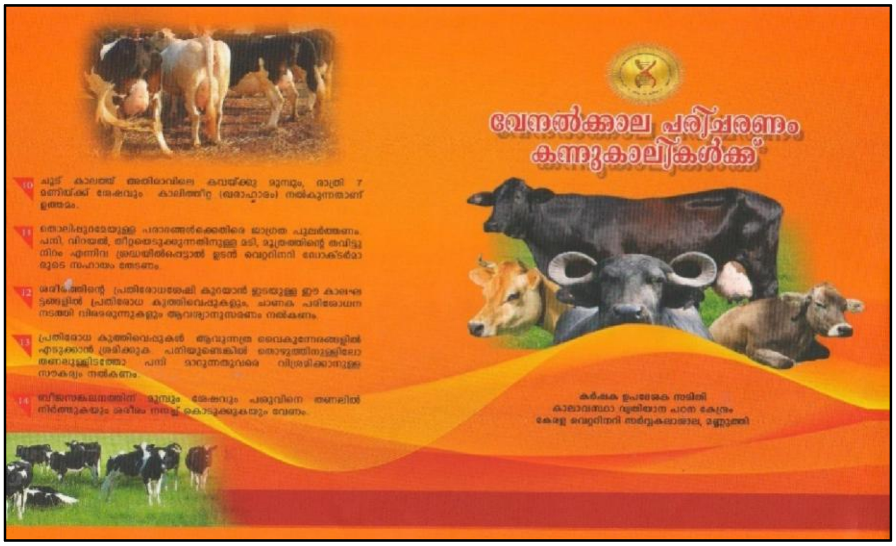
Research Centre on Pig, Guwahati were some of the prominent Resource Personnel.

Further, several awareness programmes both for professionals and farmers were organized at different parts of the state.

CAADECCS has actively involved in the workshops and seminars conducted by IMD, Department of Environment and State Disaster Management Authority. Steps have been initiated to start livestock advisory services to farmers with the help of IMD and Kerala Agricultural University. Also, CAADECCS has published various articles in local newspapers for bringing awareness among the farmers regarding the consequences of climate change on their livestock and the remedial measures to tackle these impacts.



Furthermore,CAADECCS organizes interactive sessions with farmers to address the constrains they come across in rearing their animals in this changing climate scenario. The ideas and recommendations emerging from such discussions are later given to the policy makers for taking up necessary actions. Indeed, the resource personalities from CAADECCS have participated in workshops and interactive sessions organized by Department of Environment and Climate Change for the preparation of State action plan on Climate change. CAADECCS has also came up with farmers friendly leaflets and postures to bring an awareness among local public regarding climate change.



The outcomes of the Centre havenational and global relevance on climate change adaptation and mitigation strategies in the field of Animal Agriculture. In this pursuit of excellence in climate change education, research and extension, the centre has initiated and implemented different training and awareness programmes in collaboration with reputed national and international centres. The latest of the lot, CAADECCS isorganizing a training programme entitled “Climate Smart Dairying in the Context of Global Warming” in collaboration with MANAGE, Hyderabad. The training provides awareness among veterinary professionals on the impact of global warming on dairy farming and also on the possible alleviation strategies to be adopted for sustainable animal agriculture. It represents the participation from various Faculty and students of Veterinary Universities, veterinary professionals of KVKs, ICAR institutes and state Animal Husbandry departments. The eminent faculties and scientist of national reputation will deliver lectures on topics relevant to their field of specialisation pertaining to climate change and dairy production in the aforementioned training programme.

Role of weather and climate in livestock production

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The success or failure of animal agriculture depends upon the chain of several factors viz., breed, fodder and nutrition management, environment and its interactions including weather and climate, technology and livestock farmer himself. Any weak link in the chain finally determines the animal output. Livestock farmers are encountering new challenges in terms of shortage of labourers, rise in production costs, uncertain markets and more recently, increased weather/climate risks. It is seen that extreme events such as floods and high intensity single day rainfall events and prolonged summer droughts/dry spells and heat and cold waves were on increasing trend from the last two-and-half-a-decades in a projected climate change scenario. Life cycles of animals, reptiles and birds are likely to be adversely affected due to rising mercury in addition to mortality due to heat stress. Animal raids in farmsteads and attacks in peripherals have not become uncommon due to deforestation. The human and wildlife conflicts due to deforestation and temperature rise are likely to emerge under the projected climate change scenario in the ensuing decades. Climate change also affects animal diseases and their dynamics. Interactions of animal insect pest and diseases are likely among various life species and thus the scenario of major and minor animal pest and diseases is likely to change. Vulnerability to extreme events generally is higher than vulnerability to changing average climatic conditions. The economy is likely to hit badly during the years of weather abnormalities. Prolonged summer drought, followed by heavy floods during the monsoon season as noticed in 2013 across the State of Kerala was detrimental to dairy, pig, goat and poultry farming directly or indirectly to a considerable extent. Of course, flood damage is not uncommon during both the monsoon seasons in high rainfall zones. Such weather aberrations are likely to be more frequent under the projected climate change scenario. Therefore, it is high time to take up in detail studies on interactions between weather factors in surrounding environment of animal agriculture, for which fundamental and basic studies need to be carried out in Livestock Meteorology to cope up with climate variability/climate change adaptation and mitigation.

Weather and Climate

The physical state of atmosphere at a given point of time at a given location is referred to as 'weather'. Weather is described in terms of the instantaneous or short period mean value of various atmospheric variables such as atmospheric pressure, temperature, humidity, cloudiness and sunshine, evaporation and rainfall. Weather determines the day-to-day livestock farming operations and comfort and discomforts. Climate is the long-term regime of the atmospheric variables, or the composite of the day-to-day values of the weather elements over a long period of a given place or area. The period of averaging weather may be several days, weeks, months, years or even centuries in the event of climate change. The climate is represented based on the normal values worked out for a period of 30 years, which is considered as the standard to express climatic conditions for a given place. The India Meteorological Department (IMD) used to prepare climate normals for every 30 - year period since 1901.

Weather decides animal production and thereby animal productivity while climate decides selection of animals. Similarly, animal pest and disease incidence and spread is dependent on weather while the hot spot areas of animal diseases can be delineated based on climate (**Table 1**). The tropical, temperate and polar animals can be classified on the basis of the thermal and precipitation regimes across the globe, rather mostly based on thermal regimes.

Table 1. Difference between weather and climate

Weather	Climate
Refers to physical state of atmosphere at a given time in terms of temperature, rainfall, relative humidity, sunshine hours and so on.	Refers to average state of weather (Required at least 30 years of weather data to find out the climate normals) – Ex. Rainfall and temperature normals

Decides animal behaviour and thereby milk productivity in the case of cattle and related animals	Decides geographical distribution of animals and integrated farming systems (Eg. tropical , sub-tropical, temperate and polar animals)
Day to day livestock farming is dependent on weather	Livestock farming is dependent on climate
Animal pest and disease incidence is dependent on weather	Hot spot areas of animal pest and disease incidence and their geographical distribution can be delineated based on climate
Extremes like floods and droughts and cold and heat waves depend on weather	Extreme weather prone areas can be delineated based on climate. Sea level rise depends on global warming and climate change

Seasons

Radiation received from the sun is the main source of earth's atmospheric energy and ultimately it is the fuel of the atmosphere. The atmosphere acts mostly as the medium which is transparent to the sun's radiation and opaque to the earth's radiation, and this is the driving force of atmosphere. Variations in radiation received over different regions of the globe due to its positioning with reference to the sun, together with the features of the earth, produce weather and climate. The seasons form due to the revolution of the earth round the sun. Tilt of the Earth, revolution of the Earth and the North Pole of the Earth always points in the same direction make the seasons different across the Globe. When the Northern Hemisphere experiences six month summer the Southern Hemisphere experiences winter and the opposite happens for the remaining six months. While the seasons in UK/USA are: Spring- March to May; Summer-June to August; Autumn- September to November; and Winter- December to February. The seasons in India based on temperature and precipitation are as follows:

Summer- March to May (Temperature); Monsoon-June to September (Rainfall); Post monsoon-October to November (Rainfall) and Winter-December to February (Temperature).The monsoon and post monsoon seasons in Kerala are similar to that of the Country. Winter season also is similar across the high land and high ranges. Across the low and mid lands of Kerala, winter is very mild and one can consider December and January months in winter whereas February and March fall under the real summer in low lands and temperature falls drastically during April and May depending on the pre-monsoon showers and onset of monsoon. Therefore, one should be careful while interpretation of seasonal variations for comparison.

Environmental Stress in Animal Agriculture

The environmental stress, includes the biotic stress (pest and diseases), abiotic stress (influence of weather abnormalities), air pollution, ozone depletion and UV-radiation, livestock production and nutritional management practices, exerts on animal husbandry adversely to a considerable extent (**Fig. 1**). The impact of these stresses on animal agriculture in varied climates needs to be focussed through concerted research efforts.

Weather Abnormalities

Floods and droughts, cold and heat waves, cyclones and anticyclones, cloudbursts, lightning and thunderstorms, duststorms, icestorms and snowstorms, forest fire outbreaks and sea level rise can be classified under the weather related disasters while the Earthquakes and the Tsunami fall under natural disasters (**Fig. 2**). Under the projected climate change scenario, the occurrence and intensity of weather abnormalities are likely to be more and more in the ensuing decades. The effects of drought may lead to scarcity of water and fodder during summer as seen in recent years 2012, 2013, 2014, 2015 and 2016 across various parts of the Country. It adversely affects fodder and dairy farming and the thermal stress during summer is detrimental to poultry and duck farming as both the farming systems are sensitive to drought and heat stress. The occurrence of cold wave is relevant in the temperate regions of the central and northern regions while severe heat wave conditions are prevalent during summer across the Country. However, continuous rainfall with high humidity and temperature always pose a problem in animal agriculture in the Humid Tropics and efforts are needed in this direction to understand the discomfort and its effects based on rainfall, humidity and temperature (THI) in animal agriculture across the Humid Tropics.

Ozone Depletion and UV Radiation

The greatest concentration of ozone is at an average in height of 25 km and above in the stratosphere. The ozone molecule is made up of three atoms of oxygen. It is the most efficient absorber of ultraviolet radiation from sun and thus protects all life forms in planet earth. Ozone depletion due to industrialization in recent decades is the concern of humankind and biological activities. Release of compounds like chlorofluorocarbons (CFCs), carbon tetrachloride and methyl chloroform could significantly deplete ozone layer that shielded the planet from ultraviolet radiation. The CFCs are used in a variety of industrial, commercial, and household applications. These substances are non-toxic, non-flammable and non-reactive. They are used as coolants in commercial and home refrigeration units, aerosol propellants and electronic cleaning solvents. The global average thickness of ozone is 300 Dibson units, equivalent to 3mm. The ozone losses are caused by chlorine and bromine compounds released by chlorofluorocarbons and halons. Year-to-year variation of size and depth of ozone hole depend on variations in meteorological conditions. Among UV radiations, UV-B radiation in the range of 280-320 nm is more sensitive to ozone fluctuations and reaches earth surface. A global network is created to monitor UV-B filtered radiation in terms of Minimum Erythema Dose (MED). The human-made interventions in industrial development lead to ozone depletion, thereby filtered UV radiation reaches the ground, resulting in various human, animal and crop diseases. The ozone loss has the potential to increase incidence of skin cancer, cataracts and damage to people's immune system, harm some crops and interfere with marine life. However, little is known on impact of ozone depletion and increasing UV-B radiation on ontogeny of tropical plants and human and animal diseases since studies in this direction are lacking. Because CFCs remain in the atmosphere for100 years, continued accumulation of these chemicals pose ongoing threats, even after their use is discontinued.

Automatic Weather Station

Automatic Weather Station, popularly known as AWS, is an electronic device and an automated version of the traditional weather station. Numerous weather sensors are connected to the system which automatically records and stores weather data. It is quite useful in remote areas where no frequent access is possible. The system requires hardware as well as software to log in, store, display, transfer and analyze the data. The digital data recorded can be downloaded to the laptop and transferred to the desktop since it is a computer compatible system. The transferred digital data is formatted into actual values of various weather elements through the software provided for the purpose. Every AWS has its own software depending upon the manufactures. Time interval can be fixed for recording weather data depending upon the purpose since it is a continuous recorder. Continuous AWS data are integrated at hourly or half-hourly interval for monitoring weather data, otherwise enormous data are continuously stored and no way are useful.

AWS data at Mannuthy, Thrissur, Kerala

Automatic Weather Station has been commissioned at the Centre for Animal Adaptation to Environment and Climate Change Studies (CAADECCS) on 24th July, 2013 at CoV&AS, Mannuthy Campus. It consists of a mast of 6 inch solar panel, lightning protection rod, data-logger and self (solar) power supply and its housing facility in a fibre glass material and meteorological sensors. It records meteorological parameters continuously. The meteorological sensors include solar radiation, relative humidity with radiation shield, temperature (air, dew point and wet bulb), wind direction and wind speed. These weather parameters are recorded automatically in every 10 seconds and averaged at hourly intervals. Using the AWS data, hourly Temperature Humidity Index (THI) can be worked out which is the index used to relate thermal stress in animals (Table 2).

The India Meteorological Department, popularly known as Mausam Bhavan, Government of India is one of the oldest departments in the Country, located in New Delhi. It was established in 1875. It has a network of approximately 6000 rain gauge stations and more than 550 surface meteorological observatories plus about 300 stations which include hydro-agro-meteorological, radiation, air pollution and pilot-balloon stations spread over the entire Country. The whole Country has been divided into 35 meteorological subdivisions based on homogeneity in its rainfall distribution. The aim of the department is to forecast daily weather on meteorological subdivision-wise and disseminate the same on time to the users. Almost all the State Capitals in India also have State Meteorological Centres (SMCs) to serve the weather and climate services including weather forecast needs of the States and these centres issue Farmers' Weather Bulletins (FWBs). The bulletins contain a forecast on weather elements valid for 36 hours and an outlook for the subsequent two days. The daily weather forecast is prepared for the entire Country from the weather forecasting division, IMD Pune and communicated to the Mausam Bhavan, New Delhi for dissemination across the Country. There is a vast improvement in precise short range forecasting with the advent of supercomputers along with the radar and satellite information. Cyclone forecast with a network of weather radars along the East Coast of India is a classical example for success of short range weather forecasting.

One of the prime objectives of providing weather forecast is to disseminate information to the farmers including livestock farmers on real time basis so that they can utilise the beneficial aspects of weather information to increase crop and livestock production or to minimise the damage, which may be caused directly or indirectly by unfavourable weather. Incidence of animal diseases could also be forewarned based on weather forecast if information on relationship between weather and specific pest and disease incidence is known in advance. The output of agriculture (includes animal agriculture) could be increased and recurring losses minimised if reliable forecast on incidence of pest and diseases is given timely based on weather variables. Hence, weather forecast plays a key role in sustaining agricultural/livestock production of the Country. This could be possible if information is provided to the farmers/livestock farmers, in advance, on the type of weather situations likely to be encountered and method to be adopted for efficient management of inputs.

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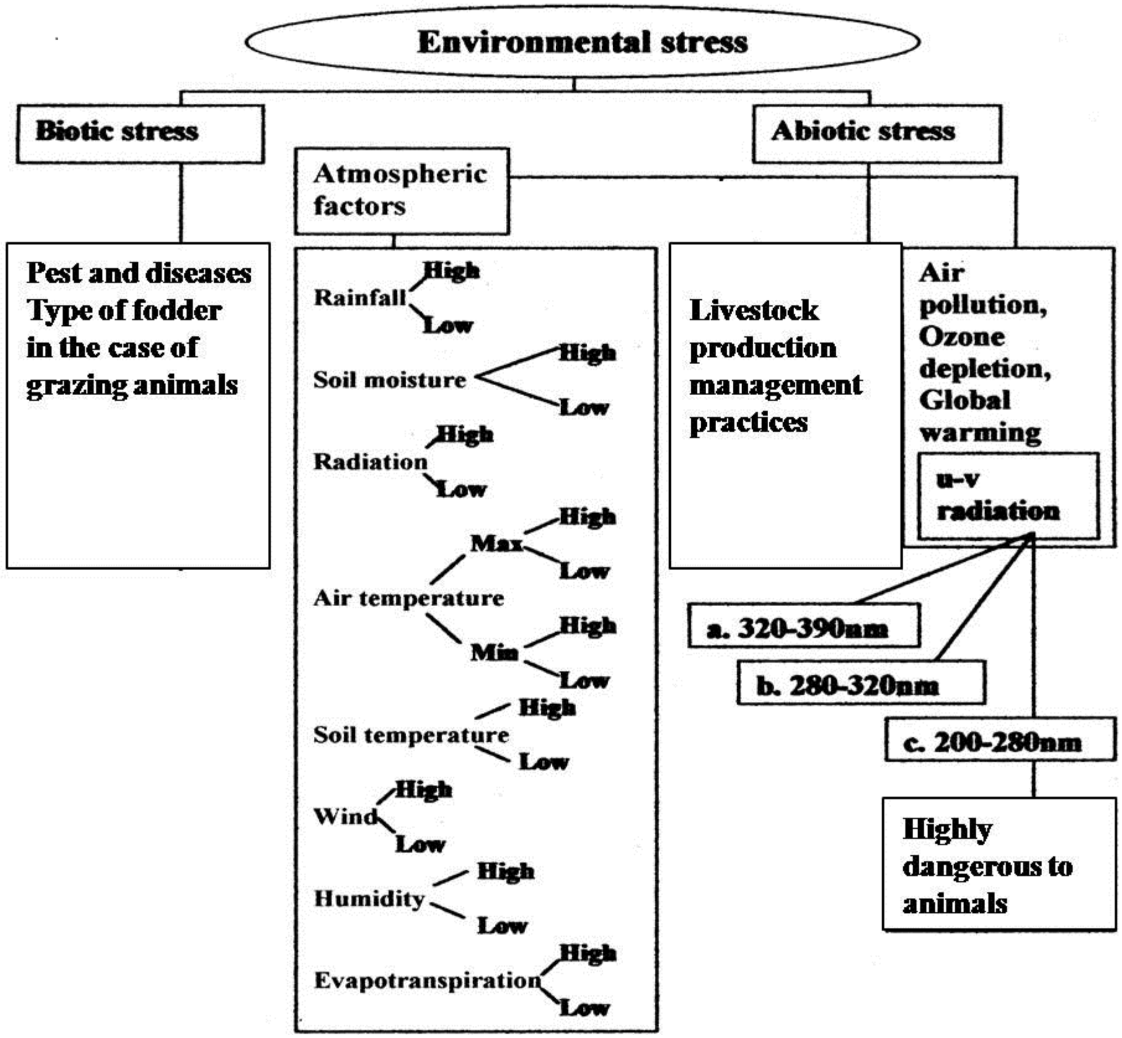

Fig. 1. Biotic and abiotic stresses in animal agriculture

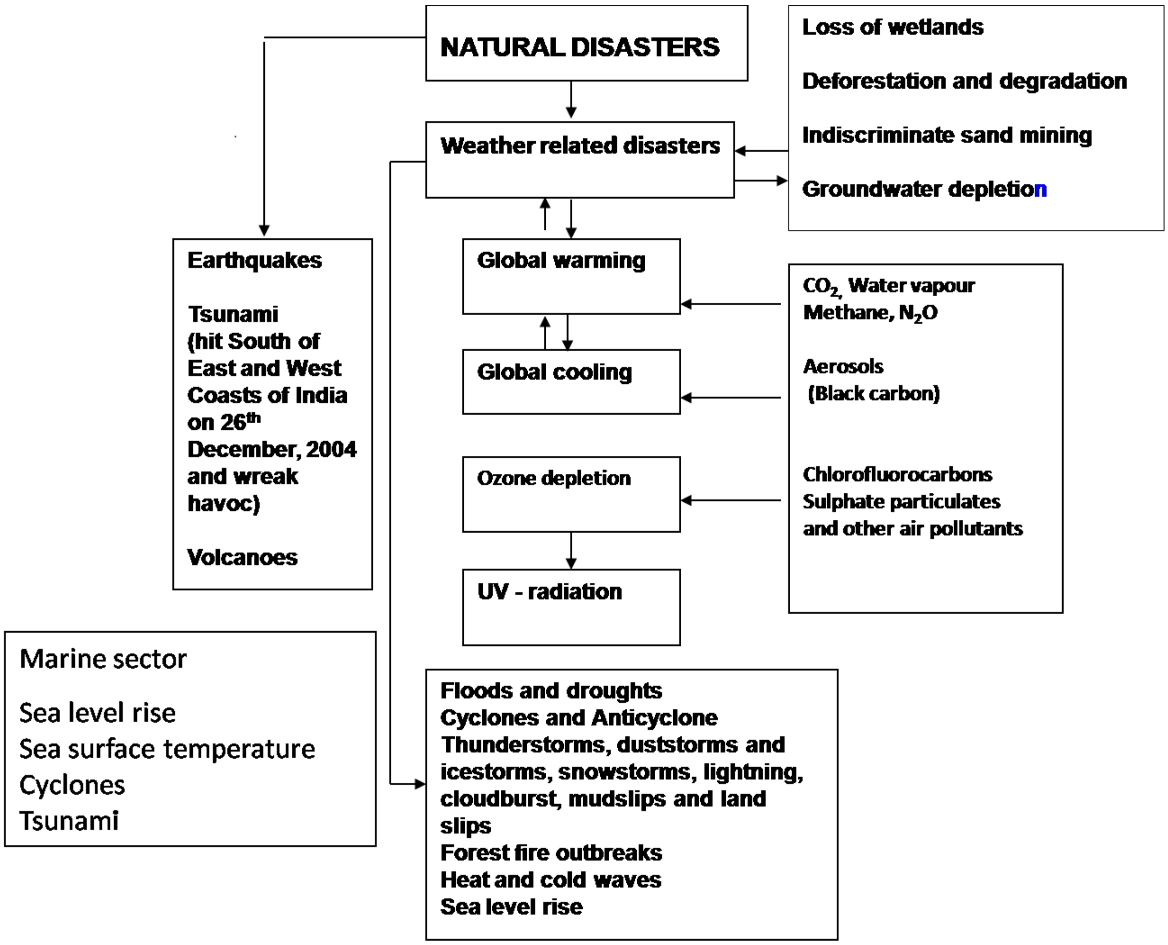

Fig. 2 Natural and weather related disasters

Table 2. Weekly AWS data (Standard Meteorological Weeks) and THI at Mannuthy in 2014

Std. Met.Week and Corresponding Month	AT	RH	SR	WS	WD	DPT	WBT	THI
01-Jan1-7	27.4	64.6	200.4	1.1	93.7	19.3	21.9	76.0
02-Jan8-14	27.9	63.8	197.6	1.2	80.1	19.9	22.4	76.9
03- Jan15-21	28.4	68.6	192.5	0.8	109.2	21.5	23.5	78.2
04- Jan22-28	27.9	57.9	219.0	1.5	80.4	18.3	21.4	76.2
05- Jan29-4February	28.1	58.7	216.3	1.3	84.7	18.5	21.6	76.4
06- Feb5-11	27.7	64.3	221.7	0.8	109.6	18.5	21.8	76.2
07- Feb12-18	27.7	77.0	172.2	0.5	138.6	22.8	24.1	78.1
08- Feb19-25	29.1	68.0	211.1	1.0	111.3	22.0	24.1	79.1
09-Feb26-4March	29.1	72.5	207.6	0.7	146.2	23.2	24.8	79.8
10- Mar5-11	29.5	68.4	205.3	0.8	114.2	22.5	24.5	79.8
11- Mar12-18	29.7	59.1	250.9	0.9	113.6	18.8	22.5	78.1
12- Mar19-25	30.3	73.6	216.8	0.6	171.9	24.3	25.9	81.6
13- Mar26-1April	30.3	68.7	233.1	0.6	147.6	22.4	24.8	80.6
14-Apr2-8	30.4	77.2	198.2	0.6	173.0	25.6	26.8	82.5
15- Apr9-15	29.1	81.4	190.0	0.5	170.9	25.2	26.2	81.1
16- Apr16-22	30.5	78.7	220.1	0.5	193.1	26.0	27.1	83.0
17- Apr23-29	30.6	81.5	197.6	0.5	176.4	26.7	27.6	83.6
18- Apr30-6May	30.0	78.3	202.4	0.6	168.9	25.5	26.6	82.1
19- May7-13	28.1	90.3	158.8	0.4	106.7	26.2	26.6	80.9
20- May14-20	29.3	81.9	212.9	0.4	165.1	25.6	26.5	81.6
21-May21-27	29.5	83.8	184.3	0.4	177.6	26.2	27.0	82.3
22- May28-3June	29.0	87.5	180.2	0.4	174.2	26.6	27.1	82.1
23- Jun4-10	27.3	93.8	152.9	0.2	75.2	26.1	26.4	80.2
24- Jun11-17	27.2	92.6	159.1	0.2	115.5	25.8	26.1	79.7
25-Jun18-24	27.3	93.8	152.8	0.4	124.3	26.2	26.4	80.2
26- Jun25-1July	28.0	90.7	175.2	0.3	127.7	26.2	26.7	80.9
32- Aug6-12	25.4	96.1	129.8	0.0	0.0	24.7	24.9	77.2
33- Aug13-19	27.3	90.9	189.7	0.0	0.0	25.6	26.0	79.7
34-Aug20-26	27.2	92.1	186.4	0.0	0.0	25.6	26.0	79.6
35- Aug27-2September	25.7	96.4	138.4	0.0	0.0	25.1	25.2	77.8
36- Sep3-9	26.1	94.7	164.3	0.0	0.0	25.1	25.4	78.3
37- Sep10-16	27.3	89.6	210.2	0.0	0.0	25.3	25.8	79.5
38- Sep17-23	27.7	87.6	210.4	0.0	0.0	25.3	25.9	79.9
39- Sep24-30	27.9	87.4	212.0	0.0	0.0	25.4	26.0	80.0
40- Oct1-7	26.4	98.9	0.3	0.0	0.0	26.1	26.2	79.5
41- Oct8-14	27.2	92.6	163.0	0.0	0.0	25.7	26.1	79.7

42- Oct15-21	27.3	88.7	184.6	0.0	0.0	25.2	25.7	79.4
43- Oct22-28	27.2	90.0	177.5	0.0	0.0	25.2	25.7	79.3
44- Oct29-4November	27.0	90.9	177.4	0.0	0.0	25.2	25.7	79.1
45- Nov5-11	27.2	90.9	160.8	0.0	0.0	25.4	25.9	79.6
46- Nov12-18	27.8	81.7	219.5	0.0	0.0	24.2	25.2	79.3
47- Nov19-25	27.4	78.6	175.5	0.0	0.0	23.0	24.2	78.2
48- Nov26-2December	26.4	73.7	150.6	0.0	0.0	20.9	22.6	76.1
49- Dec3-9	27.0	75.9	209.9	0.0	0.0	22.0	23.4	77.1
50-Dec10-16	27.7	83.1	187.0	0.0	0.0	24.3	25.2	79.2
51- Dec17-23	27.6	74.9	170.6	0.0	0.0	22.5	23.9	78.1
52-Dec24-31	27.1	78.2	171.5	0.0	0.0	22.7	24.0	77.7

AWS data from 27 to 31SMW is missing due to maintenance problem

AT – Atmospheric Temperature in ^{O}C, DBT Dewpoint Temperature in ^{O}C, WBT Wet bulb Temperature in ^{O}C

THI – Temperature Humidity Index, WS – Wind Speed m/sec, WD- Wind Direction and SR – Solar Radiation

Physiology of Thermoregulation

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Introduction

Exploring the life and life processes of animals have always been an interesting area of research since time immemorial. It is easier to deal with the 'complex' living world if one can view 'life' as a 'super-concerted conservatory of the physical world'. In this sense, phenomenon of life process entails incessant adjustments to ensure its own substantiation and further expansion. Life 'entities' thus perceive the surrounding, identify themselves in that framework, and execute the 'near best' strategies befitting the provisions vested within them. Obviously, when a living being identifies itself in the physical dimensions, the relative constancy or consistency of its existence is imperative.

Physiology deals with the constant interaction between the innate provisions of living system and what is being referred as the 'environment' wherein the system is embedded. Maintenance of the 'relative constancy/consistency' of life is the major theme of Physiology. In that way, thermoregulation deals with how the living subject negotiates with flux of thermal energy. Among various life sustaining activities, the mechanism of thermo-regulation is considered to be vital for supporting the optimum functioning of cells and thereby supporting the life of the individual itself. In case of animals including livestock and poultry there are several lines of response and cascades of events happening in the animal body with exposure to extreme temperatures ensuring their survival. If the extremity of thermal flux is too heavy or too long or if the physiological mechanisms altogether break down it culminates in succumb.

Thermoregulation is all about thermal (heat) energy

Heat is a form of energy by virtue of the velocity and conformation of particles; the former (kinetic) property being thermometer-sensitive attributes 'temperature', whereas the latter (potential) part is hidden or latent and imperceptible to a thermometer.

Specific heat is defined as the amount of heat energy required to raise the temperature of unit mass of the substance in question over 1 degree Celsius. Water, typically a polar compound, has high specific heat (1 calorie/gram) compared with many other non-polar liquids like fats and oils.

Heat capacity is the amount of heat contained by the bulk of the substance over one degree Celsius. Obviously, heat capacity is the multiple of specific heat and amount (mass) of the substance. It is noteworthy that the high specific heat and abundance of water in body enables it to deal with transfer of huge amount of heat energy with minimum temperature fluctuation.

Modes of heat transfer: In strict physical terms there are two major ways of heat transfer: ***conduction*** by particulate collision and ***radiation*** by discrete electromagnetic transfer between bodies, independent of a medium. ***Convection*** is a sub type of conduction where the internal energy is carried between bodies by a moving (flowing) material carrier. In all the three modes heat flows from a hotter to a colder point, temperature difference decays over time and thermal equilibrium is reached.

Evaporative cooling: Since the 'true' heat transfer (through conduction, convection and radiation) occurs down the temperature gradient heat always flows from hotter to cooler points in all these modes. So, when the ambient temperature rises above the animal's temperature heat flows from external environment to the animal body; the animal does not have escape. In such instances heat dissipation is solely possible through the latent (hidden) potential heat of evaporation of water from the animal body. Since water can evaporate at much lower temperatures than its boiling point and still absorb the full amount of its latent heat this method offers dual advantage to the animal. Moreover, evaporation never loads heat upon the animal; if at all it occurs, it takes off body heat. Provisions of evaporative cooling make the water content of atmosphere (humidity) an important determinant in thermoregulation. In fact, ***temperature*** and ***humidity*** are the most important meteorological parameters considered in thermoregulation. Higher the saturation of the atmosphere with water vapour (***relative humidity***) lesser the chances of further evaporation of water from the animal body and lesser the scope of evaporative cooling.

Newton's law of cooling: states that the rate of heat loss of a body is directly proportional to the difference in the temperatures between the body and its surroundings.

$Q = h \times A \times (T_t - T_{env})$

[Q is the rate of heat transfer out of the body

h is the heat transfer coefficient

A is the heat transfer surface area

$T_t$is the temperature of the object's surface

$T_{env}$is the temperature of the environment]

Practically, in all episodes of heat exchange usually between the body and the environment) Newton’s law of cooling is operational where the temperature gradient and the effective surface area are the chief determinants.

Animal: the machinery and mechanism

Animal body represents the preserved protoplasm existing in the particular point of time and space. It is the buildup of the inherited plan (genotype) assuming the acquired structure and function (phenotype). The animal embedded in or exposed to the environment engages in constant interaction with the environment. Regulation of bodily functions in fluctuating temperature is the concern in thermoregulation. The genetic constitution of an individual enables it to possess the inherited adaptive machinery (structure), which in turn, elicits the mechanism (function). The machinery is put to operation as the local/neural/endocrine feedback alerts the control system. The feedback system is the primary anatomical fabric (set up) upon which behavioural, structural, physiological and genetic level adaptations are vested. Like the variation in animals there are huge variations in their strategies. However, major principles underlying are more straight and common. The following sub titles tells the foremost ones.

The broad classification

Ectotherms and endotherms:Ectotherms depend on external sources of temperature to regulate their body temperatures since internal sources of heat are negligible. They are also called cold-blooded.. Ectotherms have a wide range of behavioral mechanisms that enable them to respond to external temperatures, such as sun-bathing to increase body temperature, or seeking the cover of shade to lower body temperature. Endotherms create most of their heat via metabolic processes, and are referred to as warm-blooded; they possess a larger number of mitochondria per cell enabling them to generate more heat from fats and sugars.

Homeotherms and poikilotherms: Homeotherms have more stable deep body temperature compare to poikilotherms. Most endothermic organisms such as mammals are homeothermic whereas animals with facultative endothermy are often poikilothermic, meaning their temperature can vary considerably.

Thermoregulation in mammals and birds

With the exposure to sub-thermoneutral environment, animal body gets prepared to send signals for thermogenesis, utilizing the brown adipose tissues, shivering and through the injection of food. The primary source of metabolic heat production comes from the synthesis and utilization of ATPs. On the other hand, there are multiple ways to expel out excess body heat to the surroundings in order to maintain thermo-neutrality. For instance, alterations in blood flow could be an ideal way of losing excess heat to the environment. Another way of transferring body heat to the environment is through evaporative cooling. However, this could result in staining the water balance and osmotic homeostasis. The execution of thermoregulatory behaviours, involving a complex integration of thermal comfort/discomfort and somatic motor control systems, would also incur the homeostatic systems. Finally, transitions into particular behavioural states (e.g., sleep, psychological stress, febrile or septic immune responses, hibernation, and starvation) could also aid for maintaining the thermal balance within the animals.

Given the complexity of theses mechanisms associated with the maintenance of homeostasis, it is not surprising that the primary integrative site for thermoregulation is in the brain. In this context, this chapter is an overview of the current available knowledge on the principal mechanisms governing the thermoregulatory control in animals.

Heat transfer processes in animals

Heat exchange between the body surface of animals and the environment occurs through three distinct physical mechanisms viz. conduction, convection, thermal radiation and evaporation. Temperature of animal body depends upon heat gain and losses, it is constant only if the sum total of gains equals the sum total of losses.

Sensible heat transfer implies dependence of heat transfer on temperature differences, this type of transfer includes radiation, convection and conduction, as distinct from evaporative transfer, which depends on differences in water vapour pressure. Conductive and convective heat transfer have in the common property that the atoms and molecules of the substance participate in the transfer of heat through the material substance by either mechanism. Conduction occurs when a material substance is macroscopically motionless and convection is brought about by flow of a material substance which occurs faster than conduction.

(i) Conductive heat exchange

Conduction is the transfer of heat energy from matter to adjacent matter by direct contact, without intermixing or flow of any material. In this mechanism kinetic energy is passed from one molecule to another by collisions. Conduction is associated with temperature gradients as faster vibrating molecules, characteristic of higher heat energy, strike slower vibrating molecules and give up energy. Energy is dissipated from regions of higher temperature to regions of lower temperature regions. When the energy is equally distributed, molecular vibrations are on the average, uniform and energy exchange by conduction is equal in all directions. That is heat is transferred from the hotter of any objects to the cooler objects which are in contact with each other, the rate of heat loss depends on the temperature difference between the environment, and on the area of contact, this is not a major cause of heat loss because the low thermal conductivity of air and the limited area of contact between the body and the solid environment .However this changes if the animals becomes emerged in water as more of the body will be in contact with the water thus much more heat will be lost and at a much faster rate.

This method of heat loss requires that the animal have physical contact with surrounding objects. When an animal wades into a pool, it is cooled by conduction. It is an important consideration for bedded animals since the loss of heat by conduction to the substrate is an important component of the total heat loss. Above mentioned method is an important source of heat loss, however it is a major cause of heat gain for the reptile species. Their metabolism depends directly on the environmental temperature. In the morning, after the environmental temperature drop of the night, they have a very low body temperature and metabolic rate. Thus movement is sluggish, to counteract this and warm up quickly the animals will orientate its body in the direction of the sun to absorb the radiated heat the sun gives off, additionally the animal will find a rock of sold surface to sit in the sun, as the sun has already warmed up the rocks the underneath of the animal, will conduct the heat from the rock in to its body as an additional source of heat.

(ii) Convective heat exchange

Convective heat transfer is brought about by flow of a material substance. Convection currents of air remove heat from the surface of dry skin as the air passes over it, and occurs much faster than conduction. It is the movement of air resulting from local pockets of warm air being replaced by cooler air and vice versa. Less specific heat capacity of the air allows air in contact with the skin to be warmed rapidly. Warm air being less dense than cold air, rises up and replaced by cold air. This may take place primarily either through forced convection or through natural convection. Forced convective heat transfer is due to wind impinging on the surface and natural convective transfer occurs in still air or at low wind speeds, and is due to warmed air rising from the skin surface as a result of its decreased density.

(iii) ***Radiative heat transfer*** Radiation is the emission of electromagnetic "heat" waves. Heat comes from the sun in this manner and radiates from dry skin the same way. Beams of radiant energy emitted by the object travel between objects at the speed of light. Because of thermal-radiation heat transfer, objects can exchange heat at a distance. Animal body loses heat via electromagnetic waves, when these waves fall on to a cooler object or surface it will absorb the waves as heat.

The reflectivity of coats is an important factor in determining the animal's heat load from solar radiation, but radiation is scattered forwards from the hairs towards the skin as well as being reflected back to the environment. Reflectivity of coats is depend up on its colour and arrangement of hair or feather. Although a light coat is more reflective than a dark coat, more radiation reaches the skin through a light coat than through a dark coat, and the depth of penetration depends on wind speed as well as on coat colour and the arrangement of hair within it. With a dark coat, incident radiation is more likely to be absorbed in the outer layers, with the heat being dissipated by convection and long wave radiation, than would be the case with a light coat. Heat load by solar radiation is also depend on the area exposed to sun and reflectance of the surroundings.

(iv) Evaporation

Evaporation is a potentially potent mechanism for heat transfer because the change of state of water from a liquid to a gas absorbs a great deal of heat per gram of water. The heat is absorbed from the surface where evaporation occurs and is carried away with the water vapor. Change of state from liquid to vapour is always accompanied by cooling, the evaporation from the body's surface depends on temperature, humidity and air currents and can be regulated via sweating and panting. Sweating will not cool unless it is evaporated, thus environmental factors like humidity and the speed in which the air is moving are important when determining the efficiency of sweating, furthermore bids have no sweat glands and many mammals only have them on the pads of their feet thus heat loss comes about via the rapid movement of air over their mouth and upper respiratory tract when they are shallow breathing or panting.

Mechanism of thermoregulation

Mechanism of adaptation starts when the animal is repeatedly exposed to a non-lethal stress. They modify their morphological, behavioural and physiological characteristics in response to thermal challenge, which helps to reduce the change in state of thermal equilibrium.

Morphological adaptive mechanisms

Natural selection or human selection act as the tool to develop morphological modifications within the species or breeds. Variation in limb size in tropical and temperate zone, fat storages, skin colour and body size are some of the examples for morphological adaptations.

Behavioural adaptive mechanisms

Animal try to reduce the impact of stressor by adopting behavioural adaptations like seeking shades or shelters, changing postures, wallowing, reducing or increasing feed intake etc.

Physiological adaptive mechanisms

Duration of exposure to the stressor determine the physiological adaptions either short term or long term. Neuroendocrine reactions act as the main regulating and coordinating mechanisms for thermoregulation. This will trigger the biochemical adaptions to set in, changes in metabolic rate, proteins and membrane lipids. Gene expression is the fundamental mechanism for adaptations. Genetic capacity of the animal for change will determine its ability to respond successfully to an environmental stressor.

Role of nervous system

With an aim of maintaining the body temperature, animals have thermo-receptors in their body to detect the sudden as well as gradual changes in the surrounding weather. These receptors are distributed throughout the body viz., skin, hypothalamus and other parts of the brain. Although this mechanism works in coordination with the signals from the brain, little is known about the neural circuit of thermo-regulation. The analysis of the neural circuit for thermo-regulation has not made any remarkable progress in last couple of decades. Initial studies were concerned with the membrane mechanism of thermal sensitivity. Later, with the advancement in science, researches were conducted to delineate the afferent as well as efferent pathways associated with thermoregulation in brain.

In an effort to identify the signals produced for thermo-regulation, various models were introduced. Irrespective of different models, the results have coincided towards identifying excitatory efferent signals produced by the sensory neurons. Most of these sensory neurons have cell bodies located in peripheral ganglia and axons that extend out to measure the temperature of key thermoregulatory tissues (e.g., the skin, spinal cord, and abdominal viscera). A separate set of sensory neurons are located within the brain itself and measure the temperature of the hypothalamus. Skin temperature acts as an input to trigger the thermoregulatory effectors, as well as to guide the changes in behavior. Because of this reason, skin behaves differently at different parts to attribute to thermo-regulation. Further, the thermo-sensitivity of the spinal code is mediated by the same sensory neurons that measure temperature of the skin.

In addition to the peripheral tissues, brain itself sends inputs to the thermo-regulatory system. The most sensitive site in the brain is the midline of POA, located between the anterior commissure and optic chiasm that when heated elicits dramatic and coordinated heat-defensive responses, such as panting, sweating, vasodilation, and cold-seeking behaviour. However, cooling has different actions such as vasoconstriction, BAT thermogenesis, and shivering. Additionally, brain can sense the increase in temperature, which provides POA a warmth sensation.

Role of endocrine system

Endocrine Response is the major regulators for animal adaptation by activating adrenal and thyroid gland. The stress induces changes in the pituitary hormone secretion which result in altered metabolism, immune competence and behavioural changes in the animal (Afsal et al., 2018). General endocrine responses to thermal stress include an increase in the concentration of glucocorticoids, adrenaline, and noradrenaline. The changes in catecholamine concentrations provide an index of the level of activation of the autonomic nervous system and reflect the initiation of brain pathways that are involved in maintaining the homeostasis.

The HPA axis gets activated when an animal receives stress through various sense organs and also response to the stimulus is coordinated by brain centre. Further, it might activate the adaptive responses pertaining to the neuro-endocrine system of the animals. The activation of the HPA axis may depends on the different direct and indirect factors. The corticotrophin-releasing hormone (CRH), adrenocorticotropic hormone (ACTH) and glucocorticoids are the primary products of HPA axis which ultimately controls the stress response pathways in animals (Herman et al., 2011). Further, the activation of HPA axis may result in enhanced production glucocorticoids like cortisol, which is indicated as the major stress-relieving hormone and also identified as a reliable biomarker for quantifying the severity of stress in animals (Angel et al., 2018). Also increased level of cortisol would favour hepatic gluconeogenesis which helps in the production of glucose from non-carbohydrate sources and maintains the energy metabolism to support life-sustaining activities. Moreover, their stimulation may be influenced by a wide variety of factors with respect to the individual animal and sex, age, and physiological stage (Palme, 2012). Application of non-invasive techniques for monitoring glucocorticoid metabolites in faecal samples is a useful tool for assessing the welfare of dairy animals. Another important endocrine product secreted from adrenal gland is the aldosterone which involves in the regulation of electrolyte mechanism in the animal. Moreover, the animals are exposed to thermal stress conditions would cause severe dehydration which might result in the activation of the renin-angiotensin-aldosterone pathway to restore the fluid and electrolyte balance. Similarly, the pineal gland is a neuro-endocrine transducer, which is responsible for the melatonin production and influences the seasonal changes pertaining to the reproductive capability in different animals. Finally, the significant effect of glucocorticoid on melatonin level during heat stress establishes adrenal-pineal gland relationship which was evident in the importance of menacing the animal productivity mainly in tropical countries. Understanding the characteristics of melatonin would assist in implementing a new methodology for the photoperiod-dependent breeding programme in animals by inducing changes in the perception of photoperiod and the annual pattern of reproduction. Similarly, the thyroid gland produces two types of hormones triiodothyronine (T_3) and thyroxine (T_4) which aid the regulation of metabolic activity in the animal. Also, the functions of thyroid glands are mainly dependent on the environmental condition the animals are exposed to. The changes in the ambient temperature suppresses the activity of thyroid hormone in blood level and also identified these hormones to be the stress indicators for assessing the heat tolerance in the farm animals. Generally, lower activity of the thyroid glands helps to reduce the metabolic energy expenditure of animals coping them to extreme environmental conditions. Similar results of inhibited thyroid hormone concentration level were also reported in various livestock species like cattle, sheep and goats were exposed to thermal stress. This could be an adaptive response shown by the animals to regulate the internal metabolic heat production without compromising the vital functions of the body. Further, the lower levels of the thyroid hormones could be partially attributed to the compromised nutritional status of the heat-stressed animal, which could be attributed to the lower feed intake associated with behavioural adaptive responses.

Conclusion

Neuro-endocrine response is the principal regulator of stress response in animals and it forms the basis for regulating and coordinating all other adaptive response in animals. The detailed discussions on various mechanisms and pathways associated with neuroendocrine regulation have identified several biological markers such as cortisol, T_3, T_4, epinephrine, and norepinephrine. Further, in-depth understanding of the hidden intricacies of neural and endocrine regulation of adaptive responses in animals provides the scope for intervening points to protect them against the adverse impact of climate change. However, breed differences established for the level of neuroendocrine responses in different animals. Understanding the plasticity of endocrine mediated changes in metabolism, within and between species, is critical for predicting how the animals are responding to different environmental stressors and this could help to identify the suitable management strategies.

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Climate Change and Dairy Cattle Production: Emerging Concepts and Technologies for Sustenance

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1. Introduction

While climate change is a global phenomenon, its negative impacts are felt more severely by poor people in developing countries, who rely heavily on the natural resource for their livelihoods. Rural poor communities depend a lot on agriculture and livestock for their survival. Further, animal agriculture is amongst the most climate-sensitive economic sectors in India. Dairy farming provides employment, sustainable income and social security to a large population across the globe.Climate change and global warming cause great threat to entire livestock population across the world. Impact of climatic extremes and seasonal fluctuations on herbage quality and quantity are considered as imperative source of influence on the well-being of livestock in extensive production systems. This can result in impairing reproduction and production efficiency of grazing animals. The extreme heat during summer months negatively impacts grazing animals, and is capable of inducing nutritional imbalances. In arid and semi-arid areas, livestock are often considered to be one of the most important means of food and economic security for poor and marginal farmers. Inadequate and low quality feed is a major factor in under-production of animals in arid and semi-arid tropical regions.Under-nutrition in livestock can occur in late spring and summer due to increased energy output for thermoregulation and concurrent reduction in energy intake. While understanding the science of animal nutrition continues to expand and develop, most of the world's livestock, particularly, ruminants in pastoral and extensive mixed systems in many developing countries, suffer from permanent or seasonal nutritional stress. This chapter is an attempt to collate information on new concepts that are emerging to assess dairy production and to highlights the various technologies available to improve livestock production under the changing climate scenario.

2. Climate change impact on dairy cattle production

Climate change can directly negatively influence growth, milk production, reproduction and meat production. Further, climate change can indirectly reduce livestock production through sudden disease occurrences. Climate change associated heat stress could negatively influence body weight and body condition score. Both the quantity and quality variables were affected with respect to both milk and meat production. Climate change associated environmental stressors could affect reproduction in both male and females resulting in reproductive failure. All these negative impacts could cause severe economic loss to the dairy farmers.

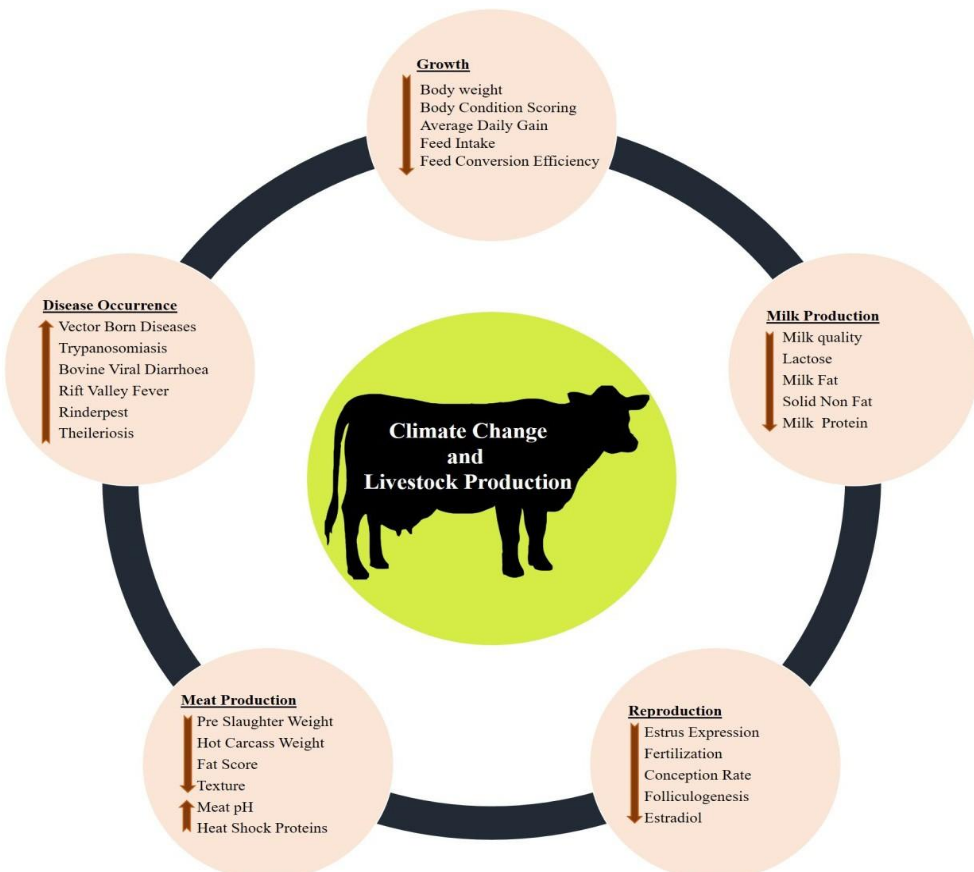

Fig.1. Various impacts of climate change on dairy cattle production (Source: Sejian et al., 2018)

3. Emerging concepts in climate change associated livestock production

3.1. Concept of multiple stresses impacting farm animals

In Indian context, mostly extensive system of livestock rearing is being practiced. In this system of livestock rearing, efforts were made only to quantify the impact of heat stress on livestock production. However, in the changing climate scenario apart from the usual suspect heat stress, there are numerous other environmental stresses which hamper livestock production. The projected climate change (CC) seriously hampers the pasture availability especially during the period of frequent drought in summer. Thus, livestock suffer from drastic nutrition deficiency. Both the quantity and the quality of the available pastures are affected during extreme environmental conditions. Further, with the changing climate, animals have to walk a long distance in search of pastures. This locomotory activity also put the livestock species under enormous stress. Hence in the changing climate scenario, it’s not only the heat stress that need to be counteracted but the nutrition and walking stress are also of great concern.

When exposed to one stress at a time, animals can effectively counter it based on their stored body reserves and without altering the productive functions. However, if they are exposed to more than one stress at a time, the summated effects of the different stressors might prove detrimental to these animals. Such a response is attributed to animal’s inability to cope with the combined effects of different stressors simultaneously. In such a case, the animal’s body reserves are not sufficient to effectively counter multiple environmental stressors. As a result their adaptive capabilities are hampered and the animals struggle to maintain normal homeothermy. Fig. 2 describes the concept of multiple stressors impacting livestock production.

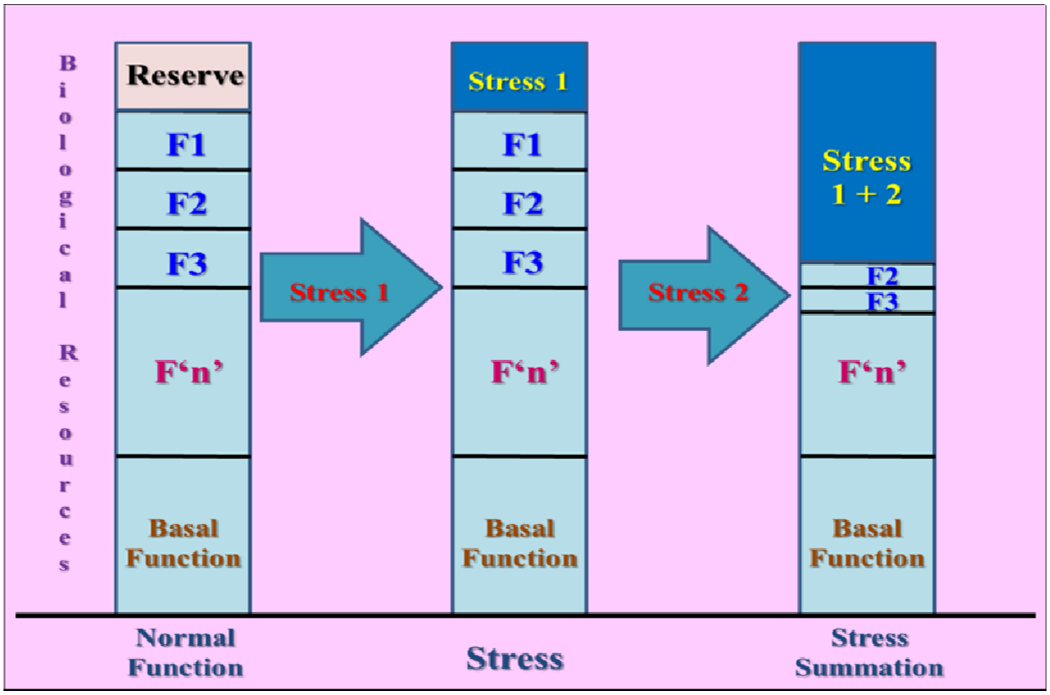

Fig.2. Pictorial representation of concept of multiple stressors on livestock production. If two or more stressors occur simultaneously, the total cost may have severe impact on biological function (Source: Sejian et al., 2012b)

3.2. Advanced thermal indices to quantify heat stress response

The THI was first used to assess the severity of heat stress in the dairy animals. The THI can be used as a forecast system to assess the possible threat or danger to the animals due to climatic variations. Currently, there are several THI indices that are in use to assess the quantum of heat stress in animals. However, THI has two drawbacks as it does not take into account solar radiation and wind speed, which are also considered important cardinal weather parameters, greatly influencing the animal response to heat stress challenges. This has brought the drive in the scientific community to develop advanced thermal indices to address these drawbacks of THI indices. Heat load index is developed as an improvement which overcomes the perceived deficiencies in the THI index. It uses a combination of black globe temperature, air movement and relative humidity. The HLI uses two equations based on the threshold value of black globe thermometer (Gaughan et al., 2008):

$HLI\ BG \geq 25 = 8{:}62 + (0.38 \times RH) + (1.55 \times BG) - (0.5 \times WS) + e^{(2.4 - WS)}$

$HLI\ BG < 25 = 10.66 + (0.28 \times RH) + (1.3 \times BG) - WS$

where BG is the black globe temperature in °C, RH the relative humidity in %, WS the wind speed in m/s and e the exponential. The HLI is an ideal indicator of the temperature status of the animal and it can explain 93% of the alterations in panting score (Gaughan et al., 2008). Further, the HLI considers the variation in the genotype whereas THI index does not.

3.3. Agro-ecological zone-specific breed identification

Sustaining livestock production in the changing climate scenario requires efforts to identify best indigenous breeds to survive in different agro-ecological zones. In series of studies conducted at ICAR-NIANP, three different indigenous breeds Osmanabadi breed from Karnataka, Malabari breed from Kerala and Salem Black breed from Tamil Nadu were compared for their climate resilience capacity. Based on several phenotypic and genotypic traits studied it was established that Salem Black breed was able to adapt and produce better as compared to Osmanabadi and Malabari breeds during heat stress exposure. The significantly lower respiration rate, rectal temperature and HSP70 gene expression in the Salem Black as compared to the Osmanabadi and Malabari groups exposed to heat stress indicate better resilient capacity of the Salem Black breed. Therefore, promoting the Salem Black breed among the local farmers may prove beneficial in improving their livelihood security.

3.4. Rumen microbes associaed adaptive potential through metagenomics approach

The ruminant animals and gut microbiota has evolved simultaneously while adapting to climatic and pastoral environments. The major component in ruminants playing a crucial role in their productivity is the rumen microbiome. This is characterized by its high population density, wide diversity and presence of myriad microbial interactions. The rumen microbial composition plays an indispensable role in ruminant physiology, nutrition, pathology and host immunity. Over the past few years, metagenomics has emerged as a powerful tool to study the rumen microbiome. Recent studies identifying rumen microbial community for novel enzymes, uncultured methanogens, and other metabolic pathways have opened new insights in this area. However, there are very few metagenomics studies conducted on heat stressed animals. This also is a potential area of research which could open up new pathways towards amelioration and mitigation of heat stress in farm animals. At ICAR-NIANP we organized a study involving heat stress influence on rumen microbial diversity. The study, being first of its kind, provides novel insights into influence of both genetic and environmental interaction on rumen microbial diversity at different taxonomic levels in goats during heat stress exposure.

3.5. Transcriptomics approach to elucidate the heat stress pathways

Heat stress has severe implications in livestock, affecting its production, economic returns and also from animal welfare point of view. In general, livestock species possess several adaptive mechanisms to combat the adversities of heat stress. This however varies between species, breeds and also among individuals. Assessing the functional pathways that have been altered in animals due to heat stress would enable to understand the molecular adaptive mechanism adopted by animals. This may also aid to identify thermo-tolerant animals/breeds which could be used for future breeding. One such study was conducted at ICAR-NIANP using transcriptomics approach to elucidate the different pathways associated with heat stress response in two indigenous goat breeds. The variations in the stress pathways altered between the two breeds, KanniAadu and Kodi Aadu shows an evident difference in the adaptive strategies adopted by these breeds to combat the adversities of heat stress.

4. Technologies to ameliorate heat stress in farm animals

The impact of hot conditions cannot be completely removed where animal production occurs in tropical and sub-tropical regions. However as knowledge regarding the impact of heat stress on biological functions advance, the alleviation methods become more sophisticated. Managing animals during heat stress is as much about the people as it is about the animals. There are several ameliorative strategies that should be given consideration to prevent economic losses due to environmental stresses. Reducing the impact of climatic stresses on livestock production requires multidisciplinary approaches which emphasize animal nutrition, housing, and animal health. With the implementation of management strategies, producers are able to reduce the impact of heat stress. Better management of livestock, may reduce the initiation of thermoregulatory mechanisms which allows for better energy utilisation for growth and/or production. In the face of climate change the continued development of heat stress management tools are needed to ensure the sustainability of animal based agricultural enterprises. Fig. 3 describes the various strategies to sustain livestock production in the changing climate scenario.

Fig.3 Various strategies to sustain livestock production in the changing climate scenario

5. Conclusion

Stress is continually imposed upon dairy cows to produce more and more milk. To maximize yield, it is imperative to keep cows as comfortable as possible and maintain feed intake for conversion into milk. Heat stress negatively affects cow comfort, dry matter intake and, subsequently, milk yield; thus, management strategies must be applied to counter hot/humid environmental conditions that can lead to mastitis, increased SCC and reduced milk quality. Control is based on provision of fresh, cool, clean drinking water, and increased energy density of rations and use of feed additives, as well as the use of cooling mechanisms including shade, fans, sprinklers, tunnel ventilation, commercial coolers and cooling ponds. Scientific research can help the livestock sector in the battle against climate change. Research must continue developing new techniques of cooling systems such as thermo-isolation, concentrating more than in the past on techniques requiring low energy expenditure. New indices that are more complete than THI to evaluate the climatic effects on each animal species must be developed and weather forecast reports must also be developed with these indices, to inform the farmers in advance. Above all to beat the climate change or in any case not to let the climate beat livestock systems, researchers must be very aware of technologies that are available to ameliorate the condition. Such efforts could help to sustain livestock production in the changing climate scenario.

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Impact of Heat Stress on Dairy Animals

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Climate change is one of the emerging and most important challenges facing the livestock worldwide. An increase in temperature by 0.2^{o}C per decade has been predicted by current climate models. Variation in climatic variables like temperature, humidity and radiations cause a potential risk in the growth and production of livestock. Among all stressors, heat stress is important as it reduces the productivity of the animals in subtropical and tropical regions. Homeotherms exhibit compensatory reactions to restore thermal balance when exposed to moderate climate change. The degree of resistance to climate change for maintaining core body temperature varies with species due to their differences in thermoregulatory mechanisms. When the heat load of the animal increases more than the normal capacity, a part of energy used for production will be deviated to maintain thermal balance

High ambient temperature coupled with increased air humidity causes extra discomfort and elevates the stress level of the animal. Effective evaporative heat loss through skin and lungs depends on the moisture content of air. Temperature humidity index represents a combined effect of air temperature and humidity which is associated with the level of thermal stress. It is used as an indicator of degree of thermal stress on animals. Temperature humidity index of 72 and below indicates absence of heat stress, 73-77 indicates mild thermal stress, 78-89 denotes moderate thermal stress and above 90 as severe heat stress.

One of the greatest challenges to production facing dairy farmers is heat stress and the strain that it causes the lactating dairy animals. Heat stress is chronic in nature, there is often little relief from the heat during the evening hours, and intense bursts of combined heat and humidity further depress performance. Lactating dairy animals create a large quantity of metabolic heat and accumulate additional heat from radiant energy. Heat production and accumulation, coupled with compromised cooling capability because of environmental conditions, causes heat load in the animal to increase to the point that body temperature rises, intake declines and ultimately the animal's productivity declines (West, 2003).

Under thermal stress, a number of physiological and behavioral responses vary in intensity and duration in relation to the animal genetic make-up and environmental factors through the integration of many organs and systems viz. behavioral, endocrine, cardio-respiratory and immune system (Altan*et al.*, 2003). The primary non-evaporative means of cooling (viz. conduction, convection and radiation) becomes less effective with rising ambient temperature and an animal becomes increasingly reliant upon sweating and panting to alleviate heat stress (Kimothi and Ghosh, 2005). Sweating, high respiration rate, vasodilation with increased blood flow to skin surface, high rectal temperature, reduced metabolic rate, decreased DM intake, efficiency of feed utilization and altered water metabolism are the physiologic responses that are associated with negative impacts of heat stress on production and reproduction in dairy animals (West, 1999). Further exposure to elevated temperatures and high temperature humidity index (THI) evokes a series of drastic changes in the animal's biological functions that include depression in feed intake; disturbances in metabolism of water; protein; energy and mineral; hormonal secretions; enzymatic reactions and blood metabolites. Such changes result in impairment of production and reproduction performances of the animals.

Impact of heat stress on Physiology of Dairy Animals

Heat stress effects health of dairy animals by affecting directly or indirectly the normal physiology, metabolism, endocrine and immune system.

Physiological response

Immediate response to climatic stress is reflected by physiological parameters like respiratory rate (RR), body temperature, skin temperature and heart rate. These parameters indicate the level of discomfort / comfort of animal (Bianca, 1965). These responses have been used as sensitive physiological parameters of environmental alterations or as indicator of comfort and adaptability to harsh environment (Roman-Ponce *et al*., 1977). The animal's ability to withstand the severity of climatic stress in warm conditions had been physiologically assessed by means of alteration in pulse rate (PR), respiratory rate and body temperature (Leagates *et al*., 1991).

Rectal temperature had been acknowledged as vital measure of physiological status and model indicator for appraisal of stress in animals (Lefcount *et al.,* 1986). When buffalo calves were subjected to 40.5^{o}C @ 8 h per day for three months, Joshi and Tripathy (1991) observed elevation in rectal temperature from 102.0^{o}F to 103^{o}F. They recorded an increase of 2.6^{o}C in rectal temperature, when buffalo calves were exposed to direct sunrays in the month of June and July. They opined that the rise in RT in heat stressed animals indicated disturbance of the homeothermic status of the animals due to failure in efficient heat loss by physical and physiological process of thermolysis.

Vaidya *et al*. (2010) assessed the effect of THI on the physiological parameters of Murrah and Karan Fries cattle. In both the species they recorded a significant increase in RT during summer (THI=85). Hamzaoui*et al*. (2013) evidenced a higher RT (+ 0.58^{o}C) in milking goats kept in climatic chamber (THI = 77 – 85) compared to comfort zone conditions (THI= 60 – 65).

Male buffalo claves exposed to temperature of 40.5^{o}C showed increased respiration rate from 29 to 59 per minute (Joshi and Tripathy, 1991). Respiratory rate could be used as an indicator of heat stress (Habeeb *et al*., 1992). Pulse rate reflects primarily the balance of circulation along with general metabolic status. The PR increased on exposure to high ambient temperature, due to accelerated blood flow from the body core to the periphery to enhance thermolysis by sensible and insensible means (Marai *et al*., 2007).

Feed intake and rumen physiology

Elevated environmental temperature reduces feed intake by directly inhibiting the feeding center in the hypothalamus. Feed intake begins to decline at air temperatures of 25-26°C in lactating cows and reduces more rapidly above 30°C in temperate climatic condition and at 40°C it may decline by as much as 40%, 22-35% in dairy goats or 8-10% in buffalo heifers (Das *et al.*, 2016). Reducing feed intake is a way to decrease heat production in warm environments as the heat increment of feeding is an important source of heat production in ruminants. Thus, negative energy balance is experienced by the animals. This leads to poor body weight and body condition score. Heat stress alters the rumen physiology, thus increases the risk of animal to metabolic disorders and health problems.

Nonaka *et al.* (2008) reported animal under heat stress had reduced acetate production while propionate and butyrate production increased as rumen function altered. This led to reduced roughage consumption, change in rumen microbiome, change in pH from 5.82 to 6.03, reduced rumen motility and rumination. Subsequently, affecting health by lowering saliva production, variation in digestion patterns and decreased dry matter intake.

Acid-base balance

Heat stress in animals increases respiratory rate and sweating which results in body fluid loss, thus elevating maintenance requirements to control dehydration and blood homeostasis. Increased respiratory rate may lead to respiratory alkalosis due to loss of carbon dioxide through lungs increases and blood carbonic acid concentration reduces. As a compensatory mechanism, the animals will increase urinary excretion of bicarbonates in order to maintain carbonic acid: bicarbonate ratio in blood. Chronic hyperthermia also causes severe or prolonged inappetence which further aggravates the increased supply of total carbonic acid in the rumen and decrease ruminal pH thereby, resulting into subclinical and acute rumen acidosis.

Immune system

The immune system is the major body defense systems to protect and cope against environmental stressors. Leukocyte's count increased by 21-26% and RBC count decrease by 12-20% in thermally stressed cattle that could be due to thyromo-lymphatic involution or destruction of erythrocytes (Das *et al.,* 2016). Heat stressed animals exhibited reduced hematocrit and hemoglobin levels, which could be due to increased attack of free radicals on erythrocyte membrane leading to hemolysis or reduced hemoglobin synthesis due to inadequate nutrient availability as a result of reduced feed intake (Srikandakumar and Johnson, 2004).

In heat stressed animals, down regulation or suppression of L-selection expression on the neutrophil is observed due to increased plasma level of cortisol. Poor L-selectin expression affects the phagocytic function of the neutrophils, thus increasing the risk of heat stress animals to infective diseases. Climate change may bring about substantial shifts in disease distribution and outbreaks of disease prevalence in previously unexposed animal populations possibly with the breakdown of endemic stability.

Cellular response

General response of cells to heat stress are inhibition of DNA synthesis, transcription, RNA processing and translation, inhibition of progression of the cell cycle, denaturation and aggregation of protein, increased degradation of protein through proteasomal and lysosomal pathways, disruption of cytoskeletal elements (microtubules, microfilaments and intermediate filaments) and changes in membrane permeability leading to accumulation of intracellular sodium, hydrogen and calcium ions.

Oxidative stress

Heat stress is one of the factors which cause ROS mediated oxidative stress in farm animals. Body employs antioxidants to quench these free radicals. Antioxidants fall in two broad categories-- enzymatic and non-enzymatic (Agarwal and Prabhakaran, 2005). The enzymatic antioxidants include superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx). These enzymatic antioxidants act by scavenging both intracellular and extracellular superoxide radicals and preventing lipid peroxidation of plasma membrane. Non-enzymatic antioxidants include vitamin C, A & E and proteins like albumin, transferrin and glutathione (GSH) and play important roles in combating oxidative stress

The major defense in detoxification of superoxide anion and hydrogen peroxide, are superoxide dismutase (SOD), catalase and glutathione peroxidase (GPx). SOD and catalase protect the cell from the damage due to the secondary generation of highly reactive hydroxyl group from superoxide ion to H_2O_2.

Lallawmkimi *et al.,* (2010) studied the effect of winter and summer seasons on antioxidant status of growing, heifer and lactating Murrah buffaloes and reported significantly higher SOD, catalase and GPx levels during summer compared to winter in all the three experimental groups. Kumar *et al.,* (2015) observed a significant positive correlation of THI with the erythrocyte catalase activity in Murrah buffalo. The increased production of H_2O_2 due to increased activity of SOD during heat stress resulted in a coordinated increase in GPx.

ROS status in animals is often determined using the Thiobarbituric Acid Reactive Substance (TBARS) assay that measures acetaldehyde generated from products of lipid peroxidation. The erythrocyte TBARS concentration increased in heat exposed cattle and buffalo (Kumar *et al.*, 2007).

Plasma protein

The level of blood parameters reflects the metabolic activities of animals. Serum albumin and total protein concentrations have been used as indices for nutritional status. Acute exposure of six months old Egyptian buffalo calves to elevated temperature of 33-43^{o}C and 40-60% RH induced significant reduction in plasma total protein by 14% (Nessim, 2004).

Endocrine response

Hormones in blood are important as a potential indicator of the physiological status of animal. Thyroid hormones played an important role in animal's adaptation to environmental alterations. The thyroid function declined as an acclimation response to reduce heat stress. The reduction might be due to effect of heat on hypothalamo-pituitary axis to reduce thyroid stimulating hormone which in turn enabled the animals to reduce basal metabolism (Johnson, 1987).

Thyroid hormones are important for acclimation, heat acclimation reduced the levels of T_3 and T_4 in an effort to reduce endogenous heat and well adapted animals showed this pattern (Horowitz, 2001). Thyroid hormones influence different cellular processes in the body. Their calorigenic activity accounts for around 50% of the basal metabolic rate of normal animals. Reduced levels of thyroid hormones in heat stress is an adaptive response and also it might be an attempt to decrease thermogenesis and metabolic rate (West, 2003).

Acute heat exposure to 33-43^{o}C and 40-60% RH induced significant decrease in plasma T_3 by 35.25% and T_4 by 17.59% in buffalo calves (Nessim, 2004). Wanker *et al.* (2014) observed a significant decline in T_3 and T_4 with increase in temperature from 25^{o}C to 40^{o}C in adult dry buffalo calves.

When animals were exposed to high ambient temperature, cortisol secreted by adrenal glands stimulated physiological changes in the body and enhanced the tolerance of the animal to stress. Cortisol significantly increased in animals exposed to high temperature and gradually declined during long-term exposure. The gradual reduction in cortisol level during chronic stress might be a result of animal's adaptation to acute thermal stress (Silanikove, 2000).

Concentrations of cortisol were altered in acute and chronic heat exposure, the levels elevated during acute stress and declined in chronic thermal stress. The initial rise was due to activation of adrenocorticotropin releasing mechanism of hypothalamus by activation of thermoreceptors of the skin. While decline in cortisol to normal levels during chronic stress, indicated a negative feedback and decrease in transcortin (Collier *et al*., 2008). When animals were exposed to heat stress, hypothalamo-pituitary-adrenal cortical axis (HPA) received signals from thermal receptors on skin and mediated hormonal changes (Minton, 1994). When young and old buffalo calves were subjected to acute heat (33-43^{o}C, 40-60% RH), their plasma cortisol concentrations were significantly elevated (Nessim, 2004).

The elevated response of cortisol levels to acute stress enhanced glucose formation, stimulated proteolysis and lipolysis, thus provided energy to animal to help alleviate the reduction in feed intake (Cunningham and Klein, 2007). They also suggested that cortisol act as a vasodilator to help dissipate heat from the body.

Impact of Heat stress on Production and Reproduction performance of Dairy Animals

Heat stress challenges the production and reproduction performance dairy animals. The milk production declines. Milk composition is also affected.

Milk yield and composition

Reduced milk production is the first perceived consequence of heat stress. Heat stress affects the productive performance of dairy animals by reducing their dry matter intake, feed efficiency and milk yield. Reduced feed intake during heat stress is the major reason for reduced milk production in dairy cows. The optimum environmental temperature for lactation depends on species, breed and degree of tolerance to heat or cold. The milk yield of Holstein cattle declines at temperature above 21°C, in case of Brown Swiss and Jersey cattle it declines at about 24 to 27°C whereas milk yield of Zebu cattle declines only above 34°C. At a temperature of 29° C and 40 % relative humidity the milk yield of Holstein, Jersey and Brown Swiss cows was 93, 97, and 98 % of normal, but when relative humidity was increased to 90 %, yields were 69, 75, and 83 %

of normal respectively (Berman, 2005). The stage of lactation determines the severity imposed by heat stress on the animals. Animals in mid lactation are more heat sensitive compared to early and late lactating animals.

Milk fat, solids not fat and milk protein percentage decreased by 39.7, 18.9 and 16.9% respectively (Kadzere *et al.,* 2002). Milk fat and protein content declines when THI goes beyond 72. Analysis of protein fraction revealed a reduction in casein, lactalbumin, Immunoglobulins G and A. Continual genetic selection for greater performance results to increased heat stress sensitivity and decreased trend in lactating curve and milk quality in dairy animals during summer.

Animal reproduction

It is reported that the heat stress reduces length and intensity of estrous period therefore less conception rate occurs. So heat stress may reduce the fertility of dairy cows in summer by poor expression of behavioural signs of oestrus due to a reduced estradiol secretion from the dominant follicle. In these situations, the calving interval becomes longer. So lifetime production of dairy animal comes down. Heat stress during pregnancy slows down growth of the foetus due to decreased blood supply to the uterus which causes placental insufficiency to provide maternal nutrient, so leads to decreased fetal growth and calf size. Even there is early embryonic death in cows exposed to heat stress. Heat stress also leads to reduced seminal volume and sperm concentration. It is reported that ejaculate volume, concentration of spermatozoa and sperm motility in bulls are lower in summer than in winter season.

Impact of heat stress on disease incidence

It is reported that increased milk somatic cell counts and a high incidence of clinical mastitis in dairy cattle occur during hot summer months. Reduction of thermal stress by air conditioning or shade management resulted in a lower frequency of clinical mastitis in cows than those exposed to their natural environments. Singh *et al.* (1996) reported higher incidence of clinical mastitis in dairy animals during hot and humid weather due to increased heat stress and greater fly population associated with hot–humid conditions. Kumar *et al.* (2004) reported that the hot–humid weather conditions were found to aggravate the infestation of cattle ticks which act as vector for various protozoan diseases

Conclusion:

In terms of adaptation measures, it is generally faster to improve welfare, production and reproduction performances of animals by altering their microenvironment. Despite its importance, there are few effective strategies for reducing the effects of heat stress on animal's health and performance. The major strategies providing elaborate housing involving shade, sprinklers, fans, air conditioner etc. are capital intensive, not very efficient and is of limited use for small and medium size dairies. Nutritional management and genetic development of thermotolerance breeds along with manipulation of microenvironment are key components for sustainable livestock production in hot tropical climate.

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Impact of climate change on Milk Productivity of Bovines

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Dairying is an important enterprise for many countries of the world and is especially important source of income generation for rural families. The demand for milk increases with rise in population (Hammami et al., 2009; Tollens et al., 2004). With global population growth rate of 1.2 to 1.3 percent per year means 75-80 million more people each year. Using the world average per capita milk consumption, the increase in milk consumption of 7-9 million tons per year. The expression of the inherit genetics merit varies from one environmental condition to another and is greatly influenced by non-genetic factors (Javed et al., 2002; Das et al., 2003). The performances of temperate genotype in tropical conditions are 30-40% lower than that of the countries of their origin. Environment and genetic interaction play an important role in the expression of the full genetic potential (Misztal et al., 2002; Rivas, 2006; Scholtz et al., 2010). Seasonal heat stress effect on milk production, fertility and reproduction of dairy cattle is worldwide and causing heavy economic loses to the dairy industry (Wolfenson et al., 2000).

Climate Change and Milk Production:

Climate change has indicated a 1.5°C increase in global temperature, with projected rises expected to range from 0.3 to 4.8°C by the end of the twenty-first century (IPCC 2014; 2014a; 2018). It's surprising to know that the first decade of the twenty-first century (2000-2009) was hotter than every other decade in the previous 1300 years. According to available data, the year 2016 was the hottest year. By 2050, the United Nations predicts a massive rise in global population (UN 2013) so the food industry is under tremendous pressure to supply and a balance must be established between production, animal health and the environment. Ensuring food security at the national level is therefore a high priority. The issue is especially important because it provides the link between production and availability of milk on the one hand and potential use on the other hand. It is a primary objective in the livelihoods and aspirations of farmers should be able to produce milk for the growing demand, and provide for a better tomorrow. Developing countries may experience a decline of between 9 and 21 % in overall potential agricultural productivity as a result of global warming at the world level. The anticipated rise in temperature between 2.3 and 4.8°Cover the entire country together with increased precipitation resulting from climate change is likely to aggravate the heat stress in dairy animals (Nardone et al. 2010). High producing dairy cows suffer from metabolic exhaustion, making them more susceptible to heat stress (Kilgannon and Eid 2018).

Climate variability in India:

The climate of India is mainly dominated by the high temperature (April to September). The whole year can be divided into four seasons based on the similar meteorological conditions viz. (i) Winter season (January and February) (ii) Hot weather season (March to May) (iii) Hot humid season (June - September) (iv) Post monsoon season (October to December). Year to year deviations in the weather and occurrence of climatic anomalies / extremes in respect of these four seasons are:

(i) Cold wave, fog, snowstorms and avalanches
(ii) Hailstorm, thunderstorm and dust storms
(iii) Heat wave
(iv) Tropical cyclones and tidal waves
(v) Floods, heavy rain and landslides
(vi) Droughts

The cold and heat waves are the major threats to the livestock productivity in different parts of India. After 2000, heat waves further intensified in different parts of India. According to the Glossary of Meteorology (AMS, 1989) heat wave is "a period of abnormally uncomfortable hot and usually humid weather of at least one day duration, but conventionally lasting several days to several weeks". An operational definition often used for a heat wave is three to five successive days with maximum temperatures above a threshold. Cold wave/ wind chill are the apparent temperature felt on the exposed animal's body owing to the combination of temperature and wind speed. As wind velocity increases, heat is carried away from the animal's body at a faster rate, driving down both the skin temperature and eventually the internal body temperature below their normal temperature and to a state of hypothermia. According to modeling and other studies, increased global anthropogenic emissions may result over India for the 21st century-

According to the IPCC, annual mean surface temperatures will increase by 3 to 5°C (A2 scenario) and 2.5 to 4°C (B2 scenario) by the end of this century. Simulation studies conducted by the Indian Institute of Tropical Meteorology (IITM) in Pune, warming will be more pronounced in northern India. The Indian summer monsoon is the product of interactions between land, sea and atmosphere. Simulation of the Indian summer monsoon mean pattern as well as variability on an inter-annual and intra-seasonal scale has been a challenging problem. According to some simulations conducted by the IITM in Pune, summer monsoon intensity may increase starting in 2040 and by 10% by 2100 under the IPCC's A2 scenario.

An expected deficit of 65 percent of green fodder and 25 percent of dry fodder is expected for Indian livestock by 2025 (Singh, et al., 2013). In 1987 drought in India, affecting over 168 million cattle due to a lack of feed and fodder, as well as severe water shortages. Before the next year's rains, 18 million cattle out of 34 million were confirmed to have died in Gujarat, one of the worst-affected states. The 34.5 million cattle were affected by drought in the arid state of Rajasthan in the north-western part of the country, which is extremely drought-prone. Drought damaged total 7.8 million hectares of crop land in the state which leads to dropped in fodder availability from 144 to 127 million tons.

Climate change can be a chronic stressor for dairy cattle because they usually stand outside during most of the year. Cold, heat, humidity, rain, ice, and wind are all stressors that affect the reproductive and endocrine systems. Heat stress is one of the well-studied climatic stressors. Heat and cold stress have different effects, despite the fact that they are linked by temperature, and the effects of each vary depending on season, latitude, and strength. When animals are subjected to adverse climatic conditions, they gradually build up excess heat and exhibit symptoms such as decreased feed intake, nutrient consumption, and ruminal disorders (Marchesini et al. 2018). Physiological and metabolic acclimatisation to heat stress can take long duration, resulting in decreased growth and production losses (St. Pierre et al. 2003; Thornton et al. 2009).

For homeostatic functions, animals constantly collect and process external and internal information (Nakamura and Morrison 2008). These mechanisms differ among and between the species, but they all need a stable internal environment for growth and development (Collier and Gebremedhin 2015). The homeorhetic responses of animals are challenged and altered when they are exposed to high ambient temperatures, humidity, or both (THI), solar radiation, and heat waves. Heat stress syndrome develops when animals are unable to lose excess metabolic heat by various heat loss mechanisms (conduction, convection, radiation, and evaporative cooling) (Collier et al. 2019).

Environmental conditions will vary depending on the geographical locations, but the effect on the tropics and subtropics may be significant (Nardone et al. 2010; Reynolds et al. 2010). Climate change will have direct and indirect effects on livestock production, soil productivity, pasture supply, crop yield, water quality and quantity, vectors, pathogens, and parasites, as well as vectors, pathogens, and parasites (Thornton et al. 2009; Nardone et al. 2010; Garnett 2009; Reynolds et al. 2010).

Table: Average ambient temperature of different district and milk production: -

Name of the district	Avg. temperature (in °C)	Avg. milk production of cross breeds (in Lit.)
Jaipur	25.17	5.45
Lucknow	25.01	4.00
Ludiyana	23.50	7.58
Ambala	23.45	6.44
Bhopal	24.85	6.01
Patna	25.58	3.50
Jodhpur	27.09	3.27
Chennai	28.27	4.65
Kolkata	26.98	5.48
Hyderabad	26.10	4.86
Nagpur	26.85	3.29
Mangalore	29.74	3.8
Cuttack	27.72	3.15
Ananthpur	28.61	3.21
Tiruvanthapuram	27.10	5.65
Ranchi	24.33	6.00
Guwahati	24.21	5.85

Bangalore	23.80	6.34
Aurangabad	25.04	3.78
Agartala	24.86	5.50

Source: -*Indian Meteorological Department and Directorate of Animal Husbandry (2016)*

Factors which determine the severity of heat stress: -

1) Temperature & Humidity: Directly affects the heat stress

2) Size of animal: Smaller is the size larger will be the body surface of skin & more will be number of the sweat glands per unit of body weight and less will be the heat stress.

3) Ventilation: It provides provision of fresh air and displaces contaminated & warm air with the surrounding.

4) Hair coat: Long hair length and dark colored hair are more susceptible to heat stress compared to small and lightcolored hair.

5) Water Availability: Water intake has cooling effect on the animal body.

6) Housing: Exhaust fan, water sprinkler, shade, Ad libitum water decrease the surrounding temperature of animal.

7) Breed: Indigenous breeds has more heat tolerance and resistance power compared to exotic breeds.

8) Skin Color: Melanin pigment is responsible for color of the skin. Dark color skin has more heat tolerance level.

Responses of animal to heat stress

- Increase in body temperature above 102.6ºF
- Increase in respiration Rate (>80 breath per min)
- Reduce activity
- 10-15% reduction in Feed intake
- 10-20% reduction in Milk yield
- Increased in peripheral blood flow and sweating
- Reduced fertility rate in both male and female animals
- Increased mortality rate

Impact of temperature humidity index (THI) and global warming:

Temperature humidity index (THI) is a very useful tool to measure heat tolerance of bovine species. Preez et al. (1990) and Johnson (1976) reported that milk production is not affected by heat stress when mean THI values are up to 72. Whereas the milk production and feed intake begin to decline when THI reaches 72 and continue to decline sharply at a THI value exceeds 76 (Molee et al., 2011). Per unit increase in the THI above 72 causes decrease in milk yield by 0.2kg (Noordhuizen*et. al.*, 2015).

Table: Classification of level of heat stress based on THI values

S. No.	Range of THI	Level of Heat Stress	References
1	<72 72-75 79-88 89-98 >98	Comfortable Mild Stress Moderate Stress Severe Stress Death	Armstrong, (1994)
2	<72 72-75 79-88 89-98 >98	Comfortable Mild Stress Moderate Stress Severe Stress Death	Moran,(2005)
3	<70 70-72 72-78 78-82 >82	No stress situation State of alert Critical state Dangerous state State of emergency	Costa et al., (2015)
4	56.71-73.21 75.39-81.60 80.27-81.60	Normal Stress Critical	Dash et al., (2016)

Effect of long term and extreme events on milk production in India:

There is normally a decrease in milk production for cattle/ buffaloes under heat stress (Singh and Upadhyay, 2008; 2009). This decrease can be either transitory or long-term depending on the length and severity of heat stress. The decrease in milk production can range from 10 to >25% (Upadhyay et al., 2009a). The negative impact of temperature rise due to global warming on total milk production for India has been estimated about more than 15 million tons in 2050. Animals with limited water access will experience warming effect more than that of buffaloes dissipating heat by water wallowing (Upadhyay et al., 2009). A sudden rise in Tmax during summer and a fall in Tmin cause a negative impact on milk yield of cattle. The increase in

Tmax (>4 □) than normal during summer and decline in Tmin (>3 □c) during winter was observed to impact the milk production negatively in crossbred cattle and buffaloes. The decline in yield varied from 10-30% in first lactation and 5-20% in second and/ or third lactation. The extent of decline in milk yield was less at mid lactation than either late or early stage. The negative impact of sudden temperature changes,i.e., cold wave or heat wave on milk yield of cattle/buffaloes were not only observed on next day of extreme event but also on the subsequent day (s) after extreme event, thereby indicating that Tmax increase during summer and Tmin decrease during winter cause short to long term cumulative effect on milk production of cattle and buffaloes. The return to normal milk yield took 2-5 days with a variable response. The decline in milk yield and return to normal yield after and extreme event was also dependent on subsequent day (s) Tmax and Tmin. The lactation period of buffaloes were shortened by several days (3-7) during extreme summer when THI was more than 80. The expressions of estrus and reproductive functions were also negatively impacted. Excessively distressed buffaloes with higher rectal temperature (more than 40°C) did not exhibit estrus or exhibited estrus symptoms for short duration that often remained undetected (Upadhyay et al., 2009).

Table: Influence of heat stress on milk yield of cattle and buffaloes

Increase	Decrease milk	References	Breed
Each value THI	0.020 to 0.29 Kg	Behera et al., 2018	Buffalo
	0.16lit./d/animal	Singh and Upadhyay (2008)	Sahiwal cow
	0.43lit./d/animal	Singh and Upadhyay (2008)	Karan Fries
Temperature			
From 20-30^{o}C	9%	Marai and Habeeb,2010	Buffalo
Average temperature above 21^{o}C			
1.6^{o}C	4.50%	Marai and Habeeb, 2010	Buffalo
3.2^{o}C	6.80%		
8.8^{o}C	14%		
THI above 69			
Each unit THI	0.41 Kg	Bouraoui et al., 2002	HF Cow
Each unit THI	0.41 Kg	Spires et al., 2004	HF Cow
THI above 72			

Each unit THI	0.2 Kg	Hill and Wall, 2015	HF Cow
Each unit THI	0.2 to 0.32 Kg	Ravagnolo et al., 2000	HF Cow

Mitigation strategies to overcome the effects of climate change:

Since climate change could result in an increase of heat stress, all methods to help animals cope with or at least alleviate the impacts of heat stress could be useful to mitigate the impacts of global climate change on animal responses and performance. Three basic managemental tools/ schemes for reducing the effect of thermal stress have been suggested (Kumar et al., 2009):

- Physical modification of the environment
- Development of genetically less sensitive breeds and
- Improved nutritional and managemental practices.

Physical modification of the environment:

The methods for microenvironment modification include: shades, ventilation, combination of wetting and ventilation. Shades are the simplest method to reduce the impact of high solar radiation/ climate change. Shades provide a cooling effect to animals by protecting them from direct sunlight. These shades may be naturally either in the form of trees or manmade rooftops. Trees shades provide cooling as moisture evaporates from the leaves (Da silva, 2004). Shades can help dairy animals in reducing heat stress and physiological responses (Singh and Upadhyay, 2008; 2009). During the afternoon, the protected animals have lower physiological responses (RR, PR, RT, and ST) and produce more milk and protein (Singh and Upadhyay, 2009). For relief from heat stress, proper ventilation in a shelter is essential, if possible, natural ventilation should be maximised by building open-sided structures (Bucklin et al., 1992). The use of fans to provide forced ventilation is a very efficient way to lower the temperature (Kumar et al., 2009). Spray evaporative cooling is a good way to keep cool dairy cattle and buffaloes. Mist, foggers, and sprinkling systems are the available cooling devices. However, using a sprinkling and fan system for 30 minutes before milking has been shown to be effective in relieving dairy animals from heat stress and reducing the effects of heat waves in grazing systems (Valtorta et al., 2002).

Feeding strategies:

- Increase number of feedings/day particularly during morning, afternoon and night hours i.e. feeding during cooler hours to reduce SDA of feeds.
- Maintain energy intake with decreased dry matter intake.
- Increase dietary protein density to compensate lower intake.
- Increase dietary mineral concentration (Na, K etc.).
- Ratio / balance of cations (Na & K) and anions (Cl & S) are also important.
- Feeding Total Mixed Ration (TMR) should be preferred over component or separate ingredient feeding.
- Well-balanced TMR- diet formulation at optimum fibre level- encourages DMI; minimize rumen fermentation fluctuation & pH declines.

Supplementation of antioxidants:

Several studies have been conducted at NDRI, Karnal, to alleviate the negative effects of thermal stress and the findings are presented here. Vitamin E supplementation improved levels of a-tocopherol and lowering levels of thermal stress markers such as HSP72 mRNA expression in lymphocytes and antioxidant enzymes (SOD and CAT) in the blood of heifers, and lactating murrah buffaloes during the summer and winter seasons.The experimental group of lactating buffaloes produced more milk than the control group further demonstrated the beneficial effect of vitamin E supplementation during climatic extremes (Lallawmkimi et. al., 2013). Ganaie et al. (2013) showed the beneficial effect of vitamin C feeding to primiparous Murrah buffaloes during summer season. The results indicated that the deviations in immune status and oxidative stress caused due to thermal stress restored towards normalcy by supplementation of vitamin C. Kumar et al. (2013) supplemented chromium to Sahiwal cows during the summer and winter seasons. Chromium supplementation improved immunity and growth efficiency compared to the control group.

Additional means of reducing heat stress effects:

- Selective crossbreeding- The indigenous breeds of cattle which are more heat tolerant due to more sweat gland density should be given more preference over less heat tolerant temperate breed of cattle.
- Selection of heat tolerant animals with in breed for future breeding programmes.

Conclusions:

The effects of global warming are expected to be more disastrous in the tropics in the near future thus it is suggested to devise an optimized model balancing genetic components to environmental stress factors for selection. It is necessary to select animals not only for their production genetic merit but also for their resistance to environmental and physiological stresses in tropical and subtropical areas, To avoid this mishap, an integrated approach involving improved cooling capacity, efficient nutrition formulation, and assisted techniques such as proxy indicators for adaptability, quantitative trait loci (QTL), gene chip, and marker assisted selection is expected to increase production as well as their adaptability under temperate and tropical environmental conditions.

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Thermo tolerance and adaptive behaviour in dairy cattle

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Introduction

India, in terms of dairy production has very broad economic and social dimensions. Dairy production is worth noting in order to achieve the change in socio-economic status and also improved income in our country. India accounts for about 19% of global milk production and continuously ranking first overall with the production of around 198.4 million metric tons. This shows a per capita availability of about 407 grams per day. According to DAHD & F (2018-2019), the milk yield (Kg/day) of indigenous cows is 3.73, exotic cows is 11.48, non-descript cow is 2.41, crossbred cows is 7.61, indigenous buffalo is 6.19, goat is 0.47.Dairying is taken up by rural households of around 73 million mainly include poor and landless farmers. Rural households take dairying because of two main factors which includes low capital investment and there is a steady return to lead their livelihood. It generates self- employment for the rural masses (DAHD & F 2018-19).

Climate change impact on dairy production

Climate change is posing a serious threat for livestock sector development in India. Among all climatic variables, high ambient temperature is considered to be most detrimental in animals. The temperature rise between 2.3 and 4.8 °C with increasing precipitation more likely to results in aggravating the heat stress majorly in case of dairy animals. There is increasing demand for milk nowadays and hence there is increased concern about global climate change which causes heat stress in dairy animals and decrease milk production. By 2050, global warming will further causes threat in the production of milk about 15 million tons. Indigenous cattle least affected in case of climate change when compared to that of high producing crossbred and exotic. The impact of heat stress in dairy cattle includes the decrease in milk yield, decreased appetite, feed consumption is reduced and NEFA reduction in blood which in turn decreases the glucose supply in mammary gland. During the exposure to high ambient temperature, there is decrease in DMI which also accounts for decreased milk production as a thermo regulatory protective mechanism.

Heat tolerance in dairy cattle

Heat tolerance, known to resist the heat stress in animals which is considered to be of great economic importance especially in case of dairy cattle (Sánchez *et al.*, 2009). Heat tolerance refers to the ability of the animal to tolerate heat while all other condition remains constant. In order to counteract the effects of increased ambient temperature beyond the range of thermo neutral zone, dairy cattle ensure the tolerance to heat stress which is considered as an adaptive process (Saizi*et al.*, 2019). It is very important in considering the increase in ambient temperature and also increased productivity which might further elvate the stress in dairy animals. The dairy cattle production is increased with the lowering of THI and the cattle which are less sensitive to high ambient temperature are considered to be tolerant to heat (Bernabucci *et al.*, 2014). Environment influences the sensitivity to heat stress than any other factors. Nguyen *et al*. (2016) stated that as there is rise in THI, the dairy cattle which is beyond the comfort zone, there are various heat tolerance expressed by the animal which includes the decrease in fat, milk and protein.

Importance of tolerance to heat stress

Polsky and von Keyserlingk (2017) stated that heat stress is one of the critical problems facing the dairy industries worldwide as it affects the dairy cattle drastically. Dairy cows would be subjected to more heat stress as a result of climate change. (Gauly*et al.*, 2013). In tropics and sub tropics during summer heat load is more (Ammer*et al.*, 2016). Heat stress can result in decrease in productivity, performance and severe heat stress can cause the death of the animal. Segnalini*et al.* (2013) emphasised the use of effective adaptation methods to help dairy cows cope with the symptoms of heat stress. Bernabucci *et al*. (2010) mentioned that high producing cattle may face heat stress even in normal environmental temperature which increases basal metabolic heat production. The degree of the reduction in milk yield as the THI rises above the comfort threshold can be used to determine the heat tolerance level. (Nguyen *et al*., 2017). The recognition of tolerance to heat stress is necessary as it impacts on food supply and food security. Heat stress has a detrimental impact on farm production, putting the market food supply chain in danger. (Bernabucci *et al.*, 2010).

Adaptation in dairy cattle

Generally animal possess many adaptive mechanisms in order to cope with the changes in the surrounding climate. Adaptations in animals are usually determined by physiological, anatomical, biochemical, morphological and behavioural responses of the animals which make their survival in a particular environment. Resilience is considered to be the one of many measures of sustainability. Resilience means the extent to which a change can occur in a system but it still retains its own structure while stabilising the options that can be developed (Walker et al 2002). The resilience concept includes four components; resistance, vulnerability, connectedness and adaptability.

a) Physiological adaptation

The dairy cattle exhibit various physiological adaptation mechanisms in order to cope up the changing adverse climate condition around the world. The physiological determinants that are involved in the adaptations of heat stress includes respiration rate (RR), skin temperature (ST), sweating rate (SR), pulse rate (PR) and rectal temperature (RT) (Indu et al 2015). Respiration rate which is a means of evaporative heat loss is known to be the ideal biomarkers in case of heat stress (Indu et al 2015). Circulation and metabolic status can be assessed by PR in homeostasis. Cardiovascular and respiratory system is usually influenced by high ambient temperature and humidity along with season and timings of a day (Marai et al 2007). Rectal temperature depicts the core body temperature in a heat stressed animals. The evaporative cooling mechanisms through cutaneous means are brought by increased sweating rate. Every species has its own thermo neutral zone and exposure to high temperature may cause body temperature rise from its thermo neutral zone. Sensitivity of the animals to the upper critical temperature (UCT) has been established that even 1 ºC rise in body temperature (from UCT) can easily bring down the production status of dairy cattle (McManus et al 2009). Thus, the physiological traits help the animals to adjust with the extreme climatic condition. While doing that the productive capacity of livestock are being compromised mostly for maintaining the proper supply of energy for carrying out the important physiological functions of the body (Samad et al., 2019; Aleena et al 2017).

b) Metabolic adaptation

Metabolic fluctuations in heat stressed dairy cows ultimately results in reduced growth, reproduction and milk production. (Alameen et al., 2012;Nardone et al 2010). This is because of feed intake reduction in case of heat stressed cattle. Protein and energy metabolism affected negatively by excess heat (Koch et al 2016; Yan et al 2016). This reduction in both growth rate and milk production found to result in low metabolic rates (Cardoso et al 2015). Dietary energy together with heat stress influences the energy metabolism in cows. Yan et al (2016) mentioned that the dietary energy is way more partitioned in order for the maintaining the body and very less energy are being channelized towards production traits. There is modification in feeding pattern in dairy herd in order to counter act heat (Hammami et al 2015). High milk-producing dairy cattle are prone to the impacts of heat stress more when exposed them to high ambient temperature. Metabolic adaptation to heat stress also includes an alteration in the post-absorptive metabolism apart from the decreased energy expenditure. Nutrient partitioning shifts and favours the reduction of heat produced endogenously (Koch et al 2016). Bernabucci et al (2010) mentioned that high ambient temperature necessitates a metabolic response. Metabolic responsiveness differs between lactating cows and late pregnant cows and also between lactating stages. In case of early lactating cows which is under heat stress, adaptation mechanisms involve the change in the substrate utilization for energy along with decreased heat production (Koch et al 2016). Further, gluconeogenesis and glycogenolysis are increased in order to supply more glucose which is used for production of milk (Loor et al 2005). The production of heat from fatty acids reduced and there is a shift towards glucose metabolism in the production of energy in lactating cows experiencing heat stress (Koch et al 2016).

c) Behavioral adaptation

Dairy cows show behavioral responses when introduced to high environmental temperature to maintain homeostasis. (Polsky and von Keyserlingk., 2017). Dairy cattle prefer to stand in shade, standing period increases, also times spend around water troughs increases (Schütz et al., 2010). Dairy cattle spend a lot of time in the shade and this lowers feed intake in standing condition, and reduced feed intake helps to decrease metabolic heat generation. The increase in heat generated by ruminant feeding is a significant source of heat generation. (Kadzere et al., 2002). Cows that are not shaded have a higher response and use more behavioural coping mechanisms than cows that are shaded. During summer cow alter their grazing behavior as they shift this to cooler time of the day (Gauly et al 2013). Also when heat stressed and have a high respiratory rate, dairy cows that are more resistant of heat stress prefer to graze for longer periods of time. (Pereira et al 2014).

d) Genetic adaptation

The genetic ability of an organism is considered to be of key component in case of adaptation which will make the animal survive under stressful situations. Genetic selection is used for breeding climate-adaptive ruminants for sustainable livestock production. Genetic adaptation is generally a slow process which is subject to ever-changing biological, geological and climatic conditions (Dobzhansky 1970). Fitness and adaptation influence genetic mechanisms. There is a low heritability when it comes to adaptation traits in cattle. The genetic adaptive behaviour of Indian cattle is mainly because of lower metabolic rate and increased heat loss capacity. Genetic selection in Bos indicus is done based on their fall in fasting metabolism and growth rate under normal condition (Frisch et al., 2010). The presence of gene variation that is related to hair and skin characteristics, immune responses, cellular response, systemic response and tick tolerance have also been referred in many genomic studies. Given recent developments in genomics, selecting for HT in high milk-producing dairy breeds and applying it into breeding programmes may be equally useful in preventing the detrimental correlation between HT and performance traits and delivering faster outcomes.

Conclusion

Heat stress has become a major problem for dairy producers because of the associated low milk production and huge economic losses. Increase in temperature because of climate change worsened the after effects of heat stress in the dairy herd. Cows alter their physiological state to maintain homeostasis to decrease the heat load. Early prediction of heat stress related risk provides reduction in detrimental effect of the dairy cattle's health. Heat stress in cows may be identified by apparent clinical symptoms that occur in conjunction with elevated air temperatures and established relative humidity levels. It is more important to keep the air temperature is maintained at a constant level, or to have sufficient long rest periods in lower temperatures with an effectively working ventilation system placed above the cows to cool them, using quality ventilation air or wind speed, than it is to keep the air temperature at a constant level for dairy cattle's health and efficiency. The THI value, as well as the values of other indices, is typically the significant factor in determining how to predicting heat stress. THI calculations are used for measuring risk factors for cows are also inaccurate since they only include factors that influence the microclimate. Within herds and across regions, there is difference in responding to heat stress, indicating that some cows are more suited to high temperatures than others. However, in order to maintain good wellbeing standards for dairy cattle, a wider strategy is needed, which recognizes the value of considering how heat stress will lead to negative affective states and that heat reduction solutions should, where possible, take into account cows' natural adjustments to aversive factors.

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Microclimate Manipulations in Dairy Farms

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Along with the stock, housing forms a major investment in dairy business and hence needs scrupulous design aimed at cost reduction without compromising animal comfort and management easiness. Proper housing design is important for dairy cattle and the personnel involved. Housing needs of the animal depends on physiological, physical and behavioral factors of animal and human factor including labour. Suitable stress ameliorative interventions for cattle and buffaloe are important. The ruminants increase greenhouse gas levels in the atmosphere, so the provision to mitigate methane should also be established. In India, a great diversity exists in the design of dairy animal shelters. Efficiently designed sheds can help lessen the thermal stress thereby increasing feed intake, milk production and reproductive efficiency. Loose housing and Conventional barns are two major systems of housing for dairy animals. In loose housing cattle are kept loose in an open paddock throughout the day and night except at the time of milking and treatment. This provides more avenues for natural behavioural expression. Shelter provided at the side of paddock for cows to retire during rains and sun. In paddock and shelter common automated water trough should be provided. An environmental aspect of housing the farm animals not only has a long history but is necessarily multi-disciplinary. An understanding of needs of the animal can be derived from physiological, physical and behavioural studies and these may need to overlap with meteorological data and economic considerations. The design of suitable ameliorative interventions draws on information and principles from the applied physical disciplines such as engineering (Clark, 1972)

According to Yousef (1984), many large gaps remain to be bridged but important accomplishments have been made to ameliorate environmental impacts in improving livestock in the regions where climatic stress prevail for a significant part of the year. The use of flip- fan system combined with shade to create a cooler and more uniform microclimate compared with conventional and stationary fans, misters, and shade undoubtedly proves that technology is fast advancing in this area (Anderson et al., 2013). So, stress evaluation and efficacy of ameliorative interventions are extremely relevant in today's context.

As stated by Nienaber et al., (1999). Ravagnolo et al., (2000) the maximum temperature and humidity were the most critical variables to quantify heat stress, and both variables were easily combined into temperature humidity index which can thus be used to estimate the effects of heat stress on production

An automated THI based controller with multiple relays could help the livestock in reducing the thermal stress an there by improve productivity.High producing dairy cattle reared intensively in hot regions of the world require combined effect of two or more different ameliorative methods combined scientifically to optimise the strategy to keep animals core boy temperature constant. Thermal stress is a major constraint in realizing true genetic potential of high milk producing cattle in the hot regions of the world. The severity of various thermal stress factors varies spatially and temporally. Various management strategies are used to ameliorate thermal stress in dairy cattle. Direct cooling of the animal and indirect cooling by reducing the effective thermal load inside the shed are the most effective among these strategies due to its immediate and easily measurable effect. Sprinkling water, forced ventilation and roof wetting etc. are some of the measures commonly being practiced in many medium to large dairy farms. But the unpredictable and dynamic nature of the weather situation makes it difficult for the farmers/managers to find out the optimum time and duration of ameliorative measures required for their livestock. Simple timers with temperature cut-offs does not take humidity factor into consideration, whereas in real situation the thermal stress is a function of effective thermal load contributed by many weather parameters. More over such timers controlled only one relay. The effective thermal load is represented by various indices, of which the THI (Temperature Humidity Index) which takes in to account the temperature and humidity is a practically useful index in dairy cattle discomfort. So, a THI based automatic controller (ASWASA) which controls direct and indirect cooling for optimisation of amelioration was developed by KVASU. (Prasad, 2014).

The controller was found effective in reducing thermal stress in crossbred cattle (Harikumar, 2016). The controller is useful in medium to large dairy farms and has found to be successful in farm trials too. The controller is presently made available for direct purchase by farmers from the department of Livestock Production Management, College of Veterinary and Animal Sciences, Mannuthy, Thrissur.

Housing and management of cattle differs world-wide according to the existing agro-climatic conditions. In the tropics, livestock are subjected to thermal and nutritional stresses and sustaining their production potential will be one of the biggest challenges that have to be addressed in the near future. A multidisciplinary approach involving nutritional and environmental modifications ensures comfort and better production performance. Proper site selection, spacing, roofing and flooring patterns, provision for *adlibitum* drinking water will help to reduce the impact of thermal stress in animals. Special management interventions like roof wetting, combination of intermittent wetting and forced ventilation are also widely in practise, especially in high tech dairy farms across the tropics, the effectiveness of which is improved by Temperature Humidity Index (THI) based automation. Thus, the major intervention in dairy farming for climate resilience is the development of housing modifications from a futuristic angle

Importance of dairy farm roofing in thermal stress alleviation

As in any other animal housing, the structure, design and materials used for dairy farm roof is extremely important in controlling the indoor environment. An ideal roofing material must be light, durable, and strong, waterproof besides having high reflectivity, low under surface emissivity and low conductivity. It must be economical and should not condense moisture inside the barn (Narwaria*et al.*, 2017). The roof should provide sufficient shade and prevent direct solar radiation from entering the shed, which in turn depend on the material and its conductivity. Different ventilation and roofing patterns are being used to suit the local climatic conditions and to ensure maximum natural ventilation and gas exchange between the interior and exterior of the animal houses. Monitor roof is considered to be the most suitable roof type for shorter span tropical buildings, as it serves the purposes of ventilation.

Clay tiles, reinforced cement concrete, galvanized iron sheets, asbestos, corrugated aluminium sheets, thatch are the commonly used roofing materials in different parts of India. These preferences are found to vary according to the agro-climatic condition of the locality and economic status of farmers. A study in Kerala indicated that majority of cattle sheds had tiled roofing (32 per cent) followed by tin sheet (22 per cent), asbestos (19 per cent), thatched with coconut palm leaves (12 per cent), aluminium sheet (7 per cent) and concrete (3 per cent) (Prasad *et al.,* 2013). Narasimha *et al.* (2019) reported that the majority (69.33 per cent) of the Deoni cattle farmers in Telangana state used thatched material followed by Galvanized Iron (22 per cent) and asbestos sheets (8.67 per cent) for covering the sheds.

Roofing modifications like thermal insulators, polythene shade cloth, mud plastering, solar panels, roof paints, evaporative roof cooling *etc*. Help in further reduction of thermal stress in cattle (Narwaria*et al.,* 2017). When metallic or conducting materials are used, the upper side should be made reflective. Aluminium sheets were found to be reflective to solar radiation and were reasonably durable. Wooden boards and synthetic vegetable boards were popularly used as roof lining for tiled and galvanized iron roofing for better insulation. Further researches on these materials for better use in dairy farms are the need of the hour. Effectiveness of roofing can further be increased by adjusting the height of the roof, angle and length of the eaves *etc*. But in case of small holder production systems the cheap and easily available local materials like palm leaves and dried grass should be the materials of choice. Efforts are needed to increase the durability of these materials.

Besides ensuring animal welfare, roofing has a significant role in improving the growth and production efficiency of dairy cattle. A study was conducted in eighteen Jersey cows randomly allocated into barns with thatch, corrugated asbestos sheet (AC sheet) and corrugated galvanized iron sheet (CI sheet) roofing. No significant difference was noticed in feed intake and milk production, but both showed an apparent increase when housed under thatched roof Another study in crossbred Vrindavani calves reported increased body weight gain in calves housed under polycarbonate roof with adjustable height (Maurya*et al.,* 2018). Even though the influence on production appears to be negligible, roofing definitely has a role in ensuring cow comfort.

On the other hand, even though the roof provides the much needed shade during the day time, it also has the ill effect that it increases the indoor temperature during night when compared to outside temperature. This increases stress during night. In the climate change scenario, where nights are predicted to be hotter, this may hamper the chance of the dairy cattle for its physiological recuperation in the night. Hence, it may be assumed that allowing the animal to paddocks during early hours of the day or designing movable roof structures may become a necessity in future.

Importance of dairy farm flooring in climate change adaptation

Flooring is one of the most important components of animal housing as far as animal health and welfare are concerned. The lying cow is in direct body contact with the floor for 12 to14 hours per day (Lendelova and Pogran, 2003). Different flooring materials are being used for different types of livestock all over the world. Cement/concrete, vitrified paving bricks, granite stones, wood, bricks, gravel are the different flooring materials used in animal houses.In dairy animals the most common flooring material used is cement concrete. But, cows housed on concrete floor has greater chance of developing or exacerbating the existing heel erosionsand hence are at greater risk of becoming lame when compared to cows on rubber (Andreasen and Forkman, 2012).Straw served dual purpose of providing softness and thermal insulation and was also popularly used as bedding material (Tuyttens, 2005), but mastitis-causing pathogens proliferated very quickly in straw and sawdust (Zdanowicz*et al*., 2004), which has led to increase use of sand in free-stall housing. The cushioning effect of sand floor was found to protect the animals from developing lesions on body parts, increased the feeding and resting time and thus increased overall welfare of animals when compared to concrete flooring (Sahu*et al*., 2019). Wooden floors are preferable to keep the floor warm and comfortable, especially in hill stations where timber is cheap. In tropical climate, slated wooden floors will also provide desirable floor ventilation which facilities maximum cooling of animals in summer. Synthetic flooring using composite bricks, rubber mat with grooves and ridges are also popular now-a-days. Rubber mat provide a clean, soft and comfortable surface. But in a study conducted in Kerala, by Prasad *et al*. (2013) it was inferred that the rubber mat floor had significantly higher temperature than concrete floor during the day time. Though rubber mat flooring has many obvious advantages, its effect on thermolysis, animal comfort and physiological significance in hot humid conditions has to be explored by further research.

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Evaluation of climatic variables to assess thermal stress in dairy cattle

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Introduction

Thermal stress can be defined as the effect of climatic variables on animals which results in increased body temperature and subsequent physiological changes. Thermal stress has considerable impact on animal welfare and compromises productive and reproductive performances particularly in tropical and subtropical regions (Habeeb, 2020). In dairy cows, it results in reduced milk output with lower milk quality characteristics, reduced dry matter intake, poor udder health and reduced breeding efficiency. The grievous economic loss due to thermal stress in dairy production is a serious concern which demands continuous intervention in management practices. Climatic variables such as ambient temperature, relative humidity, air velocity and solar radiation are highly dynamic in nature especially in tropical region and also they are inter-dependant. Thorough understanding and constant monitoring of climatic variables and their combined effects are absolutely required for designing the potential environmental stress alleviating strategies in dairy production. This is an attempt to understand important climatic variables and different bioclimatic indices for the benefit of environment management for sustainable dairy production.

Climatic variables

a. Ambient temperature

The ambient temperature is the average air temperature surrounding the immediate vicinity of an animal whether interior or exterior of the shelter. According to Berman *et al.* (1985) the upper critical air temperature for dairy cows is 25 to 26°C. The basic thermal exchange processes of conduction, convection and radiation are all depending on a thermal gradient, therefore as air temperature elevates above a critical point, the thermal gradient is reduced and heat dissipation becomes less effective. As ambient temperature increases there is a marked shift to evaporative cooling from non-evaporative cooling. The extent and duration of ambient temperature is primarily depending on latitude and the regions closer to the equator experience increasingly higher level of thermal stress (West, 2003). The effect of diurnal fluctuation of ambient temperature can be studied only if continuous logging of data is possible. Electronic loggers are available with functions to record and store temperature (^{o}C or ^{o}F) of every second to hour continuously for months and can be retrieved conveniently (Eg. HOBO ProV2 loggers, Onset Computer Corporation, USA).

b. Relative humidity

Relative humidity is the ratio of the vapor pressure of the moist air to its saturation vapor pressure at its temperature and it is expressed in percentage. It is calculated by dividing actual vapor pressure by saturation vapor pressure, then multiplying that number by 100. Generally, hygrometer is used to measure relative humidity which contains a dry thermometer and a wet thermometer. The paired temperature values can be used to find the relative humidity using hygrometric tables. Electronic loggers like HOBO ProV2 loggers can also be used to log relative humidity continuously. Studies from hot humid weather areas in the world found a decline in milk production due to heat stress when the relative humidity was increased even when the temperature remained the same (Bohmanova *et al.,* 2007). When high ambient temperature is coupled with a high relative humidity, stress intensity increases and therefore a combined effect of temperature and humidity is always accounted in thermal stress assessment.

c. Solar radiation

Solar radiation can greatly influence heat load and alter the ability of the animal to maintain thermal balance (Shane and Mader, 2003). The solar radiation reaching the earth is highly variable and depends on atmospheric processes such as scattering and absorption**.**

Black globe temperature

Black Globe Temperature monitors the effects of direct solar radiation on an exposed surface. It is the measure of radiant energy and one of the most common climatic variables used for assessing thermal stress. Unfortunately, it is usually not reported in meteorological data. The black globe temperature can be measured using a sensor which includes a thermometer inserted in the center of a copper globe with a diameter of 15cm and coated with black matte paint**.** Solar radiation from the sun heat up the exterior of the black globe, and the wind blowing across the globe cools down the globe, and the thermometer inside the globe measures these changes. When exposed to radiation, black globe thermometers usually record a higher temperature than ambient temperature.

Electronic devices are available for logging the data (E.g. Heat stress meter, HT30, Extech Instruments Corporation, USA). Apart from the direct observations, Dimiceli andPiltz (2013) derived an equation to estimate black globe temperature with accuracy of 0.5˚F after considering thermal emissivity, atmospheric vapor pressure and dew point temperature. Hajizadeh*et al.* (2017) also estimated black globe temperature from environmental variables such as wet bulb temperature, dry bulb temperature, solar radiation and relative humidity.

Pyranometer is a device that measures solar irradiance from a hemispherical field of view incident on a flat surface while pyrheliometer is used to measure specifically the direct beam solar irradiance. The standard international unit of irradiance is watts per square metre (W/m^2). The duration of the bright sunshine at a place can be measured by using a photoelectric sunshine recorder.

d. Wind velocity

Rate of air flow is as important as temperature and humidity when animal comfort is considered. The air velocity over the skin increases the evaporative loss from the skin in hot humid tropical climate. In general wind velocity means the wind speed measured at 2 m above ground and it is the measure of air movement (measured in m/s). An anemometer is the instrument used for measuring wind velocity and the direction of the wind. The effective air velocity recommended for dairy cattle during heat stress is from 1.8 to 2.8 m/s (Bailey *et al*., 2016). Promoting the air circulation inside the shelter reduces the temperature and humidity near the animals. Rate of evaporative cooling from animal body depends on air movement and temperature gradient with respect to the micro environment. An anemometer is the instrument used to measure the wind velocity. There are five major types of anemometers such as cup anemometer, hotwire anemometer, windmill anemometer, laser Doppler anemometer and sonic anemometer.

Bioclimatic Indices

Bioclimatic indices account for the combined effects of environment temperature, relative humidity, solar radiation and wind velocity above the animal's thermo-neutral zone and indicate the effect of heat load on animals. According to Jendritzky*et al.* (2002) there are more than 100 indices developed in last 150 years. (Table 1) Majority of them are for human applications mostly based on temperature and relative humidity to represent the thermodynamics between the human body and the thermal environment. The Temperature Humidity Index (THI) is the most common bioclimatic index, originally developed for humans by Thom (1959) and got extended to cattle by Berry *et al*. (1964). THI is a single value depicting the integrated effects of ambient temperature and relative humidity associated with the level of heat stress. The Livestock Weather Safety Index (LWSI) formulated by the Livestock Conservation Institute (1970) was considered as the basis for classifying the various categories of THI. As per this index, THI value 70 or less is considered as normal, 71-78 as alert and 79-83 as danger. THI 83 or above is classified as emergency and requires immediate attention. Different authors provide different THI threshold values at which heat stress begins, ranging from 68 to 74 units (Herbut*et al.* 2018).

Table 1. Commonly used bioclimatic indices

Bioclimatic indices	**Climaticvariables incorporated**	**Source**
Temperature Humidity Index (THI)	Dry bulb temperature (°C), Relative humidity (%)	Thom, (1959)
Temperature Humidity Index (THI adjusted)	Temperature humidity index, Wind velocity (m/s) Solar radiation (W/m^2)	Mader *et al.* (2006)
Temperature Humidity Index (THI)	Dry bulb temperature (°C) Relative humidity (%)	Bohmanova *et al.* (2007)
Temperature Humidity Index (THI)	Maximum daily dry bulb	Ravagnolo and Misztal

	temperature (°C), Minimum daily relative humidity (%)	(2000)
Temperature Humidity Index (THI)	Dry bulb temperature (^{o}C) Wet bulb temperature (^{o}C)	Yousef, (1985)
Black Globe Humidity Index (BGHI)	Black globe temperature (°C) Dew point temperature)	Buffington *et al*. (1981)
Equivalent Temperature Index (ETI)	Air temperature (°C) Relative air humidity (%) Wind velocity (m/s)	Baeta *et al*. (1987)
Heat Load Index (HLI)	Black globe temperature (°C), Relative humidity (%) Wind velocity (m/s)	Gaughan *et al*. (2008)
Respiration Rate predictor index (RR)	Air temperature(°C) Relative air humidity (%) Wind velocity (m/s) Intensity of solar radiation (W/m^2)	Eigenberg *et al*. (2005)
Comprehensive Climate Index (CCI)	Temperatures adjusted for solar radiation, Wind velocity (m/s) Relative humidity (%)	Mader *et al*. (2010)
Index of Thermal Stress for Cows (ITSC)	Air temperature (°C), Wind velocity (m/s),ERHL effective radiation heat load (W/m^2), Partialvapor pressure (kPa)	Da Silva *et al*. (2015)
Humidex	Dry bulb temperature (°C), Relative humidity (%)	Masterton and Richardson (1979)
Skin Temperature Humidity Index (STHI)	Infrared skin surface temperature (°C),	Collier (2011)

	Dew point temperature (°C),	
Livestock Poultry Heat Stress Index (LPHSI)	Dry bulb temperature (°F) Relative humidity (%)	LPHSI (1990)
Environmental Stress Index (ESI)	Dry bulb temperature (°F) Relative humidity (%) Solar radiation (w/m^2).	Moran *et al*. (2001)
Wet Bulb Globe Temperature Index (WBGTI)	Wet Bulb Temperature (°C) Dry Bulb Temperature (°C) Globe Temperature (°C)	Alfano *et al*. (2014)

Although air temperature and relative humidity may be most important in determining the exchange of heat between the animal and its surroundings, other relevant microclimate factors, such as solar radiation, wind movement and sunlight, also play significant roles in levels of thermal stress. Gaughan *et al.* (2008) developed Heat Load Index (HLI) with black globe temperature (°C), relative humidity (%) and wind velocity (m/s) for successfully predicting panting responses of different feedlot cattle during high heat load.

Black Globe Humidity Index (BGHI) is a comfort index for dairy cows based on the effects of dry bulb temperature, relative humidity, solar radiation and air velocity. According to Collier *et al*. (1981) the correlation of BGHI to milk yield is greater under conditions of high solar radiation (no shade) than under a shade structure. BGHI≤70 had little impact on dairy cattle and BGHI≥75 markedly reduces feed intake. Respiration rates and rectal temperatures of dairy cattle are directly related to BGHI (Buffington *et al*., 1981).

Skin Temperature Humidity Index (STHI) can account for differences in microenvironment around the animals with a greater accuracy of measuring environmental heat load than BGHI or THI.

Baeta *et al.* (1987) developed an Equivalent Temperature Index (ETI) to evaluate the impacts on heat dissipation and lactation performance in Holstein and Jersey dairy cows. It showed significant positive correlation with rectal temperature and respiratory rate in tropical environment.

According to Harikumar (2017), BGHI, LPHSI and HLI are the major bioclimatic indices which showed high correlation with physiological and behavioural stress responses in dairy cows of tropical humid region.

The primary difference among most of the thermal stress index equations is on the level of emphasis placed on relative humidity and therefore different equations can be suited for different geographic areas (Bohmanova *et al.*, 2007). According to them, in humid climates, indices with more emphasis on relative humidity were found to be suitable. However, indices with the more weightage on ambient temperature are preferred in climates where relative humidity does not reach the extent that could compromise evaporative cooling.

Conclusion

Thermal stress assessment in dairy cattle requires extensive and continuous data of climatic variables of highly dynamic nature. Diurnal fluctuations of the environment and its effects on animal body are most important and therefore must be accounted in detail. Otherwise, THI may under estimate or overestimate the effect of an adverse event, especially if nighttime events are ignored. The major drawbacks of the existing indices are that they use a one dimensional approach, where only the intensity of the variable is measured, not the duration of the exposure to adverse thermal conditions. THI formulas that determine the environmental risk factors for dairy cows are unfortunately still imperfect because they consider only the microclimate rather than animal responses or structural characteristics of cattle shelters. It would seem advisable to extend the scope of research on bioclimatic indices for including physiological responses of animals and physical properties of cattle shelters in order to design and establish climate smart dairy shelters.

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Assessment of Environmental Stress in Cattle in Field Conditions

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Production and health of animals depend mostly on environment in which they live. A satisfactory environment for any livestock is the one that ensures not only optimal productivity but also meets the health and behavioral needs of the animals. A satisfactory environment is the one that satisfies the following four criteria: thermal comfort, physical comfort, disease control and behavioral satisfaction. An environment in which stressors are minimized would likely be favorable for efficient production of products derived from domestic farm animals and for helping ensure the well-being of those species. Hence for assessing the effect of environmental stress in animals a comprehensive index that include the environmental variables, physiological variables of animals, biochemical indicators, health indicators, production and welfare are needed.Reduced milk production resulting from heat stress counteracts tremendous genetic progress achieved in increasing milk production. Due to high metabolic heat increment, especially in the warmer months, high producing dairy cows may enter heat stress much earlier than their lower producing counter parts. In order to ensure optimum productivity of the dairy cattle, understanding of the existing housing patterns and the environmental stress in various agro-climatic regions are very essential. The major points to be explored in the field conditions are

1. The different housing patterns existing in different agro-climatic regions
2. Effect of environmental stress on dairy cattle under different housing patterns
3. Suggest suitable housing pattern for dairy cattle in various agro-climatic regions
4. To develop a model database on climatic variables, housing pattern and dairy cattle productivity

The study on the effect of environmental stress in dairy cattle involves a comprehensive analysis of the stress factors, environmental variables, climate change in the study areas, existing animal housing systems, effect of seasons, physiological variables of animal, biochemical blood profile, production and reproduction performance of animals.

The field assessment should be carried out in two phases. The first one involves the base line survey to identify the existing dairy cattle housing system and the second one involves the seasonal stress assessment of the cattle in selected farms.

Field Data Collection

A survey can be conducted in the selected agro-climatic regions with a pre-structured interview schedule for identifying the existing dairy cattle housing patterns, production and management measures. Based on the survey, the major housing patterns existing in the region can be identified and categorized for further detailed investigation. The survey can be limited to a particular stratum also, so that the farms with at least a minimum number of milking cows can be selected. A pre-tested interview schedule can be filled on the spot with observation and interview with the dairy farmers.

Climatological variables

Past data

Past data on temperature (maximum and minimum), relative humidity, rainfall and wind velocity for past years can be collected from the National Data Centre, Indian Meteorological Department and the annual compounded growth rate can be worked out for the climatic variables to study the climate change in the study area.

Present data

Out of the total farms selected from each agro-climatic zone, either maximum-minimum thermometer and digital thermo-hygrometers or automatic data loggers can be installed in the representative shelter types, at least one each in every agro-climatic region for measurement of the climatic variables.

Seasonal effect

The study should be conducted for one year duration and the period should be divided into four seasons as South West monsoon (June – August), North East monsoon (September -November), cold season (December - February) and summer season (March - May) for understanding the seasonal effect very clearly.

Physiological variables

Physiological constants such as rectal temperature, respiration rate and pulse rates can be recorded between 12.00 noon and 2.00 pm while visiting the farmers in the field.The rectal temperature and skin temperature are recorded in degrees Celsius (^{0}C). The respiration rate is expressed as breaths per minute (bpm).

Haematological profile of animals

Whole blood can be collected between 12.00 noon to 2.00 pm from each cow through jugular vein puncture into tubes: one containing EDTA for haematological analyses, the other without EDTA for biochemical analyses as described by Grunwaldt, *et al* (2005).

Haematological Studies

The following blood parameters can be analyzed by the autohaematology analyzers available.

i. Total White Blood Cells - (TWBC)

ii. Total Red Blood Cells - (TRBC)

iii. Haemoglobin - (HB)

iv. Haematocrit Value - (HCT/PCV)

v. Mean Corpuscular Volume - (MCV)

vi. Mean Corpuscular Haemoglobin - (MCH)

vii. Mean Corpuscular Haemoglobin Concentration - (MCHC)

viii. Red Blood Cell Distribution Width - (RDW)

ix. Total Platelet - (TPLT)

x. Mean Platelet Volume - (MPV)

xi. Platelet Distribution Width - (PDW)

xii. Plateletcrit – (PCT)

Bio-chemical profile of animals

The serum can be examined for the selected enzymes using a semi auto/auto clinical chemistry analyzer by standard methods described by Bergmeyar (1983) with the available commercial kits.

i. Aspartate aminotransferase - (AST)

ii. Alanine aminotransferase - (ALT)

iii. Acetylcholine esterase – (AChE)

iv. Lactate dehydrogenase – (LDH)

Serum Hormones

The serum can be examined for the selected hormones by enzyme immunoassay using microwell reader by standard methods described by Bergmeyar (1983) and followed by Bhooshan*et al.* (2010) with the available commercial kits.

i. Cortisol

ii. Triiodothyronine - (T3)

iii. Thyroxine - (T4)

Electrolytes

The serum electrolytes Sodium and Potassium are also important in the stress assessment.

Milk production

The average milk production per cow in each season under different housing patterns in various agro-climatic zones can be found by taking the milk recording of the herd. The change in milk yield should also be recorded for finding out the variation in different seasons.

Reproduction

The days of first post-partum estrus, service period, and services per conception cab be recorded in each season under different housing patterns in various agro-climatic zones by taking the recording of the herd.

Statistical analysis

The collected data were statistically analyzed by one way analysis of variances (ANOVA) for finding the difference between the groups by using statistical package like SPSS. The significance was tested using Duncan's multiple range test (Duncan, 1955). Factor analysis can be used to rank the housing systems in the study area based on the significant climatic, physiologic and production parameters. The dairy housing comfort index can be constructed based on the factor scores obtained by different housing systems and the housing systems can be ranked accordingly by using statistical package SPSS.

A study was conducted in the four agro-climatic regions of Tamil Nadu viz. North Eastern zone, North Western zone, Western zone, and Hilly zone to assess the effect of environmental stress on dairy cattle and to develop a comprehensive index as per the methodology described above and the results are given below. Based on the survey, the major housing patterns existing in the region were identified and categorized for further detailed investigation. Farmers with at least five cows were selected from each agro-climatic zone with the major types of housing pattern identified for conducting the field investigation. For each season a total of thirty samples were collected (five housing types with six replicates) for measuring bio-chemical profile, haematological studies, serum enzyme analysis, serum hormone estimation and electrolyte status from each agro-climatic region. A total of 120 samples were collected for each season with a grand total of 480 samples during the whole experimental period of one year. In each sampling season the number of animals sampled in each group was always greater than the five recommended by Whitaker (2000).

Table 1. Details of animal shelters and production in the four agro-climatic zones

Agro-climatic Zones	North Eastern Zone	North Western Zone	Western Zone	Hilly Zone	Over all
No of observations (per cent)	139 (100)	70 (100)	38 (100)	30 (100)	277 (100)
Milk production					
Average number of animals per farm	6.34	7.62	8.6	2.48	6.26
Average total milk production per farm (litres)	45.35	55.00	71.07	27.35	49.69
Average milk production per animal (litres)	6.83	8.55	7.52	11.15	8.51
Location of shed					
Separate housing	125(89.9)	69 (98.6)	37 (97.4)	24 (80.0)	255 (92.1)
Attached to farmers house	14 (10.1)	1 (1.4)	1(2.6)	6 (20.0)	22 (7.9)
Number of rows					
Single row	111 (79.9)	49 (70.0)	31 (81.6)	28 (93.3)	219 (79.1)
Double row	28 (20.1)	21 (30.0)	7 (18.4)	2 (6.7)	58 (20.9)
Type of roof					
Thatch	49 (35.3)	17 (24.3)	11 (28.9)	2 (6.7)	79 (28.5)

Tile	18 (12.9)	19 (27.1)	10 (26.3)	8 (26.7)	55 (19.9)
Cement sheet	41 (29.5)	21 (30.0)	11 (28.9)	4 (13.3)	77 (27.8)
Metal sheet	31 (22.3)	13 (18.6)	6 (15.8)	14 (46.7)	64 (23.1)
Plastic	0 (0)	0 (0)	0 (0)	2 (6.7)	2 (0.7)
Type of floor					
Mud	60 (43.2)	20 (28.6)	25 (65.8)	1 (3.3)	106 (38.3)
Cement	62 (44.6)	37 (52.9)	10 (26.3)	7 (23.3)	116 (41.9)
Stones	17 (12.2)	13 (18.6)	3 (7.9)	22 (73.3)	55 (19.9)

The multiple correlation between physiologic, climatic and production parameters were worked out of the values obtained from 480 samples collected during the whole experimental period of one year. Based on the correlation coefficient 25 parameters were selected out of the total 39 parameters and used for working out the dairy housing comfort index and is given in table3.

Table 2. Multiple correlations between the parameters understudy.

	WBC	RBC	HGB	HCT	MCV	MCH	MCHC	RDW	PLT	MPV	PDW	PCT	AST	ALT	CHE	LDH	CORT	T3	T4	Na	K	RT	PR	RR	ST	BCS	MP	CMP	PPH	SP	SPC	T. Max	T. Min	T8	RH8	THI8	T2	RH2	THI2
WBC	1.00																																						
RBC	0.04	1.00																																					
HGB	-0.01	0.87	1.00																																				
HCT	0.08	0.86	0.93	1.00																																			
MCV	0.21	0.20	0.49	0.57	1.00																																		
MCH	0.18	0.25	0.52	0.40	0.65	1.00																																	
MCHC	0.03	0.04	0.24	-0.08	-0.01	0.59	1.00																																
RDW	0.34	-0.04	-0.31	-0.16	-0.40	-0.57	-0.32	1.00																															
PLT	-0.05	0.20	0.28	0.24	0.22	0.17	0.24	-0.15	1.00																														
MPV	0.18	0.16	0.35	0.44	0.64	0.47	-0.07	-0.32	0.20	1.00																													
PDW	0.08	0.16	0.38	0.32	0.61	0.68	0.33	-0.74	0.18	0.37	1.00																												
PCT	-0.30	0.20	0.36	0.40	0.40	0.23	0.04	-0.29	0.80	0.32	0.35	1.00																											
AST	0.26	0.16	0.41	0.26	0.44	0.54	0.50	-0.36	0.40	-0.09	0.47	0.32	1.00																										
ALT	0.26	0.33	0.40	0.49	0.56	0.25	-0.06	0.10	0.40	0.32	0.25	0.41	0.13	1.00																									
CHE	0.14	-0.03	-0.20	0.00	-0.14	-0.34	-0.44	0.46	-0.35	0.15	-0.29	-0.30	-0.71	0.18	1.00																								
LDH	0.35	0.57	0.73	0.61	0.52	0.57	0.43	-0.28	0.55	0.18	0.53	0.42	0.82	0.45	-0.49	1.00																							
CORT	0.26	-0.05	-0.29	-0.18	-0.23	-0.08	-0.22	0.33	-0.49	-0.11	-0.28	-0.50	-0.43	0.04	0.41	-0.41	1.00																						
T3	-0.31	-0.06	0.20	-0.02	0.00	0.28	0.49	-0.29	0.33	-0.12	0.07	0.32	0.53	-0.30	-0.66	0.31	-0.58	1.00																					
T4	-0.22	-0.03	0.26	0.12	0.28	0.26	0.27	-0.45	0.45	-0.06	0.35	0.46	0.68	0.06	-0.64	0.47	-0.61	0.72	1.00																				
Na	-0.55	0.20	0.19	0.04	-0.06	0.03	0.17	-0.27	0.21	0.03	-0.08	0.21	-0.03	-0.14	-0.13	0.05	-0.37	0.23	-0.01	1.00																			
K	0.12	-0.35	-0.43	-0.44	-0.29	-0.16	0.11	0.44	-0.23	-0.12	-0.45	-0.36	-0.27	-0.14	0.24	-0.39	0.56	-0.24	-0.47	-0.05	1.00																		
RT	-0.03	-0.37	-0.54	-0.48	-0.53	-0.39	-0.27	0.26	-0.44	-0.10	-0.55	-0.50	-0.64	-0.29	0.37	-0.74	0.72	-0.36	-0.41	-0.26	0.44	1.00																	
PR	0.11	-0.28	-0.49	-0.33	-0.32	-0.40	-0.45	0.44	-0.54	0.13	-0.58	-0.53	-0.82	-0.12	0.60	-0.76	0.66	-0.59	-0.72	-0.16	0.41	0.83	1.00																
RR	0.09	-0.33	-0.55	-0.41	-0.47	-0.44	-0.37	0.47	-0.56	-0.01	-0.60	-0.59	-0.80	-0.26	0.60	-0.80	0.71	-0.55	-0.70	-0.29	0.52	0.89	0.94	1.00															
ST	0.03	-0.60	-0.72	-0.59	-0.46	-0.53	-0.33	0.48	-0.48	-0.03	-0.61	-0.48	-0.72	-0.30	0.54	-0.84	0.49	-0.42	-0.55	-0.26	0.56	0.80	0.85	0.92	1.00														
BCS	-0.71	0.35	0.43	0.26	-0.05	0.07	0.24	-0.45	0.04	-0.29	0.25	0.21	0.14	-0.10	-0.19	0.17	-0.46	0.33	0.33	0.54	-0.49	-0.39	-0.49	-0.47	-0.49	1.00													
MP	-0.25	0.44	0.54	0.41	0.37	0.41	0.30	-0.49	0.42	-0.05	0.60	0.47	0.57	0.17	-0.52	0.63	-0.62	0.44	0.53	0.38	-0.56	-0.84	-0.83	-0.90	-0.92	0.60	1.00												
CMP	0.11	0.26	0.19	0.28	0.14	-0.08	-0.17	0.24	0.03	0.33	0.12	0.19	-0.25	0.41	0.07	0.11	-0.05	-0.27	-0.23	-0.13	-0.03	-0.21	0.09	0.00	0.00	-0.16	0.08	1.00											
PPH	0.21	0.03	-0.03	0.09	-0.11	-0.35	-0.37	0.14	-0.23	0.28	-0.20	-0.25	-0.46	0.13	0.32	-0.26	0.30	-0.48	-0.28	-0.42	-0.09	0.55	0.58	0.56	0.47	-0.28	-0.60	0.27	1.00										
SP	0.38	-0.07	-0.17	-0.03	-0.15	-0.37	-0.44	0.40	-0.26	0.22	-0.35	-0.26	-0.45	0.19	0.30	-0.26	0.46	-0.38	-0.37	-0.47	0.15	0.54	0.63	0.57	0.50	-0.56	-0.65	0.43	0.81	1.00									
SPC	0.41	-0.14	-0.24	-0.13	-0.14	-0.27	-0.34	0.52	-0.18	0.09	-0.37	-0.19	-0.29	0.18	0.17	-0.17	0.45	-0.15	-0.31	-0.34	0.33	0.34	0.45	0.38	0.35	-0.64	-0.47	0.43	0.34	0.82	1.00								
T. Max	0.00	-0.52	-0.68	-0.51	-0.40	-0.51	-0.41	0.43	-0.61	-0.07	-0.48	-0.52	-0.78	-0.28	0.64	-0.87	0.55	-0.59	-0.69	-0.28	0.53	0.71	0.83	0.91	0.94	-0.38	-0.82	0.04	0.43	0.42	0.26	1.00							
T. Min	-0.12	-0.54	-0.69	-0.54	-0.45	-0.54	-0.39	0.38	-0.57	-0.08	-0.48	-0.47	-0.81	-0.33	0.62	-0.90	0.45	-0.53	-0.64	-0.18	0.47	0.70	0.80	0.88	0.93	-0.29	-0.78	0.04	0.40	0.35	0.18	0.99	1.00						
T8	-0.07	-0.54	-0.68	-0.54	-0.43	-0.52	-0.39	0.38	-0.60	-0.08	-0.49	-0.51	-0.77	-0.32	0.62	-0.88	0.51	-0.56	-0.65	-0.19	0.48	0.74	0.83	0.90	0.95	-0.31	-0.82	0.00	0.43	0.38	0.20	0.98	0.99	1.00					
RH8	-0.06	0.62	0.75	0.59	0.43	0.58	0.41	-0.50	0.42	0.04	0.51	0.36	0.70	0.25	-0.55	0.79	-0.36	0.48	0.55	0.28	-0.44	-0.65	-0.76	-0.82	-0.95	0.47	0.82	-0.14	-0.43	-0.47	-0.34	-0.92	-0.93	-0.93	1.00				
THI8	-0.08	-0.54	-0.68	-0.55	-0.43	-0.51	-0.38	0.37	-0.61	-0.08	-0.49	-0.51	-0.77	-0.33	0.61	-0.88	0.50	-0.55	-0.65	-0.17	0.49	0.74	0.83	0.90	0.94	-0.30	-0.82	-0.02	0.42	0.37	0.19	0.98	0.99	1.00	-0.93	1.00			
T2	0.00	-0.51	-0.67	-0.51	-0.42	-0.52	-0.41	0.46	-0.61	-0.08	-0.52	-0.53	-0.78	-0.28	0.64	-0.87	0.55	-0.58	-0.70	-0.25	0.54	0.72	0.85	0.92	0.94	-0.39	-0.83	0.04	0.42	0.42	0.28	1.00	0.99	0.99	-0.92	0.98	1.00		
RH2	-0.04	0.63	0.74	0.58	0.40	0.56	0.41	-0.46	0.44	0.01	0.50	0.37	0.71	0.21	-0.57	0.80	-0.39	0.49	0.54	0.27	-0.42	-0.68	-0.79	-0.84	-0.96	0.45	0.84	-0.11	-0.47	-0.49	-0.34	-0.93	-0.94	-0.95	0.99	-0.94	-0.93	1.00	
THI2	0.08	-0.48	-0.63	-0.50	-0.41	-0.41	-0.29	0.46	-0.66	-0.12	-0.48	-0.62	-0.70	-0.38	0.68	-0.82	0.52	-0.50	-0.74	-0.20	0.58	0.61	0.76	0.84	0.85	-0.36	-0.74	-0.10	0.23	0.27	0.21	0.94	0.91	0.90	-0.81	0.91	0.94	-0.81	1.00

BCS-Body condition score, MP-Milk production, CMP-Change in milk production, PPH-Days of first post parturient heat, SP-Service period, SPC-services per conception, X8-Parameter at 8.00 am, X2- Parameter at 2.00 pm

Table 3. Ranking of housing systems and dairy housing comfort index

Sl. No	Agro-climatic zone	Housing System based on roofing	Overall Rank	Rank in agro-climatic zone	Housing comfort index
11	North Eastern Zone	Tile	3	I	1.17537
12		Thatched	6	II	0.6393
13		Cement sheet	7	III	0.62732
14		Metal sheet	11	V	-0.11986
15		Open	10	IV	-0.01114
16	North Western Zone	Tile	8	I	0.38899
17		Metal sheet	9	II	0.37114
18		Cement sheet	12	III	-0.17183
9		Open	14	IV	-0.47193
10		Thatched	15	V	-0.74321
111	Western Zone	Cement sheet	16	I	-0.7844
112		Open	17	II	-0.93999
113		Thatched	18	III	-1.45285
114		Metal sheet	19	IV	-1.57605
115		Tile	20	V	-1.63564
116	Hilly Zone	Cement sheet	1	I	1.83584
117		Metal sheet	2	II	1.35513
118		Thatched	4	III	0.9113
119		Open	5	IV	0.90149
120		Tile	13	V	-0.29897

The result showed that the climatic condition of the particular agro-climatic zone and the choice of housing materials play a major role in deciding the comfort level of the animal in the individual housing system. Hence, considering the trend in climate change, the dairy housing systems need further research in improving the comfort level of the animal for improving the production and ensuring the welfare of the animals.

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Strategies to alleviate heat stress and enhance production in cattle

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Introduction

In the changing climate scenario, heat stress is of major concern among livestock owners as it affects drastically livestock production which otherwise contributes 40 per cent of world's agriculture gross domestic product (GDP). Hence there is an urgent need for reviewing the various strategies to counter the heat stress impact on livestock production. Heat stress is one of the major concerns which affect the production potential of dairy cattle almost in every part of world. Elevated temperature and humidity negatively affect feed intake leading to negatively affecting the reproductive potential which ultimately decrease milk production. Changes in climate would directly lead to reductions in summer-season milk production and conception rates in dairy cows, because voluntary feed intake (VFI) is the primary factor influencing the production capacity of livestock. High yielding cows more susceptible to heat stress than the low yielders. Apart from reducing the milk production, heat stress can also reduce the quality of milk.

Apart from management strategies, such as providing dairy cows shade, increased ventilation and cooling of the surrounding air by fans alone or in combination with sprinklers, dairy cows are better able to minimize the detrimental effects of heat stress on milk production, reproduction and their immune system. In addition, giving plenty of good clean drinking water, minimum handling, grazing during early morning and late evening hours are very beneficial to improve livestock production. Apart from these managemental interventions, nutritional strategies also must be given equal importance which not only will help the animal to survive the stress but will also it ensure optimum availability of energy for production processes.

There is no single fool proof strategy for alleviation of heat stress. Instead, a three pronged, multidimensional intervention, involving a holistic application of physiological, management and nutritional approaches, viz., **adaptation, mitigation and amelioration** strategies are essential to alleviate heat stress and sustain, if not enhance milk production under the changing climate scenario, in lactating dairy cows. Key interventions/ tools, with special emphasis on nutritional strategies, in all of the above three approaches, are discussed hereunder.

I. Adaptation strategies

Adaptation strategies refers to techniques adopted for alteration, acclimatization or adjustment to the heat stress. The various nutritional adaption strategies recommended against heat stress are:

1. Improving Water Availability

Adequate clean drinking water should be provided at all times in the shed to the animals. Water has a high specific heat which promotes heat dissipation in the heat stressed animal, decreases the metabolic load, provokes an increase in dry matter intake (DMI) and milk yield.

II. Mitigation strategies

Mitigation strategiesrefers to measures for alleviation or relief from the heat stress. Heat stress was found to increase methane production, the second most potent and significant anthropogenic greenhouse gas after carbon dioxide. Daily methane (CH_4)emissions are positively correlated to the indoor air temperature, with ambient temperatures of above 40^0 C resulting in increased methane production which is a loss to the animal. Therefore, mitigation strategies of heat stress, primarily revolve around decreasing methane production to the extent possible, so that milk production and reproduction are not interfered with. The various methane mitigation strategies recommended are:

Methane mitigation

Seven to eight per cent of the gross energy of ruminant diet is lost as methane. 4.50 g methane is produced for each 100g of carbohydrate digested. Any given strategy for methane mitigation has to address one or more of the following goals: (1) reduction of hydrogen production that should be achieved without impairing feed digestion - management, genetic and nutritional interventions and (2) stimulation of hydrogen utilisation towards pathways producing alternative end products beneficial for the animal and/or an inhibition of the methanogenic archaea (numbers and/or activity). The potential mitigation strategies to reduce enteric methane emission, are given below:

A. Management interventions

1) **Reducing Livestock Numbers -** Scientific slaughter of old and incurably diseased animals.

B. Genetic interventions

1) **Genetic selection of animals** that consume less feed or produce less CH4 per unit of feed.

C. Nutritionalinterventions

Increasing the efficiency of livestock production by improving the efficiency of ruminant animal performance will generally lead to a reduction of CH4 emitted per unit of animal product (25–75% depending on animal management practices). There are two aspects of this, viz., nutritional manipulation via increased feed intake and appropriate feed composition.

(a) Increasing feed intake:

(1) Increasing feed intake decreases the methane emission per unit of feed intake. As milk yield increases, methane emitted per unit of milk yield decreases. This is because of two reasons; viz.,

a. Mainly by the rapid passage of feed out of the rumen and

b. As intake increases, the methane emission associated with the essential, but non-productive, requirements for maintenance is diluted.

(b) Appropriate feed composition:

(1). Decreasing dietary fibre and increasing starch will reduce methane emission. The proportion of concentrate within the diet has been reported to be negatively correlated with methane emissions.

(2). Increasing dietary lipids (both vegetable and animal lipids) are also considered useful in terms of reduced rumen methanogenesis. Possible mechanisms by which added lipid can reduce methane production is by reducing fibre digestion (mainly in long-chain fatty acids)

(3). Increasing the proportion of concentrate in the diet will generally reduce rumen pH and as methanogens are pH sensitive; this will also tend to reduce methane emission. Replacing structural carbohydrates from forages (cellulose, hemicellulose) in the diet with non-structural carbohydrates (starch and sugars) results in a lower CH_4 production because the relative proportion of ruminal hydrogen produced and subsequently the CH4 production also declines.

(4). Methane emissions are commonly lower with higher proportions of forage legumes, such as fodder lucerne and lucerne hay in the diet, partly because of the higher soluble carbohydrate and lower fibre content, the faster rate of passage and in some cases, the presence of condensed tannins. CH_4 production in ruminants tends to increase with maturity of forage fed and hence young forages are better than mature forages as far as reducing CH4 production is concerned.

(5) Methanogenesis tends to be lower when forages are ensiled than when they are dried and when they are finely ground or pelleted than when coarsely chopped

(6). Improving the nutritive value of the feed given to grazing animals by balancing the diet with concentrates, or by breeding-improved pasture plants, should result in reduced methane emission.

(c) Preparation and processing of feed:

Grinding or pelleting of forages to improve the utilisation by ruminants has been shown to decrease CH_4 losses, when fed at high intakes. The lowered fibre digestibility, decreased ruminally available organic matter and faster rate of passage associated with ground or pelleted forages can explain the decline in CH_4 production.

(d) Grazing Management

Implementing proper grazing management practices (rotational grazing, mixed pastures and early grazing) and improving the quality of pastures will increase animal productivity and lower CH_4 per unit of product.

(e) Increasing longevity/ extended lactation

Extended lactation can reduce the energy demand of cows and methane by approximately 10 per cent. Extended lactation is always considered as an option for herd, and selected breeds suited for extended lactation. The longer the cows stay in a herd, the lower the number of replacements required, and thus, the lower the total farm methane emissions.

(f) Inducing Acetogenesis and feeding probiotics

Reductive acetogenesis is a natural mechanism of hydrogen utilisation that coexists with methanogenesis in the gastrointestinal tract of many animals. The final product of the reaction, acetate, has the additional advantage of being a source of energy as well as fat for the animal. However, in the rumen environment, acetogens are less numerous and less efficient than methanogens, in the competition for reducing equivalents. This is probably because acetogens need a higher concentration of hydrogen in the medium to reduce CO2 into acetate than that required for methanogens to reduce CO2 into CH_4. In addition, the former reaction is thermodynamically less favourable. Attempts to increase the natural rumen population of acetogens have been assayed but without success.

(g) Defaunation

Defaunation is the complete removal of protozoa from the rumen ecology and consequently reduces methane release. It reduces the number of methanogens which are associated ecto- and endo-symbiotically with protozoa.

(h) Mitigation Through Chemical Inhibitors

(1) Nitrates

Recent research have shown promising results with nitrates decreasing CH4 production by serving as a terminal electron acceptor and therefore may behave as alternate hydrogen sink and can be converted to ammonia and used in the rumen as a source of nitrogen. The nitrate and nitrite along with CO_2 are the hydrogen acceptors in the rumen.

(2) Sulphates

In the rumen, sulphate is reduced to sulphide. Sulphate dependent methane oxidation with the use of methane and/or acetate is thermodynamically more favourable in anaerobic conditions like rumen.

(3) Organic Acids

Fumaric and malic acids, the direct metabolic precursors of propionate, have also been studied as alternative hydrogen sinks in the rumen. Addition of sodium fumarate consistently decreased methane production and malate, which is converted to fumarate in rumen, stimulated propionate formation and also inhibited methanogenesis in some *in vitro* studies.

(4) Ionophores

Among ionophore antibiotics, monensin is the most studied in ruminants. Monensin specifically targets bacteria producing H_2 and formate. Ionophores inhibit gram- positive microorganisms responsible for supplying methanogens with substrate for methanogenesis. ie., they reduce the amount of H_2 available for methanogenic bacteria and attaches to the cell membrane of ruminal bacteria and protozoa, resulting in an increase in propionate producing organisms, thereby bringing about a reduction in the proportion of acetate relative to propionate in the rumen and hence effectively lowers CH_4 production. Monensin also brings about inhibition of protozoa, which produce hydrogen and are colonised by methanogens.

(5) Halogenated Compounds

Halogenated methane analogues such as chloral hydrate, amichloral, 2-bromoethane sulphonate, chloroform and cyclodextrin are highly effective at reducing methane production, by reacting with coenzyme B, which functions at the last step of the methanogenic pathway.

(6) Prebiotics in ruminants

Prebiotics such as galacto-oligosaccharide (GOS) supplementation are speculated to enhance the propionate production by stimulating *Selenomonas, Succinomonas and Megasphaera* with simultaneous inhibition of acetate producers such as *Ruminococcus and Butyrivibrio* and resultant low methane production.

(7) Nitro compounds

Less toxic nitro compounds such as 3-nitropropanol, may have the potential to be used as an alternative to decrease CH4 production in ruminants. In the presence of the appropriate nitro compound, formate, lactate and H_2 served as electron donors of *D. detoxificans*.

(8) Propionate Enhancers

Within the rumen, hydrogen produced by the fermentation process may react to produce either methane or propionate. By increasing the presence of propionate precursors (e.g. pyruvate, oxaloacetate, malate, fumarate, citrate, succinate, etc.), more of the hydrogen is used to produce propionate and methane production is reduced. Propionate precursors can be introduced as a feed additive for livestock receiving concentrates. The propionate precursor malate also occurs naturally in grasses, and research is being conducted to identify affordable natural sources, e.g. alfalfa and engineered feed stocks with high concentrations of propionate precursors. As propionate precursors naturally occur in the rumen, they are likely to be more readily acceptable than antibiotic or chemical additives.

(i) Manipulation of Rumen Microbial Ecosystem

(1) Probiotics/ Direct-Fed Microbials

Direct-fed microbials (DFM) used in ruminant nutrition are

a. Yeast-based products (YP):

Yeast cultures reduce methane production in three ways: (1) by reducing protozoa numbers, (2) by increasing butyrate or propionate production and (3) by stimulating acetogens to compete with methanogens or to co-metabolise hydrogen, thereby decreasing methane formation.

b. Methane Oxidisers

Methane-oxidising bacteria (methanotrophs) could also be introduced as direct-fed microbial preparations. The oxidation reaction would compete with the production of methane, which is a strictly anaerobic process. Methanotrophs are a unique group of methylotrophic bacteria, which utilise methane as their sole carbon and energy source.

(2) Bacteriocins

Bacteriocins are antimicrobial proteinaceous polymeric substances, produced by a variety of gram negative and gram positive bacteria. Bacteriocins could prove effective in directly inhibiting methanogens and redirecting H2 to other reductive bacteria, such as propionate producers or acetogens. The most well-known bacteriocin is nisin. Nisin obtained from *Lactobacillus lactis* ssp. *lactis* has also been shown to decrease methane production *in vitro*. It is nearly as potent a methane inhibitor as monensin.

(3) Fungal Metabolites

Secondary fungal metabolites from *Monascus* spp. reduced enteric methane emissions, by a shift in VFA pathways, decreasing the acetate to propionate ratio. The main microbial modifications observed were reduction in methanogen numbers, suggesting a specific and toxic effect on this microbial group.

(4) Methane-Reducing Species

Mitsuokellajalaludinii has been demonstrated as an efficient methane-reducing agent in the rumen by competing with methanogens for hydrogen, necessary for growth by both. Moreover, *Mitsuokellajalaludinii* may not only decrease gas production in livestock but also improve ruminal fermentation and, in turn, improve feed efficiency.

(5) Phage Therapy

The lytic potential of phages, viz., siphophages that can infect methanogens (*Methanobacter, Methanobrevibacter and Methanococcus* spp.) and their genes make them an important tool for methane mitigation strategies.

(6) Plant Secondary Metabolites

This category includes a variety of plant secondary metabolites (PSM), specifically tannins and saponins, which have been extensively studied for their CH_4 mitigating potential.

(a) Tannins

Tannins are plant polyphenols of varying molecular size and exist in two forms in plants: hydrolysable and condensed tannins (CT). Tannins as feed supplements or as tanniferous plants have oftenshown potential for reducing CH_4 emission by up to 20 per cent. The hydrolysable tannins tend to act by directly inhibiting rumen methanogens, whereas the effect of condensed tannins on CH4 production is more through inhibition of fibre digestion.

(b) Saponins

Saponins are naturally occurring surface-active glycosides with foaming characteristics, occurring in many plant species. They usually consist of a sugar moiety linked to a hydrophobic compound, either triterpenoid or steroid in nature. Saponins reduce methane production via inhibition of either protozoa or methanogens or both. Because of their anti-protozoal activity, saponins might have the potential to reduce CH_4 as protozoa have both an ecto- and endo-symbiotic relationship with methanogens, and methanogens associated with protozoa are estimated to be responsible for 9 to 37 per cent of the total CH4 production in the rumen. Anti-methanogenic activity of saponins is believed to occur by limiting hydrogen availability to methanogens and rechannelling of metabolic hydrogen from methane to propionate production in the rumen. In addition, saponins, due to their chemical structure, may display antibacterial properties by reducing the number of bacteria producing H2 thus resulting in the inhibition of H2 production—a substrate for methane formation.

(7) Essential Oils

A wide range of essential oils (derived from garlic, thyme, oregano, cinnamon, rhubarb, frangula, etc.) has been shown to decrease methane production *in vitro* in a dose-dependent manner, but at high doses, the decrease in methanogenesis was accompanied by adverse effects on fermentation such as reduction in VFA production and feed digestibility.

(j) Immunisation for Reducing Enteric Methane Mitigation

Developing vaccines against methanogenic rumen archaea are based on the concept of a continuous supply of antibodies to the rumen through saliva. The vaccine also works by triggering an animal's immune system to produce antibodies against methanogenic bacteria that live in the rumen of the animal. A new anti-methanogenic vaccine has been developed using subcellular fractions (cytoplasmic and cell wall-derived protein) of *M. ruminantium M.*

Amelioration strategies

Amelioration strategies refers to practices for improvement, enhancement or betterment of the animal, which is subjected to heat stress. The various amelioration strategies recommended against heat stress are:

A. Management strategies

(1) Physical protection

Physical protection with artificial or natural shade presently offers the most immediate and cost-effective approach for enhancing the productive and reproductive efficiency of animals. Evaporative cooling also can be effective. Various shade management systems have been evaluated extensively and generally result in improved feed intake and productivity. Sprinkling the animal in the morning, minimal handling of animal on hot days and providing bedded barns help to decrease the solar heat load on the animal.

(2) Ideal shed requirements

In tropical and subtropical climates, providing shade becomes an important factor. It is suggested that a well-designed shade structure should reduce the total heat load by 30 to 50 per cent. Cattle generally prefer shade from trees rather than constructed structures. Trees are effective at blocking incoming solar radiation, and moisture evaporating from their leaves helps cool surrounding air.

Space requirements are essentially doubled in hot and humid climates to provide additional open area for improved air movement, which in turn increases the rate of heat loss from a cow's body surface.

Fans should be tilted downward at a 20–30° angle (from vertical) to direct the flow of air onto the cows, and preferably they should be kept above the sprinklers to remove the moisture. Another cooling device that might be useful is using mist and fan system. In this cooling system, mist particles are sprayed onto the animal's body to wet the hair. A fan is then used to evaporate the moisture, as a way of cooling the cows.

B. Nutritional strategies

The following nutritional interventions shall go a long way in ensuring optimum production in livestock during heat stress condition.

(1) Increase the energy and nutrient density of the ration

The energy and nutrient density of the diet can be increased by reducing the fibre, increasing the concentrates and supplementation of fat in the diet as feed intake is markedly decreased during heat stress. The above facts can be summarised as, "animals should be fed with cold diet during the heat stress condition". Cold diet is one which generates a high proportion of net nutrients for energy synthesis and reduces the basal metabolic heat generated during fermentation and metabolism.

Dietary supplementation with either lipoic or dihydrolipoic acid may improve heat tolerance and animal performance during heat stress by enhancing insulin action and subsequently increased glucose availability.

(2) Mineral Supplementation

Unlike humans, bovines utilise potassium (K^+) as their primary osmotic regulator of water secretion from sweat glands. As a consequence, K^+ requirements are increased during the heat stress and this should be adjusted for in the diet. In addition, dietary levels of sodium (Na^+) and magnesium (Mg^+) should be increased as they compete with K^+ for intestinal absorption.

Addition of electrolytes such as vitamin C in the diet was found to be more beneficial to combat heat stress in animals to improve the milk yield, maintain the acid base balance and to lower their body temperature.

Among the micronutrients, zinc which is a potent inducer of Hsp70 gene in cell culture, is indispensable for adaptation to heat stress. Besides, chromium, which facilitates insulin action on glucose, lipid and protein metabolism, has been found to be beneficial to counter heat stress impact on livestock, because glucose use predominates during heat stress and hence chromium supplementation may improve thermal tolerance or production in heat stressed animals.

(3) Antioxidant and ruminant-specific live yeastSupplementation

Antioxidant supplementation is one of the primary means of reducing the heat stress impact on livestock as their oxidative balance are generally disturbed during this stress condition. Supplementation of antioxidants, both enzymatic and non-enzymatic, provide necessary defence against oxidative stress and prevent the accumulation of oxidatively damaged molecules, viz., reactive oxygen species (ROS). The role of vitamin E as an inhibitor— "chain blocker"—of lipid peroxidation, which may occur as a result of heat stress has also been well established.

Nutritional tools such as antioxidant feeding (vitamins A, E, C, selenium, zinc, etc.) and ruminant-specific live yeast can help. Studies have shown that addition of antioxidants, especially vitamin E in the diets of cows are able to reduce heat stress and is a good strategy to prevent mastitis and retention of placenta, optimise feed intake and reduce the negative impact of heat stress on milk production.

Yeast culture has been shown to improve fibre digestion and stabilize the rumen environment. In heat-stressed dairy cows supplemented with yeast, lower rectal temperatures and respiration rates were observed, with concomitant increase in milk production.

Conclusion

In the changing climate scenario, heat stress seems to be the crucial environmental variable which decreases livestock production and fertility across the globe. Heat stress has long been known to affect animals comfort, health, growth and reproduction, which ultimately has great impacts on animal well-being and farmer's profitability. Hence implementing approaches like, nutritional strategies such as those mentioned above; hand in hand, with shelter management, modifications in the behavioural, psychological and biochemical thermoregulatory mechanisms of the animals as well as improved health services can have significant impact in ameliorating the heat stress effect on livestock sector. It should also be borne in mind that the developed strategies should be user friendly and economically feasible, if farmers have to adopt those strategies to improve livestock production in the changing climatic condition.

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Green Clean Dairy Farming

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Livestock is an important sub-sector of Indian agricultural economy which plays a multifaceted role in providing lively hood support to the rural population. The contribution of livestock sector to the agriculture output has significantly increased from1.8% to 28.4% in the year 2020 (Report, 2020). In India, 18 million people are employed in livestock sector. In the last decade, the socio-economic mobility of people has initiated a dietary diversification from cereal based to protein rich food. From the year 2009 to 2019, there was 16.6% reduction in the consumption of cereals while there was an increase of 25.4% in the consumption of milk, meat, fish and eggs, reiterating the economic principle as income rise, demand tend to shift towards protein rich items (Report, 2019). The livestock sector is gradually getting transformed from traditional to commercial and beyond, which is happening currently. From the perspective of increasing production in 80 and 90's, the current perspective is productivity, quality, , choice and value added products.

Last 70 years has seen unprecedented change in the dairy sector of India. From a milk deficient country in the year 1950, producing a meagre 17 million tonnes of milk, India has transformed into the world's largest producer of milk, producing a bulk volume of 187.7 million tonnes in the year 2019, accounting for 17.4% of the total global output (Report, 2020).

As of 2020, India also is the top country by the number of cattle and buffaloes in the world accounting for 33.33% of the world number of cattle and buffaloes possessing 305.4 Million animals (World data Atlas. 2021). Though this is a matter of pride, this is also a matter of concern as ruminants are one of the major source of anthropogenic methane emission. Methane is stated to be one of the major greenhouse gases responsible for stratospheric ozone depletion and also 25 times more potent in terms of heat trapping (Report, 2007). Livestock and climate change are interdependent and linked through a complex mechanism where adversity of one affects the other one in many ways.

Climate change and its impact on dairying

The impact of climate change is visible all over the world but South Asia appears to be most vulnerable region. The situation in India is more alarming as rural economy is primarilydependant on crop-livestock production systems. Climate change and its extreme weather events such as drought, flood, and long heat waves has been adversely affecting crop and livestock productivity thereby endangering the food security of the country. Global warming is expected to increase competition for limited fodder and water resources, pastureland degradation, and livestock diseases (Anon, 2016). As reported in India's National communication to the United Nations Framework Convention on Climate Change (UNFCCC), a rise in temperature by 2-4 °C by 2050 will negatively impact milk production by more than 15 million tons by with respect to current levels of production.

Impacts of climate change on livestock are primarily due to an increase in temperature and atmospheric carbon dioxide concentration, humidity variation and a combination of these factors. Temperature affects the critical factors for livestock production, such as water availability, animal production, reproduction and health, forage quantity and quality. Temperature increase will increase lignin and cell wall components in plants which reduce digestibility and degradation rates, leading to a decrease in nutrient availability for livestock and increased emission of methane (Hederson*et al*., 2018).

Animal health can be affected directly or indirectly by climatic change, mainly by increase in temperature. Temperature not only increases morbidity and mortality of animals but also indirectly produce change on microbes, parasites, spreading of vector borne disease, food borne disease, host resistance and feed and water scarcity (Olufemi *et al*., 2014). Climate change enhances the introduction and invasion of disease agents by altering biological variables. Climatic change affects the host distribution, density, disease emergence and the animal-human interface, a pathogen may find access to new territories, turn more aggressive where the host have become more abundant or immune compromised and activates a host-species jump (Jonathen*et al*., 2014). Climate is leading to increased incidence of zoonotic disease affecting public health with emerging disease like Avian flu, Swine flu, Nipha virus, Corona viral disease etc. Yet uncertainties about future disease trends under changing scenario remain uncertain and undisclosed.

Climatic variables tend to increase animal water consumption which might increase to three-fold, demand for agricultural lands increase due to need for 70% growth in production, and food security concern since about one-third of the global cereal harvest is used for livestock feed. Meanwhile, the livestock sector contributes 14.5% of global greenhouse gas emissions, driving further climatic change (Srivastava *et al*., 2010).

Housing and Shelter Management

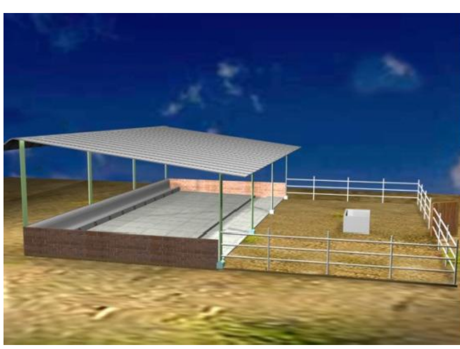
Shelters provide protection to the animals and also modify the climate to suit the species housed for improving the productivity and reproductive efficiency. Commercial farming has led to large scale microclimatic modifications subject to economy in the wake of climatic change. By controlling the microclimatic environment, productivity and reproductive efficiency can be improved. The trend that are apparent in modern society are higher production by fewer animals

Livestock and stress

During the last thirty years there were quantum leaps in the understanding of motivation, cognition, social behaviours, environmental adaptations and their underlying physiological process. Modern techniques of ethology and experimental psychology have provided new insights into sensory and motor control, hormonal effects, reproductive behaviour and social structures. This knowledge is now being applied at various levels of intensive farming for the welfare of animals for augmenting productivity (John and Lucy, 2014)

Animal welfare has become essential for animal production enterprises to be economic, effective and sustainable.

Lack of welfare orientation at any level, during any stage can result in deterioration of quality, ultimately reflecting on the economics of the enterprise. Therefore, in this contemporary era where time and money are valued more, no stock person can afford to compromise on animal welfare, where high productivity by successful reproduction is desired. In this aspect the most important change that has happened world over is loose housing system or free stall system, which is still to be adopted in large scale in India.



Loose Housing system

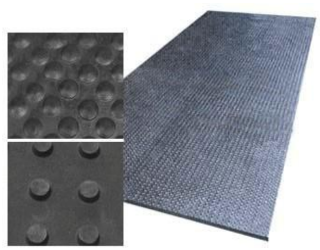
Free stall system

Cow comfort index and hygiene

Cow Comfort Index (CCI) is the proportion of cows in contact with a stall that are lying down and can be a measure of cow lameness. It is the most commonly used index and describes cow's motivation to enter a free stall and lie down. A well-managed herd would have at least 85% of cows lying down if in contact with a stall, making the ideal CCI greater than 0.85 (Cook*et al*, 2005)

In contrast, Stall Standing Index (SSI) is the inverse of CCI, which means it is the proportion of cows standing in contact with a stall. The ideal SSI is less than 0.15, and anything greater than 0.20 is associated with cow lameness (Cook *et al*.,2005).

To improve CCI provision of bedding is most important. Different materials used as bedding are sand, straw, wood shavings, dry solid manure and rubber mats (Ferraz*et al*., 2020). A lying cow has an increased blood diffusion through the udder (around 5 litres/min) compared with a standing animal (around 3 litres/min). This improves the milk production (Temple *et al*., 2016). But proper disposal of bedding materials is another concern. Rubber mats provide comfort and thermal insulation but if not properly cleaned, will increase the microbial load and hoof problems.


Straw Bedding Siliconised rubber mat

Controlling thermal changes

Thermal changes impair the production traits such as growth, milk and meat yield and its quality and also the reproductive performance of the animal.

Air temperature if high can be regulated by increasing the height of the roof, providing insulation, increasing air movements by providing fans, by evaporative cooling (air coolers) if humidity is less or by air conditioning. Increasing the height of the shed is a simple means to reduce the heat load and to improve ventilation of houses. As majority of heat load accumulates in the shed due to reflected radiation rather than direct radiation, planting trees and fodder around the shed can drastically reduce the heat load in the shed.

High rise animalsheds

Insulating materials can be placed below the roof which will reduce the influx of het into the building. In Indian conditions, sawdust or straw may be used as good insulating material having insulation value R=1.75 or more (Sivakumaran, 2015). Other insulating material such as polystyrene or polyurethane or polyethylene can also be used. A temporary thatch roof over the asbestos, tile or G.I sheet roof can reduce the temperature considerably. Roof vents may assist in air movement and relief of sensible heat released by the animals in hot climate asheat accumulates at the apex of the roof.

Roof sprinkling: This consists of setting up water sprayers to trickle water down. These require large amounts of water about 9000 litres/hour for an averaged sized shed. The sprays should be turned on before the temperature starts rising. Up to 5° C reduction in internal house temperature is possible with this system. This system of cooling does not increase the humidity within the sheds. This is the best method for alleviating heat stress in regions where humidity is high.

Low temperatures can be modified by providing different types of heaters.

a) Humidity

Among the climatic variables relative humidity is the most difficult factor to be modified. High humidity can be reduced by providing de-humidifier. Low humidity can be modified by sprinkling, fogging and misting.

b) Wind

Wind can be regulated by erecting wind barriers or increased by providing fans. Also different types of ventilators and windilators can be provided to increase or decrease air movement in the sheds. Interior cooling systems are designed to increase heat loss by convection or evaporation, which can be effectively accomplished by using fans. Vertically mounted fans within the house do not reduce temperature, but they move hot, moist air away from the animals by convection and so, panting becomes more efficient. Air speeds of 3m/s is helpful. Higher speeds can be detrimental (John, 2013)

Paddle fans are more suitable in Indian conditions. It should be placed 7 meters centre with one row of fans for each 11 meter of building width.

Windilators Fans for animal houses Horizontal paddle fans

Fan requirements

Before installing fans, the following aspects has to be taken into account

a) Air volume requirement: It is based on average body weight of animal and their heat production and dissemination.
b) Throw: It is the distance an air jet will travel before its velocity is decreased to 75 feet per minute
c) Impringent air jets: Air that is allowed to travel adjacent to smooth surface, generally a ceiling or side wall. Such air jets will travel approximately 25 per cent farther than a similar air jet.

Evaporative cooling

Evaporative cooling can be effectively employed in dry regions where the relative humidity is between 40-50 percentages. 3-4 air coolers can be used in animal sheds which can lower the temperature to the range of 15-20 degree centigrade, if the relative humidity is 20 percentages and to 8-10 degree centigrade if the relative humidity is 60-70 percentages. If the relative humidity rises above 70 percentages, the animals become progressively more stressed as the panting response will lose efficiency. Therefore, it must be kept in mind when using evaporative cooling technology in animal houses.

Internal fogging

High pressure fogging systems i.e. 400-600 psi (28-41 bar), produces droplets size of 10-15 micron, which are more effectively evaporated and minimize the residual moisture. Lower pressure system i.e. 100-200 psi (7-14 bar) giving droplet size greater than 30 micron may be used in less demanding situation (John, 2013).

Reducing enteric methane emission

Enteric rumen methane emission can be considerably reduced by reducing the coarse, dry fibrous diet**.** In this aspect, for the maintenance of the rumen ecosystem and to maximise microbial protein digestion without wide rumenpH variation. Total Mixed Ration system (TMR) has emerged world over. In this system, the green grass, concentrate feed, hay and buffers are mixed together to so as to follow the basic ruminant feeding principle that there is no drastic change in the feed and the rumen ecosystem is optimized for the maximum multiplication of microorganism.

T.M.R Wagon

TMR has been mechanised with the use of TMR Wagon. There are two types of TMR wagon a) Distributor type-movable wagon and b) Stationary wagon. In these initially the components of the concentrate feed like maize powder, oil cakes, bran are added, and they are ground and mixed. A weighing scale provided in the wagon ensures that the ingredients are in optimum proportion. Then hay is cut, loaded and mixed and at last the chopped green grass is loaded. Then buffers like sodium bicarbonate at the rate of 0.73% level is added. All the ingredients are mixed uniformly. The unloading conveyor is lowered and the mixed feed is distributed to the cows in the barn.

Reaper cum chaff cutter

TMR Wagon

Advantages of TMR

1) High total dry matter intake therefore increases in milk production
2) Maintenance of rumen eco system and high microbial protein utilization
3) Maintenance of energy balance after calving
4) No incidence of SARA
5) No incidence of ruminitis, laminitis and hoof disorders

Other methods for reducing enteric methane emissions are: Feeding ionophores, removal of protozoa, reductive acetogenesis, use of plant secondary metabolites, incorporating nitrates/sulphate, disabling of surface proteins, bio-hydrogenation etc (John and Anil, 2007).

Reducing water equivalent

Water equivalent is the quantity of water utilised for the production of a unit quantity of product. It has been worked out that 3.25 Litres of water is essential for the production of one litre of milk and 80 Litres of water is utilised in a farm for washing of animals. Livestock production will be limited by climatic variability as animal water consumption is expected to increase by a factor of three and draughts prevailing in the tropics.

Automatic drinkers

Automatic drinkers reduce the wastage of water at the same time ensuresadlibitum supply of water round the clock for optimising production and saves labour. Stainless steel drinking bowls are popular in commercial dairies. Cows learn to operate them fast and it is economical as in loose housing system 1 bowl per 5 cows are only required

Stainless steel automatic drinking bowls

Cow brushes

World over, the enormous wastage of water for washing of animals is reduced by using automatic cow brushes. Cows enjoy grooming and it stimulates blood supply improving milk production and also improves the coat condition of cow. The swing brushes are switched on automatically when the cow nears the brush. The cow rubs its different body parts on the brush until the entire body is massaged.

Cow Brushes

Hygienic Milking

From the two-axis system of pricing followed in India (quantity and fat percentage), The world had moved towards three-axis system, based on bacterial load, fat percentage and quality. The milk which is secreted sterile from the mammary gland often gets contaminated during hand milking. The milk from the mammary gland of all mammal should be drawn by negative pressure (suction) than by positive pressure exerted during hand milking. Cortisol concentrations were greater during hand-milking than during machine milking (Gorewit*et al*., 1992). From all these factors, it is beyond doubt that we have to switchover to machine milking from had milking provided the teat cups, claw, milking tubes and bucket are cleaned and sanitised.

Milking process has witnessed revolutions in mechanisations from hand milking to mechanical milking machines and from mechanical milking to vacuum pump machines with pulsators. The progress from bucket type milking machine of GustasDelavel invented in 1922 to Voluntary Milking System has been phenomenal (Deepak *et al*, 2018).

Bucket type milking machine

Herring bone Parlour

Rotary parlour system

Though milking machines are available, millions of small holder dairy farmers who keeps 2-3 cows cannot afford these costly milking machine. Electrical milking machines are viable only with 10-15 cows. To solve these problems cheap and efficient manual milking machines were invented. (John *et al*.,2013)

Manure Management

The 2nd most important component for reducing methane emission from livestock is manure management. Scientific disposal of manure and other waste material from animal farms is very important as these materials can fetch subsidiary income, but if not promptly disposed, it will become an ideal breeding place for pathogen and disease carrying insects and also become a source for methane emission.Manure should be promptly and completely removed from the shed so that it may not cause disease. The four basic principles of manure management are, ➡REDUCE ➡ REUSE ➡RECYCLERECOVER.The major component of the dung limiting its transportation and use is its water content (80%).

Composition of cattle dung

Water	Organic matter	Nitrogen	Phosphoric acid	Potash
80.0%	19.09%	0.35%	0.16%	0.40%

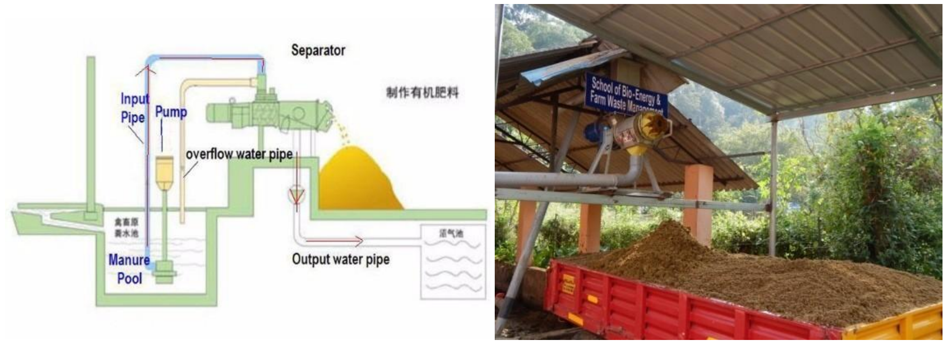
There should be provision for collection and disposal of solid and liquid waste.The liquid waste such as urine and wash water must be collected in a septic tank and utilized for irrigation or disposed off into a soak pit.The solid waste should be collected and stored in a roofed dung pit into which rain water cannot seep into and can be disposed off as dry manure or by means of a bio-gas plant and the digested slurry should be utilized for land applications.

Roofed dung pit

Alnutt's manure pit

Dung de-watering machine

Dung de-watering machine is a new addition in scientific manure management. It is a de-watering screw press machine, which reduces the moisture content of the dung to 20%. The dung mixed with equal quantity of water is pumped up by a submersible 2 HP chopper pump to the screw press, where the cow dung is pushed forward by the screw and it is pushed back by the back pressure disc, to squeeze out the filtrate. The solid phase is separated from the liquid phase, which flows through the screen. The solid fraction is pushed towards the outlet on which is installed a counter-pressure diaphragm leading to the formation of a material plug. The dried dung is discharged at the end of the screw in a powdered form. The separated water goes into the collection box from where it is pumped for irrigation. This is a good machine to convert animal excreta to odorless organic manure which retains enough moisture for the beneficial micro biome to survive. The throughput is 3 to 4 tons per hour. The power source is a 3 HP motor for the screw press. A part of the de-watered liquid is again pushed back to the manure collection pit which aids in automatic agitation and prevents settling of large solid particles in the manure collection pit. The manure is rich in organic carbon, phosphorus, potassium, calcium and magnesium. The de-watered liquid has phosphorus and potassium more than the solid fraction which can be used for fodder cultivation (John, 2020).



Dung de-watering machine

Composition of de-watered dung

	Organic Carbon	Nitrogen	Phosphorus(P2O5)	Potassium (K2O)	Calcium	Magnesium
De-watered Dung	7.45 ± 0.11%	0.81± 0.15 %	6.66 ± .29%.	0.44 ± 0.14%	19%	18%
Separated Water	1.06 ± 0.21	0.34 ± 0.23	0.86 ± 0.23	0.92 ± 0.15	8%	4%
Dung	7.22 ± 0.13%	0.78 ± 0.21%	0.72 ± 0.24%	0.65 ± 0.17%	16%	14%

A germination and shoot elongation study was conducted in de-watered dung, separated water and control as water using *pisum sativum* seeds. Germination percentage was higher in dewatered dung (92% compared to 90% in control while shoot elongation was highest in separated water compared to control (2cm in 3 days). (John, 2019)

Germination and root elongation experiment

Methane sequestration

The methane emenating from cattle dung can be effectively sequestered to produce an important cooking fuel in a biogas plant (Jyothi *et al.*, 2017.

Rumen model biogas plant

This is a new two stage digestion system; the digester is divided into acidogenic and methanogenic chamber and each chamber is provided with vertical baffles which restrict the movement of digesta through it at the same time increasing the surface area. 2 m^3 of bio-gas could be produced in 24 hours period which was collected in a bio-gas balloon. The Hydraulic Retention Time was considerably reduced in this plant to 24 days as compared to 30 days in conventional plant. The organic loading rate increased to 20 kg VS $d^{-1}m^{-3}$ (John *et al.*, 2017). One of the major drawbacks of conventional biogas plants is the inhibition of gas production as the acidogenic bacteria reduces the pH of the digester while the methanogenic bacteria efficiently operate in a in a strictly defined pH range of 8.00 to 8.50 (Shradha *et al.*,2020). The balloon could be easily transported from place to place. The composition of biogas was analysed using a bio-gas analyser(Model No. L-314 Precision scientific). The results revealed 63.5% methane, 20.4 % Carbon dioxide and 16.1 % other gases. This gas could be used in stove using a bio-gas compressor which burned continuously for 2 hours 43 minutes under high flame (Shradha *et al., 2021)*

Rumen model biogas plant

Compressed Natural Gas (CNG) Production

Natural gas is methane and 60% of biogas is methane. This process comprises of scrubbing out the contaminants in the biogas to produce pure methane and then compressing it to form CNG which can be used as a fuel for automobiles and for cooking.The CNG bottling plants consists of a high Pressure compressor, cascade of storage cylinders and a dispensing nozzle for filling the compressed purified gas in the vehicles. Dried and purified gas goes into the suction of high-pressure compressor, where it compress the gas to desired working pressure (~200 Bar) and fill into the storage cylinder. (John and Jyothi, 2009).

Compressed CNG plant

Conclusions

The latest technologies to reduce greenhouse gas emission (enteric and from manure) from dairy farming has to be adopted to prevent global warming and climatic change at the same time we have to adopt technologies to protect cows from the vagaries of climatic change and for optimising production economically to meet the demands of the growing population and for the world food security. Dairy farm biosecurity has to be stepped up to meet the challenges of emerging diseases**.** Climatic change induced emergence of newpathogen which may turn more aggressive when we have immune compromised host which may be zoonotic is the major future challenge. Uncertainties in the future disease trends under changing scenario have to be investigated and corrective steps should be adopted early for sustaining this green planet for the posterity.

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Role of Weather Based Advisories for Livestock Management in Changing Climate

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Abstract

Climate change poses formidable challenge to the development of livestock sector in India. The anticipated rise in temperature between 2.3 and 4.8°C. Over the entire country together with increased precipitation resulting from climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their productive and reproductive performance. Given the vulnerability of India to rise in sea level, theimpact of increased intensity of extreme conditions on the livestock sector would be devastating for the low-income rural community. The predicted negative impact of climate changeon Indian agriculture would also adversely affect livestock production by aggravating thefeed and fodder shortages. Thus proper management strategies are needed to reduce the impact of climate change on livestock production.

India Meteorological Department (IMD), Ministry of Earth Sciences (MoES), Indian Council of Agricultural research (ICAR), State Agriculture Universities (SAUs) and other organizations are jointly rendering weather forecast based District and Block level Agrometeorological Advisory Services (AAS) for benefits of farmers in the country under the scheme "Gramin Krishi Mausam Sewa (GKMS). AAS provides advance weather information along with livestock/ crop specific agromet advisories to the farming community by using state of the art instruments and technology through efficient delivering mechanism of the information which ultimately capacitates farmers to help take appropriate actions at farm level. Weather forecast at 12 Km resolution aggregated at district level with value addition in medium range by RMC/MCs is the basis for agromet advisory generation every Tuesday and Friday. Nowcast information on extreme weather events like thunderstorm, heavy rainfall, strong wind and hailstorm etc are provided to the farmers in advance through SMS in order to take necessary action to protect the livestock from adverse impact.

Introduction

It is a well-known fact that variable weather plays a significant role in year-to-year fluctuation in livestock production; both in intensive or traditional animal agriculture. Though complete avoidance of farm losses due to weather is not possible, however losses can be minimized to a considerable extent by making timely whether based management on livestock and accurate weather forecasts.

Weather forecasts are of four types, viz., now casting (4 to 5hrs), short range forecast (valid for 48 hours), medium range (valid for 5 days to a week) and long-range or seasonal forecast (valid for month to season). All these three types of weather forecasts are prepared by IMD through ***GraminKhrishiMousam Sava(GKMS)*** in our country and disseminated to Animal Agri farmers. Generalized forecasts have, however, the limited use in farming.

Weather information for agricultural operations and allied livestock farming shall be a tailored product that can be effectively used in crop planning and Animal Husbandry and its management. A comprehensive weather based farm advisory is an interpretation ofhow the weather parameters, in future and present will affect crops, livestock and farm operations and, suggests actions to be taken. The Agro Advisory Services (AAS) will be more effective if they are given in simple and local language that farmers can understand it.

In order to make the Agro-Met Advisory Services more successful and continuous process, it is to be supported with:

(a) Agro meteorological database,

(b) Crop conditions,

(c) Real time weather, research results on livestock and crop-weather relationships, and

(d) Skilled manpower in multidisciplinary resources and users interface.

I. Factors considered for Livestock Advisory in Animal Agriculture

i). Sensitivity of livestock production to climate change

Climate change will affect livestock production in four ways:

1. The impact of changes on feed-grain availability and price

2. The impact on livestock pastures and forage crop production and quality

3. Changes in livestock diseases and pests

4. The direct effects of weather and extreme events on animal health, growth and reproduction.

Direct effects are related to radiation, which refers to the exchange of heat between the animal and the environment. This can be affected by temperature, humidity and wind speed. Heat stress has various detrimental effects on livestock. Heat stress is a result from the animal's inability to dissipate sufficient heat to maintain homeothermy. The temperature humidity index (THI) becomes relevant under conditions of high temperature and high humidity.

An overview of local climate change Rainfall and Temperature are important climatic inputs for agricultural production, especially in the context of climate change. However, accurate analysis and simulation of the joint distribution of rainfall and temperature are difficult due to possible interdependence between them.

ii).Effects on livestock health

Climatic changes may influence livestock health through a number of factors, including the range and abundance of vectors and wildlife reservoirs, the survival of pathogens in the environment, and farming practice. Alterations in temperature and rainfall may result in the spread of disease and parasites into new regions or produce an increase in the incidence to which a particular disease is already prevalent, which will lead to a decrease in animal productivity and increase in animal mortality. Transmission of infection of zoonotic tick-borne diseases occurs when there is an overlap of activities between reservoir, vector and humans. Changes in climatic conditions may impact on all of these factors involved in disease transmission and their interactions. Abiotic factors, such as temperature and day length, impose constraints on when and how ticks quest for hosts. Beyond vector-borne diseases, intestinal nematodes develop in soil, and factors such as soil humidity and temperature have a strong influence on developmental rates. Climate change is bound to have further impact on heat-related mortality and morbidity and on the incidence of climate-sensitive infectious diseases

II. Management advisories for livestock:

***i). Breeding management**:*

Genetic adaptation to adverse environmental conditions including heat stress is a slow process and is the result of natural selection over many generations. Good environment favors high production, whereas bad environment hampers it. Selecting animals for heat tolerance needs a new understanding by livestock holders and development agencies. Adaptation traits are usually characterized by low heritability. Selection on the basis of observation of heat stress seems to be difficult and costly affair. Use of molecular markers or transgenic approaches for incorporating the heat tolerance genes seems suitable.

***ii). Feeding management*:**

To take full advantage of this, it is critical that fresh feed bepresent for all cows after milking. This is the best opportunity during the day to increase the cow'sfeed intake. During hot weather, it is critical to feed a high quality ration that will maximize feedintake, which is critical in maintaining milk production and body condition. Feedshould be freshandavailable at timeswhencows aremost comfortable andactive.Clean *ad libitum* drinking water should be ensured round the clock and water troughs / feedersshould be regularly cleaned. In view of water scarcity, drinking water should be provided in pails6-7times during theday.Animals should be let out for grazing in the morning and evening hours during the cooler parts oftheday,thereby avoidingexposure to stress.All young and adult livestock should be either housed indoors or in sufficiently cool shaded placestoavoid heatexposure.Wherever feasible, buffaloes should be allowed to wallow in specially constructed tanks.

In villages, buffaloes should be taken for wallowing in ponds and lakes. Wherever bullocks are being used for ploughing, adequate 1 hour of rest under the shade of treesshould be provided after 2-3 hours of work. Animals can be rested for a day after 2-3 days ofworkforoptimumperformance.Feed and fodder may be shifted from surplus states to deficient states to meet the requirement of animals during scarcity.

Urea-molasses mineral block lick can sustain the animals by providing protein, energy and essential minerals. It is cost effective, easy to handle and transport and available commerciallythrough milk cooperatives. Therefore, it is required that urea molasses blocks stocks (UMBS) are made available in the rain-deficient areas.

Supply enriched complete feed blocks containing dry roughage, concentrates/ unconventionalsupplements50:50ratio.Completefeedblocksmaybesourcedfromdifferentcomm ercialsources.Spray dry roughages such as paddy and wheat straw with about 10% molasses and 2% urea for maintenance of animals in fodder deficit areas. Preparation of 100 kg roughage-based enriched feed containing 88.8 kg wheat straw or any other straw/stover,10kg molasses,1kg ureaand0.5kg mineral mixture will cost about Rs.375-450per quintal.

Lactating and pregnant animals need to be provided enriched feed to meet the requirements andrest of animals be provided the maintenance diet. In case of acute shortage, lactating animals be provided feed meeting 50% of the requirements to maintain minimum level of production. Provide salt dose daily through feed (40-50 g of salt per adult animal and 10-20 g for smallruminantsandcalves).

iii). Feed processing and banking:

'Storage of surplus to feed during scarcity' is one of the traditional and promising feeds and feeding management to cope up with climate uncertainty. Storage needs processing and the common methods are chaffing, silage making, block/pellet making etc. Urea-ammoniation of low quality roughages for their enhanced usage in livestock feeding during scarcity remains the mainstay approach. Besides, the concept of total mixed ration, mixed silage, stress-relieving diets, therapeutic diets are some of the useful measures.

***iv). Strategic or catalytic supplements/additives*:**

Heat stress stimulates excessive production of free radicals. In such situation the deficiency of dietary trace element affects physiological function and particularly on reproduction. The dietary and tissue balance of antioxidant nutrients is important in protecting tissues against free radical damage. Antioxidants such as Vitamins C and E are free radical scavengers, which protect the body defense system against excessively produced free radicals during heat stress and stabilize the health status of the animal. Free radicals and reactive oxygen species play a number of significant and diverse roles in reproductive biology. Mineral mixture and antioxidant like zinc, cobalt, chromium, selenium and Vitamin E supplementation in the feed protected the ewes from these adverse effects of heat stress.

v).Disease Management:

Health care is given little attention and the sick animals are generally treated using indigenous medicines. Gastro Intestinal Parasites are not a major menace round the year due to dry conditions; however, after one week of onset of monsoon, the animals must be treated and treated thereafter on case to case basis. In arid and semi-arid region, nutritional stress also leads to chronic worm problems and thus nutritional supplementation is necessary.

Climate Services for Livestock

Under National Monsoon Mission of Ministry of Earth Sciences, IMD along with other sister organizations is continuously working on improving the forecast at all time scale to help improve the climate services to different sectors in the country and region, thus to strengthen the national framework for climate services and also to support above major initiatives of other ministries for promoting livestock and agriculture. IMD and ICAR have jointly launched to extend the AAS to block level with outreach to panchayat level farmers and are implementing by establishing Agromet unit at Krishi Vigyan Kendra (KVK) in each district. The various components of GKMS service viz. observing weather, its monitoring and forecast; crop specific advisory bulletin generation; outreach and feedback are being digitized to help develop an integrated platform, called automated Agromet Decision Support System. This includes a dynamic framework to link the existing knowledge base on livestock/ crop weather calendar, contingency action plan etc. to translate weather forecast into actionable livestock/ farm advisories for efficient decision making. Services are now available to ~43 million farmers through mobile SMS. Besides mass media, other modes of communication such as Kisan Call Center and Text To Speech, are being aggressively used to reach upto each and every end user.

Impact assessment of AAS on Livestock

Agromet Advisory Services (AAS) has significant impact in taking decision on day-to-day farming practices in livestock. National Centre for Applied Economic Research (NCAER) in 2019 conducted an impact study among the user community for estimating the economic benefits of Agromet Advisory Service under GKMS during April 2018 - March 2019 (1365 livestock farmers across 11 states of India). Key findings of impact study are:

- 76% of surveyed farmers (1365) are following advisory all the three practices viz. modification of shed/shelter; vaccination against seasonal disease; and fodder management.
- 18% of whom are doing so on two practices,
- 6% of whom are doing so on onepractice,
- 96% farmers reported that weather advisories are improving the practice of vaccination against seasonal disease

Summing up:

Given that the livestock production system is sensitive to climate change and at the same time itself a contributor to the phenomenon, climate change has the potential to be an increasingly formidable challenge to the development of the livestock sector in India. This sector has a very important role to play in the economic progress of the country as it contributes over one-fourth (26%) to the agricultural GDP and provides employment to 18million people in principal or subsidiary status. Responding to the challenge of climate change requires formulation of appropriate adaptation and mitigation options for the sector. The animals employ physiological mechanisms to counter the heat stress (Carvalho et al., 2004). The adaptation to higher temperature is also complemented by the behavioural process, such as buffaloes prefer wallowing during summer to reduce thermal loads and maintain thermal equilibrium. However, to counter the adverse effect of climate change on animal production and health, human intervention for physical modification of the environment and improvement in nutritional management practices would be additionally required Several mitigation options are available for methane emissions from livestock. In India, the possibility of capturing or preventing emissions from animal manure storage is limited as it is extensively used as fuel in the form of dry dung cakes. Hence, the scope of decreasing methane from livestock largely lies in improving rumen fermentation efficiency. There are a number of nutritional technologies for improvement in rumen efficiency like, diet manipulation, direct inhibitors, feed additives, propionate enhancers, methane oxidisers, probiotics, defaunation and hormones . Field experiments in India involving some of these options have shown encouraging results with reduction potential ranging from about 6 to 32%. Dietary manipulation through increased greenfodder decreased methane production by 5.7%.Increasing the concentrate in the diet of animals reduced methane by 15–32% depending on the ratio of concentrate in diet. The methane mitigation from molasses urea supplementation was 8.7% and 21% from use of feed additive. The livestock development strategy in the changing climate scenario should essentially focus on minimization of potential production losses resulting from climate change, on one hand, and on the other, intensify efforts for methane abatement from this sector as this would also be instrumental in increasing production of milk by reducing energy loss from the animals through methane emissions.

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Innovations in livestock insurance under changing climate scenario

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Over the past few decades climate change and climate related disaster risks have become more important than ever. The effects of climate change are unprecedented today and thus pose serious risks for human wellbeing, livelihoods and life-supporting systems. They also present serious challenges to society, in addition, increased climate variability significantly undermines the socio-economic development and environment. The consequences of climatic change, such as increase in frequency and extent of droughts, floods, cyclones, mudslides and avalanches have impacts on all sectors of economy including water, agriculture, fisheries, health, forestry, transport, tourism and energy sectors. Amongst these sectors, the agricultural sector is one of the most vulnerable sectors to impacts of climate change, which can have multiplicative effects on other sectors, as well as the economy and overall human being. The projected climate change towards warming may affect not only the crop cultivation but also on agro-climatic conditions for growing pasture vegetation, forming of feed stocks in pastures and conditions for grazing livestock. Favorable conditions for grazing livestock are determined, on the one hand, by sufficient amount of forage in pastures and on the other, by the extreme weather conditions that restrict the use of these fodders.

Livestock herds are a vital component of most of the emerging economies and India is no exceptional. Further, livestock herders and their families make up a large percentage of the poor in India.Rural farmers experience the problems of climate change to a greater extent than that of the urban populace of the country because the consequences of climate change greatly affect the productivity and productive capacity of agricultural producers. Restricted access to resources, and poverty as a result of lower income of farmers have a negative effect on the overall economic development of a country and leads to an increase in the migration of rural population to urban areas.

Developing a financially viable livestock insurance scheme is a challenge. Insuring individual animals requires a great deal of monitoring and underwriting to prevent fraud and to verify claimed losses are a result of natural causes, and not as a result of neglect or abuse. For this reason world examples of existing livestock insurance programs are supported by heavy government subsidies. There is an additional challenge to structuring an insurance product that will hedge against catastrophic events. The risk of widespread livestock losses creates a financial exposure that is too large for insurance companies to handle. In addition, the frequency and severity of a disaster is difficult to predict, so insurers must have access to substantial financial resources in the chance that a major disaster strikes and there are large indemnities to be paid.

There are several issues that deter the use of traditional insurance markets for insuring against natural disasters:

- correlated risk
  - many losses over a geographic area
  - many claims at one time can bankrupt insurance company
  - insurer may not have adequate reserves to cover all indemnities
- uncertainty about the frequency and impact of an event
  - makes premium pricing difficult
  - maximum possible liability can be very large
  - makes risk financing difficult
- short sightedness
  - infrequency of disastrous events lowers perception of risk
  - demand for disaster insurance is low-perception that the likelihood of a payout is too low to justify cost of insurance premium

Index-based insurance offers a unique approach for managing the risk of events that cause widespread correlated losses. The index-based approach to insurance means that instead of paying for each herder's individual livestock losses the insurance pays based on an objective index of livestock mortality across an entire area. The index uses sum-level livestock mortality rates based on statistics gathered by the National Statistics Office. The insurance would pay policyholders when the livestock mortality rate for the entire exceeds a specified threshold.

Innovating to Reduce Risk through Weather Index Insurance

While the basic concept is simple, effective implementation of weather index insurance is not at all simple. The continuing availability of accurate historical weather data is critical. Weather parameters required for conducting the study are temperature both minimum and maximum, rainfall, relative humidity, amount and duration of snowfall etc. It is also necessary to determine whether any of the available weather variables are in fact highly correlated with realized losses and if so, the time periods in which losses are most likely to occur. International experience has also shown that effective implementation requires careful attention to the services currently being provided by local risk aggregators as well as legal and regulatory constraints.

Demand Assessment

Before investing in data collection and product development, it is important to assess the potential demand for weather index insurance in a particular area. Personal interviews, focus groups, and surveys can be used to determine answers to the following questions:

- What are the key weather perils of concern?
- How frequently do the perils occur and how significant is the impact?
- Who is affected by these perils?
- What mitigation or informal risk transfer strategies are currently being employed?
- What is the (opportunity) cost of those strategies?
- How much are end users willing and able to pay for an insurance product?

Legal and Regulatory Framework

To facilitate the offer of weather index insurance, governments must establish an appropriate legal and regulatory framework. The legal framework should address not only the proper regulation of insurance sales but also contract enforcement. In many lower-income countries insurance is so poorly understood that courts often force insurance providers to pay indemnities for losses that were clearly not covered under the contract provisions. Conversely, insurance providers may refuse to pay claims to poor policyholders because they know that the policyholders cannot afford to have an attorney represent them in court. Thus, to protect the interests of small-scale policyholders, some sort of binding arbitration procedure is typically desirable (USAID, 2006).

Even in countries where the legal and regulatory system is more highly developed, the existing regulatory standards for traditional insurance products may not be appropriate for index insurance products. Index insurance creates unique regulatory challenges because the indemnities are not based on the actual loss incurred. Also, index insurance is highly exposed to spatially covariate losses; so the minimum capital (or contingent capital) requirements need to be higher than those for traditional insurance (Barnett and Mahul, 2007).

Data Collection and Management

For weather index insurance to be successful, both the insurer and the policyholder must have confidence that the index is being measured accurately and the data are secure from tampering. To build this confidence, the underlying index should be measured by a trusted government or private source of publicly available weather data. In addition, a sufficient amount of historical (normally daily) data on the underlying weather variable must be available for the insurer to estimate premium rates along with pasture NDVI / biomass production. The amount of historical data (i.e., weather and biomass production) required depends on the frequency of occurrence of the risk. Twenty years of data may be required to set initial premium rates for relatively frequent weather events. Thirty or forty years of data may be required for infrequent but potentially catastrophic weather events. Without having the historical data, it is difficult to calculate base premium rates and hence, the insurer would either refuse to underwrite the risk or add a large premium load to account for uncertainty (Hellmuth et al., 2009).

Need of Designing Index Based Livestock Insurance Program

The traditional individual livestock insurance (based on individual losses) was ineffective because of high loss adjustment costs due to the spread of animals among vast areas, ex ante moral hazard inducing herders failure to take effective measures to protect their stock, and ex post moral hazard leading herders to falsely report animal deaths are among the key endemic problems that plague the traditional livestock insurance program.

Monitoring individual herders is a nearly impossible task. The formal financial insurance products related to livestock mortality are unpopular among both insurance companies and livestock owners and are limited almost entirely to a small number of high value livestock (Mahul and Jerry Skees, 2006).

An alternative approach is to develop a collective system for indemnifications: indemnity payments are based on a transparent index designed to reflect the loss incurred by the herders. Such schemes are known as index-based insurance (e.g., area-yield insurance, weather index-based insurance). These schemes present some advantages (e.g., reduction of moral hazard and adverse selection, lower administrative costs), but their main impediment is the presence of basis risk, i.e., the index payout may not exactly match the individual livestock loss (Mosleh, 2016).

An index-based insurance product to indemnify herders based on the mortality rate of adult animals in a given area was recommended for the first time in Mongolia. The index-based livestock insurance (IBLI) policy pays indemnities whenever the adult mortality rate exceeds a specific threshold for a localized region. This system provides strong incentives to individual herders to continue to manage their herds so as to minimize the impacts of bad weather (i.e., if a better herder has no losses when their neighbors have had large losses, the better herder is rewarded for the extra effort by receiving a payment based on the area losses).

Data Description

Normalized Difference Vegetation Index (NDVI) – sometimes referred to as — greenness maps, is a satellite-derived indicator of the amount and vigor of vegetation, based on the observed level of photosynthetic activity. The NDVI data that is available reliably at high spatial resolution of 250 meters from Moderate Resolution Imaging Spectroradiometer (Modis) is a key instrument aboard the Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites, and have been available in real time every one to two days with the longest temporal profile since 1999. NDVI data are commonly used to compare the current state of vegetation against the long-term average condition in order to detect anomalies and to anticipate drought and have now been used by many studies that apply remote sensing data to drought management (Hellmuth et al., 2009).

We rely on NDVI data for two reasons as explained by Sommarat et al (2011). The first is conceptual. Catastrophic herd loss is a complex, unknown function of rainfall – which affects water and forage availability, as well as disease and predator pressure – and rangeland stocking rates – which affect competition for forage and water as well as disease transmission. Rangeland conditions manifest in vegetative cover reflect the joint state of these key drivers of herd dynamics. When forage is plentiful, disease and predator pressures are typically low and water and nutrients are adequate to prevent significant premature herd mortality. By contrast, when forage is scarce, whether due to overstocking, poor rainfall, excessive competition from wildlife, or other pressures, die-offs become frequent. Thus, a vegetation index makes sense conceptually.

The second reason is practical. In countries where, longstanding seasonal or annual livestock census surveys are not available as in the case of Mongolia for computing area average mortality for developing IBLI contract. It is also useful in countries where, consistent weather data series at sufficiently high spatial resolution are not available. Rainfall data from hydromet station may not be representative to settle the claims due to presence of limited number of stations. Hence, rainfall estimates derived from satellite - based remote sensing could be used as an alternative source of data (Tucker, 2005).

Training of Insurance Suppliers and Consumer Education

Insurance suppliers in lower-income countries are unlikely to be familiar with weather index insurance. Thus, they require training and capacity building opportunities to build the expertise needed to offer these unique insurance instruments. Similarly, in rural areas of many lower income countries, insurance products are not widely available. Even if potential policyholders are familiar with other types of insurance products, they will almost certainly not be familiar with weather index insurance. To make an informed purchase decision, it is critically important that potential policyholders understand the basis risk inherent with weather index insurance. That is, they need to understand that they may experience a loss but not receive an indemnity. Thus, the successful introduction of weather index insurance will require a significant educational effort. While insurance suppliers will provide some information as part of their sales efforts, potential policyholders also need information from objective sources.

Catastrophic Risk-Sharing

Local suppliers of weather index insurance policies must be able to transfer their loss exposure outside of the local area. Traditional lines of insurance (e.g., automobile, life, property and casualty) are offered on loss events that are largely uncorrelated, so the law of large numbers reduces the variance in indemnities for local insurance providers. But weather index insurance protects against spatially covariate loss events. When a policyholder collects an indemnity on a weather index insurance product, all other holders of that same policy will be collecting indemnities as well. This implies that, in any given year, indemnities can be very high relative to premiums collected. While in principle it may be possible for insurance suppliers to set aside adequate liquid reserves to cover the potential for large indemnities, in practice this is highly unlikely. There is a high opportunity cost associated with keeping such large amounts of capital in investments that can be readily liquidated. Further, in many countries there are tax disincentives for holding large reserves. Thus, index insurance suppliers generally obtain contingent capital via reinsurance. Catastrophe bonds and contingent loan mechanisms can also be used as sources of contingent capital (Barnett and Mahul, 2007).

Potential Benefits of Weather Index Insurance in Regions Affected by Climate Change

Multilateral institutions on climate change have highlighted the importance of insurance in the context of adaptation and many are pointing to weather index insurance because of the positive experiences of weather index insurance pilots in lower income countries. First, weather index insurance pilots have been designed to protect households from catastrophic weather events. Given the likely increase of extreme events associated with climate change impacts in some regions, weather index insurance could play a key role in protecting vulnerable households. In this fashion, weather index insurance increases the resilience, including the adaptive capacity, of the insured (Benjamin et al., 2009).

Second, insurance markets are likely to motivate households to adapt through price signals. Insurance has a long history of using price signals to reduce vulnerability. For many risks in lower income countries, insurance provides a first-time estimate of the monetary cost of the risk being insured. Many households may be unaware of the monetary cost of their production risk – many households have likely never been exposed to this way of thinking. The price of weather index insurance may allow households to improve their decision-making process regarding whether they need to adapt, and if they do decide to change their behaviors, how and to what extent they must change.

Third, insurance provides cash at opportune times for the insured to adapt. After a catastrophic event occurs, households must decide whether they will continue in their previous livelihood strategies, often requiring households to restock damaged assets, or if they will change livelihood strategies, often requiring capital investments. A major difficulty for lower income populations is that they lack the financial means to adapt. Cash payments from an insurer improve opportunities for farmers to make the capital investments needed to adapt or to maintain their current production strategies.

Types of risk and loss - and local capacity to cope (IPCC, 2012):

Type of risk		Type of loss			
Degree of Covariance	Frequency	Life	Assets	Seasonal production / income	Examples
High	Low	Widespread loss of life and injuries from catastrophic weather events such as hurricanes, floods or severe drought Little or no capacity to cope locally; recovery is difficult and slow	Widespread loss of homes and productive assets from catastrophic weather events Little or no capacity to cope locally; recovery is difficult and slow	Impacts of catastrophic weather events on regional production and income can be severe, with limited local coping capacity Recovery can be slow if lives and assets are also lost	Catastrophes such as tsunami, severe drought, flood, hurricane or earthquake
Medium	Medium	Some loss of life and widespread health	Widespread loss of animals from	Loss of income from poor market	Less-severe

		problems can arise from seasonal malnutrition Moderate capacity to cope with the effects of the shock locally; recovery occurs	drought or contagious diseases Moderate capacity to cope locally and slow recovery. Some people fall into poverty traps	prices; regional production and income impacts can be widespread owing to shrinkage of the rural non-farm economy Moderate capacity to cope locally and quick recovery if assets are not lost as well; some people fall into poverty traps	drought or excess rainfall in critical periods, new pest outbreaks and animal diseases
Low	High to medium	Deaths, accidents and illnesses that affect a predictable share of the population each year Some local capacity to pool these risks, but recovery from losses can be slow for the households involved	Loss, damage or disease of a predictable share of the total stock of homes or productive assets each year Good local capacity to pool these risks, but recovery from losses can be slow for the household	Low yields for some farmers due to a variety of localized weather and pest problems Good local capacity to cope with these risks; recovery is usually quick	Localized weather and pest problems (e.g. frost in a particular valley, pest outbreak in certain fields)

			s involved		

Fourth, weather index insurance can encourage adaptation by being bundled with new technologies. Bundling weather index insurance with drought-resistant fodder-seed, for example, may increase access to both the seed and insurance for households. Several arguments are advanced about the value of weather index insurance for regions experiencing climate change creates problems for pricing weather index insurance. Relative to traditional insurance products, weather index insurance has several advantages (IPCC, 2012);

- The insurance contract is relatively straightforward, simplifying the sales process.
- Indemnities are paid based solely on the realized value of the underlying index. There is no need to estimate the actual loss experienced by the policyholder.
- Unlike traditional insurance products, there is no need to classify individual policyholders according to their risk exposure.
- There is little reason to believe that the policyholder has better information than the insurer about the underlying index. Thus, there is little potential for adverse selection. Also, there is little potential for *ex ante* moral hazard since the policyholder cannot influence the realization of the underlying weather index.
- Operating costs are low relative to traditional insurance products due to the simplicity of sales and loss adjustment; the fact that policyholders do not have to be classified according to their risk exposure; and the lack of asymmetric information. However, start-up costs can be quite significant. Reliable weather and agricultural production / livestock data and highly skilled agro-meteorological expertise are all critical for the successful design and pricing of weather index insurance products.
- Since no farm-level risk assessment or household loss adjustment is required, the insurance products can be sold and serviced by insurance companies that do not have extensive agricultural expertise.

The climate-related root causes and the impacts they are likely to have (UNEP, 2012)

Climate-related risks	Impacts
Increase / decrease in temperature	• Increase in glacial melting rates, resulting in increased river flow in summer causing floods and soil erosion; • Increase in outbreaks of agricultural pests; • Increase in land degradation; • Decrease in agricultural productivity; • Increase in the extent of arid and semi-arid areas; • Expansion of infectious animal diseases and transfer of from sheep and cattle to poultry and pets • Decrease in biodiversity.
Changing rainfall patterns	• Increase in frequency and duration of droughts; • Increase in number of flood events; • Changed seasonal river flow patters • Decrease in water volume in catchments and reservoirs; • Decrease in agricultural productivity; • Decrease in livestock productivity; • Increase in extent of arid and semi-arid areas; • Increase in infectious human diseases (exacerbated by the increase in temperature), such as enteric infections, tropical fevers, parasitic diseases and malaria[1].
Extreme events a) Heat waves b) Intense rainfall	a) Increase in the frequency of heat waves • Decrease in water supply and quality; • Decrease in grassland vegetation; • Decreasing livestock productivity, particularly sheep[2]; • Increased incidence of human diseases, such as ischemic heart diseases in elderly people. b) Increase in intense rainfall events • Increase in floods, avalanches, mudflows, glacial lake bursts; • Increase in soil erosion & landslides; • Increase in river bank erosion; • Damage to infrastructure, *i.e.*hydroelectric reservoirs; • Pest outbreaks.

Prerequisites for Program Success and Expansion

However well designed the product, implementation of weather index crop insurance in developing countries requires considerable on-going management and stakeholder inputs. It should be noted that conditions in different countries, or even different regions of the same country, vary widely and it is difficult to imagine one model's being directly applicable to another situation without adaptation. Several prerequisites have been identified as essential elements of promoting a successful livestock insurance program that will form a strong platform (Shadreck, 2008). Some of these are identified below:

- A competent local project manager must be in place to ensure that all the complexities of the program are effectively handled and stakeholder obligations are met.
- A committed meteorological services authority is absolutely essential to provide timely and reliable data.
- An adequate weather infrastructure must be in place with sufficient operational weather stations.
- The distribution channel must be competent as well as committed to the project. There has to be a sophisticated understanding of technicalities of insurance and animal health, and outside expertise should be brought in supplement distributor knowledge where appropriate. There is a real need to properly research and evaluate any potential project prior to commencement.
- Ever insurance program requires well-capitalized risk carriers who have a clear understanding of the market. An understanding of data provision including the need for proxy data in some cases that increases the margin for error in pricing calculations, and profit limitations and opportunities in the rural agricultural marketplace.

Benefits of Index-Based Livestock Insurance

Weather-related risks deeply affect low-income populations through famine, displacement and devastating financial and/or property losses. As a result, these risks are a disincentive to poor families to invest in their livelihood activities, making it harder to change their economic status. Insurance is an important mechanism that allows poor households to invest in strategies with higher economic growth potential that will help shield them from the impacts of climate change. However, insurance is often not available to low-income populations because insurers do not know or cannot quantify their agricultural risks. This is especially true in locations where climate change is expected to have substantial but uncertain long-term impacts. Even where insurance is available, usually only wealthier population segments can afford it, allowing income disparity to grow.

Index-based insurance can resolve many of the inequities and challenges that are presented by traditional insurance. While traditional insurance pays based on insurance agents' individual assessments of loss, index-based insurance reduces transaction costs and avoids the problem of moral hazard by providing a system of payment that is automatically triggered when a mortality threshold is met. Index-based insurance can also provide a tool to help herders soften the impact of weather events that are made more severe by climate change. Additionally, index-based insurance provides an alternative to a reactive approach to disasters that relies mainly on domestic money diverted from other projects and international donations. This reliance often stems from a lack of understanding about risk and economic incentives and an underdeveloped insurance market. This type of diverted domestic funding can be delayed before disbursement, or can be insufficient and ineffective due to its ad hoc distribution. Even though disbursement of IBLI payouts can also be delayed, IBLI often allows for funds to be readily available as part of the insurance pool and distributed faster than emergency aid (CDKN, 2013).

To be most effective, index-based insurance should be part of a comprehensive risk management strategy that aims to reduce the risk in the livestock sector by establishing sustainable practices to better manage the pastures where livestock graze. For instance, sustainable grazing practices prevent desertification and land degradation, making livestock less vulnerable to harsh weather events. Index-based insurance provides an important method for incentivizing herders to adopt sustainable grazing practices that reduce their risk. Two options for accomplishing this are price signals (e.g., charging lower premiums for diversifying the types of livestock owned) and risk management stipulations (i.e., requiring herders to take certain actions to lower their risk as a condition of the insurance).

Index-Based Mortality Livestock Insurance in Mongolia (reproduced from CDKN, 2013)

Harsh and unpredictable weather, exacerbated by climate change, makes herders in Mongolia vulnerable to mass livestock losses. In 2010, over 50% of Mongolia's herders were affected by extreme weather, with 75,000 herders losing more than half their livestock. About 33% of the country's workforces are herders, leaving many Mongolian households – and the nation's economy – vulnerable to shocks affecting livestock populations. The Government of Mongolia's Index-Based Livestock Insurance (IBLI) Project, supported by the World Bank, developed an innovative index-based mortality livestock insurance now available in every Mongolian province. Index-based insurance programs aim to make payouts based on an index of aggregated criteria, such as livestock losses over a geographic area, rather than households' or businesses' actual, individual losses. IBLI protects Mongolian families from significant livestock loss by providing financial security, while also encouraging herders to adopt practices that build their resilience to extreme weather events. In 2012 alone, herders bought 16,000 insurance policies. This brief demonstrates how an insurance program such as IBLI can be used as part of a strategy to protect populations from climate-based risks.

Breeding and raising livestock for meat, milk and cashmere constitute an integral part of Mongolia's economy. The agriculture sector accounts for about 15% of the country's gross domestic product, and roughly 80% of the value added is livestock. In 2011, Mongolia's National Statistical Office counted about 36 million head of livestock. This large number of animals using common grazing land has led to increasing degradation of grasslands, making livestock more vulnerable to dzuds (harsh weather events that consist of drought, heavy snowfall, extreme cold and windstorms). Degraded grasslands can no longer provide sufficient vegetation, so when dzuds occur there are not enough nutrients to sustain the livestock.

Table Below Explains When and How Herders Receive Payments for Losses of Livestock (CDKN, 2013).

Livestock loss	Type of response	Function
Below the trigger point (approximately < 6 %)	None	Herders absorb these livestock losses below the trigger point because they will not affect the viability of their livelihood or reduce their adaptive capacity in the face of climate change.[xv]
Trigger point (approximately 6–30%)	Livestock Risk Insurance (LRI), (replaced the Base Insurance Product (BIP))	Herders purchase LRI for a premium from private insurance companies, which make payments when the livestock mortality rates meet the trigger point, which is the range of loss that affects the viability of herders' livelihood while also being financially feasible for insurance companies. This insurance product is meant to cover severe losses that occur about every 1–5 years. The price that the herder pays for the insurance is based on the risk associated with the species and the location – the higher the risk, the higher the cost of the insurance.
Exhaustion point met (approximately > 30%)	Disaster Response Product (DRP) (replaced by the GCC during the 2009/2010 insurance cycle)	The government provided coverage to herders who purchased the BIP or who just purchased the DRP and covered 100% of livestock losses greater than the exhaustion point. The International Debt Association financed a Contingent Debt Facility (CDF) that made payments under the DRP. The DRP was too complex and fiscally unsustainable.
	Government Catastrophic Coverage (GCC)	GCC provides government-financed insurance that prevents insurance companies from having to absorb the extremely large losses and thus keeps the cost of the insurance down. The government's financial risk is much smaller because it only covers herders who have purchased an LRI policy and only covers the insured livestock, rather than 100% of losses.

The International Panel on Climate Change (IPCC), 2012 has demonstrated that climate change is exacerbating extreme weather events worldwide and negatively impacting vulnerable populations. The IPCC's Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) has found that "a changing climate leads to changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events". The SREX case study on duds found that this impact applies to Mongolia. These more severe weather events – droughts, changes in rainfall patterns and floods – have a particularly significant impact on agriculture. An increase in temperature of almost two degrees Celsius in the past 50 years and increasingly unpredictable precipitation patterns has negatively impacted the pastures that Mongolian herders use for their livestock by increasing the intensity of droughts and duds. In addition, Mongolian herders themselves have noted how the sudden cold spells and changing rainfall patterns have caused greater livestock deaths. In order to help herders, cushion the effects of climate change and desertification, the government of Mongolia is encouraging the transfer of information and technology to herders. The government is also promoting research on sustainable herding methods to protect pasturelands, education of relevant stakeholders on adaptation methods and sustainable practices, and coordination of research and monitoring.

Understanding the Kenya Livestock Insurance Program (KLIP): Reproduced from The World Bank – ILRI Report, 2018.

Introduction

The Kenya Livestock Insurance Program (KLIP) is a Government of Kenya initiative in collaboration with County Governments, private sector actors' i.e., insurance companies with technical support from the International Livestock Research Institute (ILRI) and the World Bank. KLIP is a drought insurance program whose aim is to cushion pastoralists located in the Arid and Semi-Arid Land (ASAL) Counties of Kenya against adverse effects of forage scarcity because of severe drought. KLI P exploits remote sensing technology and innovative insurance design to bring livestock insurance to those who need it the most.

As a "Asset Protection" cover, against drought risk, KLIP aims to make payouts at the start of dry seasons following widespread failed rains and just before natural grazing/forage resources are severely depleted. This should enable pastoralists to purchase fodder, veterinary drugs and animal feeds to sustain their core breeding stock until the drought has passed and grazing conditions return to normal. At the moment, the Government is targeting vulnerable members of the ASAL communities, with fully subsidized insurance cover.

Summary of Key Features

The Risk

KLIP is a product designed to protect pastoralists and their livestock against the effects of prolonged forage scarcity. KLIP triggers payment to pastoralists when the forage situation deteriorates beyond a predetermined trigger level signaling sever forage shortage as compared to historical conditions of the specified geographical area over time.

The Index

The index in KLIP is a deviation of cumulative forage availability in the insured season. It measures forage conditions over a defined range season and it is calculated using a measure of pasture availability that is recorded by satellites. The index compares forage availability over a particular season, with the observed forage availability over a given historical period (e.g., in this case 15 years).

The Trigger

The index threshold below which payouts must be made is called the trigger level. KLIP has set the trigger at the 20th percentile. I other words, KLIP will make indemnity payments on average once every 5 seasons as determined by the historical record of forage availability over the last 1 5 years in the area.

Geographical coverage of KLIP

Currently KLIP covers 8 Countries in Kenya's ASALs, namely; Wajir, Mandera, Turkana, Garissa, Isiolo, Marsabit, Samburu and Tana River.

Geographical Clustering

The index which is the cumulative deviation of forage availability over the season is given at the insurance unit level. Provided that KLIP payments are made according to the index level, KLIP may make different payments to each insurance unit. However, every beneficiary within the same insurance unit will receive the same rate of payment (if the index is below the 20th percentile or trigger).

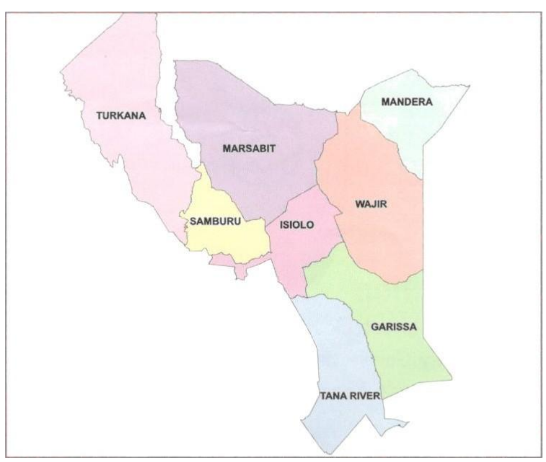


Figure. 1 KLIP Geographical coverage

Insurable Unit

KLIP covers the standards livestock types in a pastoral herd i.e. Camels, Cattle, Sheep and Goats (Shoats). The premiums are then applied to the insurable unit to arrive at the amounts payable. For an asset protection contract, the insurable unit is the amount of forage required to sustain an animal over a given season in a year of severe drought.

Sum Insured

The sum insured is the total cost of sustaining 1 Tropical Livestock Unit (TLU) throughout a drought year, multiplied by the total number of animals being insured.

For the case of the State Department of Livestock's fully subsidized program, KLIP beneficiaries are provided with :

5 TLU = 5 cattle × 14,000 = KSH[3]. 70,000

5 TLU = 50 shoats × 1400 = KSH. 70,000

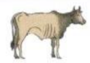
5 TLU = 3.57 camels × 19,600 = KSH. 70,000

Maximum Possible Annual Payout

An analysis of relevant data with corroboration and endorsement of key stakeholders has determined that KSH 14,000 is the amount needed to sustain 1 Tropical Livestock Unit (TLU) during severe drought conditions over the course of one year. This figure needs t0 be revised from time to time and as markets for forages, feeds, water and other relevant inputs

[3] 1 USD = 100 Kenyan Shilling (KSH)

develop.

In the case of KLIP, **1 TLU is = to 1 cow** 

The value of **1 camel**  **is 1.4 TLU.**

Therefore, the cost of sustaining 1 camel during a severe drought year is **KSH 19,600 (i.e. 1.4 x 14,000 = KSH 19,600).**

The **TLU value for 1 goat**  **or sheep**  **(shoat) is 0.1 TLU.** Therefore to get the value for **1 shoat we multiply 0.1 x 14,000 = KSH 1,400.**

Therefore, the maximum possible annual payout per **1 TLU is KSH 14,000**.

KLIP beneficiary selection

Targeting and selection of pastoralists to be listed as KLIP beneficiaries is a consultative task carried out by the Country Government bodies, the local communities and their leaders. A standard selection criterion is however provided by the State Department of Livestock i.e.,

1. The household must own a minimum of 5 TLUs and depend upon livestock for their primary source of income

2. The household must not be a beneficiary of the other government cash transfers such as Hunger Safety Net Program cash transfer program; and

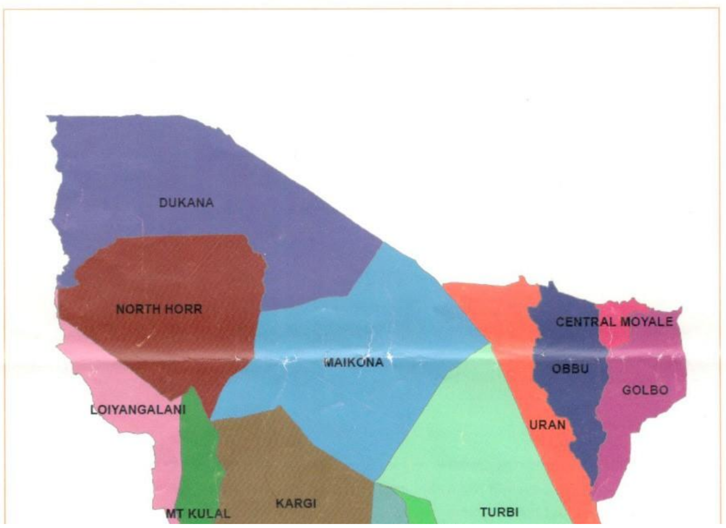
3. The household should be at least be identified by the community members vulnerable.

Minimum Payout

If there is a situation whereby the payout is very small, e.g. the payout is less than the amount of contribution paid; the insurance company will pay a minimum amount of compensation. This minimum payout could be equivalent of, but not less than, the annual contribution paid by the fund participation. Currently, the minimum payout rate is set at 5% of the insured value.

Time Coverage of KLIP For the asset protection contract, payouts are be made in August, and in February for the Long Rain Long Dry seasons and Short Rain Short Dry seasons respectively.

The Larger Marsabit County for the purpose of accurate index readings has been divided into 10 separate insurance units. These are based on the administrative units consisting of Dukana, North Horr, Maikona, Turbi, Kargi, Loyiangalani, Central Marsabit, Gadamoji, Laisamis and Mount Kulal.



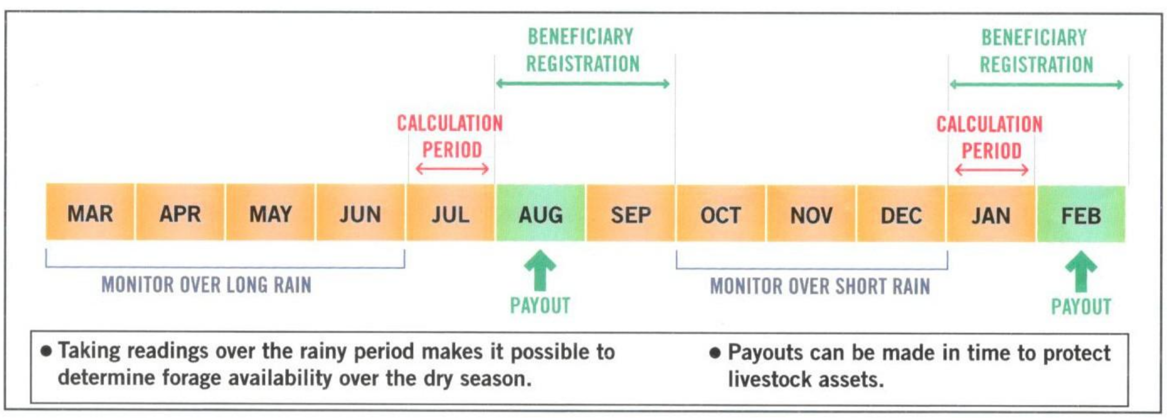


Figure 2. Different insurance units in Marsabit County.

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Climate Services

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Introduction

Increasing societal resilience and agility to deal with the negative impacts as well as windows of opportunity due to climate variability and change requires an understanding of climate, in terms of how it behaves, and how its characteristics can fluctuate and change over time. In addition, it also needs an understanding of the sensitivity of people and their livelihoods to climate conditions, the impacts of extreme conditions and the associated risks. Availability of useful, reliable, and timely information, and the ability to act on that information contribute to improved societal resilience in the face of climate variability and the capacity to adapt to changing climate, which can be realized through climate services. 'Climate services' can be defined as the timely production and delivery of useful climate data, information and knowledge to decision makers (National Research Council, 2001). To be effective, climate services should cover the full range of time and space scales of socio-economic relevance, in a manner that informs, and is informed by decision-making, risk management and resource management requirements of users.

The relationship between providers and users of climate information must be well organized and sustainable. There must be a commitment to provision of timely and high-quality information and products, addressing the requirements of the users. This requires a clear vision for climate services, and descriptions of how such services would be organized and guided, their core functions/objectives and a comprehensive list of services, from basic to advanced.

A vision for climate services

Certain principles must be common to all relevant stakeholders in their vision for climate services. Climate services should:

be 'User focused': Interaction with users and stakeholders in applied climate research, in product development and through outreach and training is critically important to the effectiveness of the climate services, and to ensuring that information and products can be easily integrated by users into their decision-systems. This interaction needs to be ongoing and sustained;

be of high quality and authoritative: Provision of sustained, reliable, unbiased climate information in the form of observed and modeled data, diagnostics (statistical descriptions of climate), monitoring products, assessments, predictions/forecasts of the future state of the atmosphere and oceans and projections (climate scenarios), at various time and space scales must be rigorous, adhering to global standards such as those set by the World Meteorological Organization (WMO) through technical regulations, guidance, manuals, etc., that ensure high quality observations, quality assured data, skillful forecasts at different time scales, and timely, uninterrupted exchange of data, information and products, developed and delivered by trained and certified personnel;

provide decision-support information: Provision of supporting information on skill, uncertainty, etc., including advice on how to interpret and optimally use the available information and products, is critical to confident use of the information by users;

communicate widely and effectively: Raising awareness of anomalous conditions, with as much lead time as possible, is needed to support effective decision-making (climate risk management), especially for public safety, protection of the environment and socio-economic security.

Organization of climate services

Climate services can be organized and delivered in several ways, based on national priorities and mandates. In some countries, there may be National Climate Centres in which most climate services are developed and delivered. In others, a suite of climate services may be performed through a group of collaborating institutions. In some cases, particularly for highly tailored services for end-users, the private sector may also play a role.

Where national capacity for delivering a broad range of climate services is at an early stage of development, especially in developing and least developed countries, WMO is undertaking establishment of a system of global and regional centres (WMO-designated

Global Producing Centres and Regional Climate Centres) that will assist countries with prediction-related information and products, with the long-term aim of strengthening their capacity in climate services.

Objectives of nationally-organized climate services must include:

i) provision of oversight on and coordination and financing of the national observing system to ensure that the networks are up-to-date, optimally distributed spatially (well-designed), well-equipped and maintained, that the observing system and its resultant observed data and metadata adhere to WMO standards, meet the needs of users, and support both national and global-scale assessments of climate and climate change;

ii) integration of global and regional data and information with national-scale data, metadata and relevant information, in well-organized and maintained archives, to support research, products and assessments for users and stakeholders, negotiations, etc.;

iii) establishment and ongoing maintenance of an operational system for development and delivery of information, products and services to stakeholders;

iv) establishment and maintenance of a platform for outreach to and interaction with user groups, for identification of user requirements, dialogue on the information, products and services, capacity-building, and for monitoring performance of the climate services from user perspective;

v) identification of the climatology of the country and relevant sub-regions, along with identification of climate extremes/hazards, to support risk assessments and climate risk management activities;

vi) development of a platform for communications with the country's policy groups, to facilitate their efforts in supporting the country's climate and climate services programmes, and international exchanges and negotiations;

vii) development of a mechanism for international communication on climate-related matters, for coordination of climate issues on regional as well as global scales;

In those countries with the capacity and mandate, climate services could include:

i) development of global/regional models for prediction/projection of climate and climate change;

ii) performance of research on earth system modelling and climate dynamics, including process studies;

iii) establishment of a mechanism to acquire and use multidisciplinary data;

iv) performance of applied climate research relevant to the interests of stakeholders in various socio-economic sectors (informed through the user-interaction mechanism noted above).

The data – an essential underpinning for all climate services

Climate Data

Climate observations (land-based, ocean-based, upper air, satellite, and remote-sensing) are essential for understanding the Earth's climate system, and for skillful prediction and projection of its future states. It is therefore essential that each country design and maintain observing networks, conduct operational data and metadata gathering, perform quality control, archive, and catalog the data. These activities are guided by WMO through its technical regulations, and its technical commissions. The WMO standards for observations, instrumentation and practices are meant to ensure that the data are robust, and provide reliable information on the climate, with minimal bias and error.

In spite of these efforts, however, it is often the case that observations made to support weather scale activities constitute the historical climate record (i.e., there are rarely separate networks operated to the higher standards preferred for climate studies). It is therefore important that National Meteorological Services (NMSs) collect and promote the use of relevant metadata on the observed data, and study the archived data to identify and biases or errors that may result from human influence (e.g. inhomogeneities related to change of site or instrumentation, instrument drift, etc.). In undertaking to provide climate services, countries increasingly need to focus on (implement) the higher standards required for climate studies.

Further, in order to make use of the wealth of climate data observed by non-NMS institutions, NMSs could take steps to improve collaboration with the relevant institutions and arrange to archive their climate data along with metadata. It would be important to note any instances of where these data would be considered 'non-standard' in terms of, for example, instrumentation, formats, flags for missing data and algorithms used, and to foster adherence to WMO standards with these alternative providers in a sustained effort for interoperability.

Socio-economic and sector-based data

Information, products and services based purely on climate data can and should be tailored to better serve the interests of the users. In addition, however, for the full range of applications that will be required, it will be necessary to acquire and work with non-climate datasets, including population statistics, human and animal health data, biological data, data on use of energy, transportation, and tourism statistics, etc. Interoperability between multidisciplinary datasets must be achieved, and for this, an effective partnership and collaboration between the various information providers is critical.

Types of climate services at national scale

A climate service at the national level identifies, produces, and delivers authoritative and timely information about climate variations and trends and their impacts on built and natural systems on regional, national, and global space scales. This information informs and is informed by decision making, risk management, and resource management concerns for a wide variety of public and private users acting on regional, national, and international scales (Miles et al., 2006).

Given the availability of data including the climate data and the relevant socio-economic and sectoral data, and the availability of a range of methods and tools including for development of various indices and products for basic to advanced tailored services for users, climate services at national levels can offer a suite of specific services covering: (1) core (basic) services and (2) advanced services.

Most NMSs offer core services for climate diagnostics and many also provide prediction at monthly to seasonal scales. The skill of such prediction is higher in some regions of the world than in others (more skill is realized in the tropics than at high latitudes at present), and concerted efforts are ongoing, including through WMO, to improve capability in climate-scale prediction through targeted research, while the countries build their service capacity and user-relationships.

Climate services can include the following:

Function	*Tasks/activities*	*Mechanisms/Outcomes*
User interaction and delivery system (client service)	Provide a service centre, including communications mechanism(s) for interface with 'clients' (users, or stakeholders)	Dialogue with and delivery to users through communications mechanisms (for output and feedback), and platforms for interaction, including National and Regional Climate Outlook Forums (NCOFs/RCOFs)
Climate diagnostics	Develop information and products based on observed and reanalysis data: statistical descriptors of climate through individual parameters and indices, including estimates of uncertainty	General products that would be of use to any sector, but also user-targeted in terms of specific parameters/indices used, timing, formats, etc. to support climate risk management
Climate monitoring	Maintain a Climate Watch, conduct analyses of climate anomalies, develop assessments of the state of the climate	Adds to the knowledge of both providers and users, and supports management of ongoing and emerging climate risks
Climate prediction	Using dynamical models, produce global- and regional-scale LRF and climate predictions (monthly to interannual time scales), and decadal scale; Using statistical approaches, produce national and sub-national empirical/calibrated climate predictions	Global climate predictions based on coupled atmosphere-ocean models are essential for regional- and national-scale climate predictions, even if relatively few countries have the capacity to run such models; Most countries should be able to use their historical climate information to develop empirical/calibrated predictions based on global/regional inputs
Climate change projections	Downscale and interpret climate change scenarios at regional and national levels, based on the available and authenticated global model projections	Information that can help users to develop effective long-term adaptation strategies
Tailored product generation for user sectors	Transformation of basic climate information to applied products, to facilitate specific as well as generic user contexts	Information that can be more readily used for decision making and climate risk management by user sectors
Education and	Develop information and	Raising awareness of

outreach	interdisciplinary training modules for awareness-raising on climate vulnerability (climate, climate impacts, climate change), and on interpretation and use of specific products	decision-makers on the ways in which climate and climate extremes can affect lives and livelihoods. Further, non-technical users will require basic instructions on how to use the available materials to best effect.
End-to-end communications	Where feasible, ensure a research through to user flow of information	Continual improvement to the climate services system

Global Framework for Climate Services (GFCS)

The World Climate Conference-3 (WCC-3) in 2009 focused on empowering decision-makers with appropriate climate information to meet society's climate-related challenges. It brought together heads of states, government ministers, industry representatives, and scientific and technical experts from many fields of practice to discuss the needs for enhanced development and delivery of climate services, and improved coordination between relevant actors. The conference concluded with strong recommendations that existing initiatives needed to be coordinated and strengthened and new infrastructure needed to be developed (Sivakumar et al., 2010; WMO, 2011). The conference called for the establishment of a Global Framework for Climate Services (GFCS; www.wmo.int/gfcs) to enable better management of the risks of climate variability and change, and adaptation to and mitigation of climate change, through the development and incorporation of science-based climate information and prediction into planning, policy, and practice.

Significant progress developing, delivering, and using climate services has been made in over more than a decade since WCC-3 and its call to establish a GFCS. Many organizations, companies, and national institutions are now actively developing climate services, and a growing number of decision-makers are keen to benefit from such services from a range of climate service providers. Hewitt et al. (2020) highlight the role of the GFCS in this worldwide effort to advance climate services, and describe successes, challenges, and potential solutions to further advance climate service development, provision, and use, which include:

- Develop (applied) science to better match scientific capability to societal needs;

- Enhance information management at the global, regional, and national scales;
- Include climate services more widely in planning and policy;
- Enhance capacity and governance along the climate services supply chain; and
- Enhance monitoring, evaluation, and knowledge management and communication.

Climate Services Information System (CSIS)

For delivering climate information effectively it is imperative that appropriate operational institutional mechanisms are in place to generate, exchange, and disseminate information globally, regionally, and nationally. The Climate Services Information System (CSIS) is the principal mechanism defined to routinely collate, store and process information about past, present and future climates. The CSIS, one of the five pillars of the GFCS, comprises a physical infrastructure of institutes, centres, and computer/information technology capabilities that, together with professional human resources, develops, generates, and distributes a wide range of climate information products and services to inform complex decision-making processes across a wide range of climate-sensitive activities and enterprises. It is how research advances and technological developments are transformed into improved operational climate information.

The implementation strategy of the CSIS is based on a three-tiered structure of collaborating institutions that will ensure that climate information and products are generated, exchanged, and disseminated in a timely manner. The immediate task for CSIS implementation is to consolidate existing climate data, products, tools, and research findings and establish an operational system encompassing core products in the areas of: (i) climate data rescue, management, and mining; (ii) climate analysis and monitoring; (iii) climate prediction; (iv) climate projection; and (v) tailoring information to specific user needs. These functions entail processes of data retrieval, analysis and assessment, re-analysis, diagnostics, interpretation, assessment, attribution, generation and verification of predictions, generation and interpretation of projections, estimation of uncertainties and communication (including exchange/ dissemination of data and products) undertaken through a global-regional-national system of inter-linked producers and providers. Formalized structures and procedures governing CSIS entities and functions are being established to ensure standardization, sustainability, reliability, and adherence to established policies and procedures. To promote best practices around the world for climate data management, monitoring, prediction, projection, and user-tailored climate information a Climate Services Toolkit (CST) is being actively developed.

Many elements of CSIS as well as CST are already in place, but concerted efforts are needed to bring together the available resources and address key gaps. Given the fact that many countries share common climate drivers (e.g., monsoons), it is imperative that a regional approach is used to implement the CSIS (Figure 1).

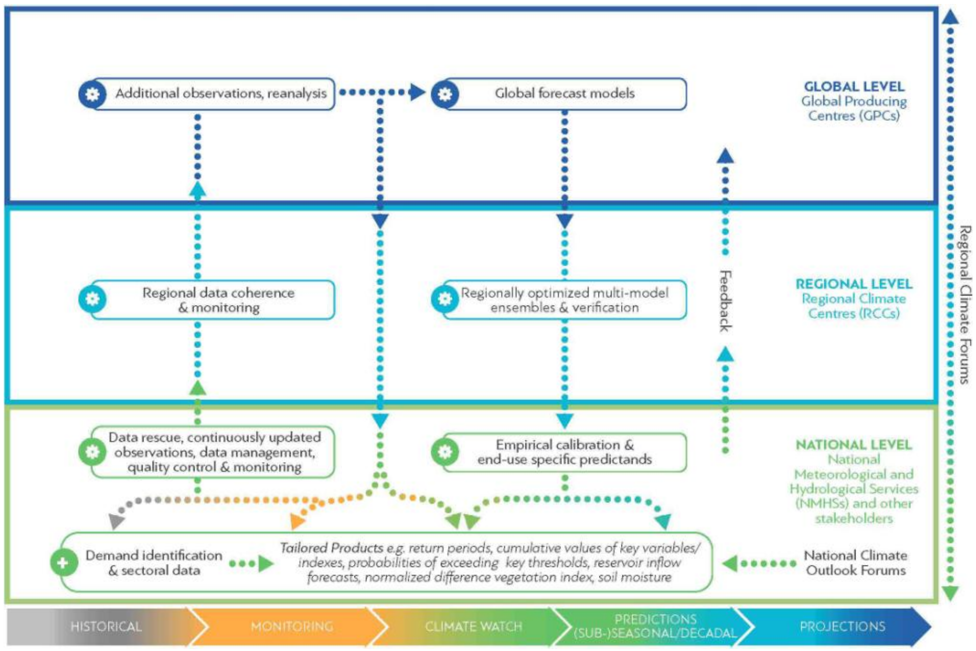

Figure 1. A regional approach to implementing the Climate Services Information System.

There has been substantial recent progress in the development of climate services in India, including the establishment of an India Meteorological Department (IMD) Office of Climate Research and Services and a WMO-designated Regional Climate Centre (RCC) in Pune and the South Asian Climate Outlook Forum (SASCOF) led by India. Further efforts are needed to develop climate forums at the state level, particularly in the local languages.

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