NAHEP ICAR NAVSARI AGRICULTURAL UNIVERSITY

Souvenir cum Compendium of National Seminar on

"Secondary Agriculture : Significance and Scope in the Era of Globalization"

November 27-29, 2019

SPONSORED BY

National Agricultural Higher Education Project (NAHEP)
Indian Council of Agricultural Research (ICAR), New Delhi

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DAIRY FARMING: CLIMATE SMART TECHNOLOGIES AND PRACTICES PERSPECTIVE

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Climate-smart agriculture (CSA) is an approach for developing actions needed to transform agricultural systems to support the development effectively and ensure food security under climate change. CSA tackles three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible.

Climate change is the most serious environmental threat to fight against hunger, malnutrition, disease, and poverty in the world. Agriculture is the most vulnerable and sensitive sector affected by climate change because of its dependency on local climate parameters like rainfall, temperature, etc. To alleviate the challenges posed by climate change, agriculture has to become "climate smart", that is, sustainably increase agricultural productivity and incomes, adapt and build resilience to climate change, and reduce or remove greenhouse gases emissions, wherever possible. Despite the recognized importance of Climate-Smart Agriculture (CSA), the dissemination and uptake of climate-smart technologies, tools, and practices in dairy farming are still largely an ongoing and challenging process. The adaption of climate-related knowledge, technologies and practices to local conditions, promoting joint learning by farmers, researchers, extension worker and widely disseminating Climate Smart Dairying (CSD) practices, is critical. There is a need for site-specific assessments to identify suitable dairy technologies and practices needed for CSD. So, the extension can play an important role in helping the farmers to cope with the diverse impacts of climate change by using an appropriate approach to create awareness and make them aware of the different adaptation and mitigation strategies in dairying.

Climatic change could affect dairy farming in several ways: productivity, in terms of quantity and quality of milk; dairy management practices, through changes of feed and fodder quantity and quality; environmental effects, in particular in relation of frequency and intensity of rainfall, temperature, reduction of crop diversity, morbidity, mortality; adaptation, as organisms may become more or less competitive, such as drought-tolerant varieties of fodder, tillering maize. To alleviate some of the complex challenges posed by climate change, agriculture (including forestry and fisheries) has to become "climate smart", that is, sustainably increase agricultural productivity and incomes, adapt and build resilience to climate change, and reduce and/or remove greenhouse gas (GHG) emissions, where possible. CSD contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is composed of three main pillars: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; reducing and/or removing greenhouse gas (GHG) emissions, where possible. Extension providers can play a major role in supporting CSD through the following: technology development and information dissemination, strengthening farmers' capacity, facilitation and brokering, and advocacy and policy support. Rural Advisory Services (RAS) contribute to achieving CSD by disseminating climate information and technologies on production practices for climate adaption through innovative approaches, such as paravets, clinics and participatory video (Digital Green, the case from India), climate-smart villages, climate training or workshops, *etc*.

IPCC, 2007 revealed that Agriculture contributes about 13.5% of global emission and in case of India INCCA, 2007 reported that agriculture contributes 18 percent of the total GHG emission. Further FAO, 2006 revealed that the agriculture animal sector is responsible for approximately 18 percent or nearly one fifth of human induced GHGs emissions. In the present time it is a crucial issue of concern to sustain the farming in view of changing climate scenario. Agriculture which is the backbone of Indian economy is an imperative source of greenhouse gases (GHGs) emission which is an important reason of global warming. Data show that agriculture is directly responsible for the release of 5100-6100 mega tonnes (Mt) carbon dioxide equivalents (COe) a year that is roughly the same as the world's transport sector and it contributes a disproportionate amount of two high impact gases, nitrous oxide (N_2O) and methane (CH_4). Agricultural practices are responsible for approximately 47 percent of human generated methane emissions and 58 percent of nitrous oxide emissions.

In this perspective, a range of practices which come under the heading of 'climate smart dairy (CSD)' could increase milk production, help dairy to become more resilient to climate change and reduce emissions of GHG. Climate smart dairy farming practices helps the world in keeping aim to meet out future demand of milk requirements without further increase in emissions. In the scenario of climatic change, adaptation is the first priority; This may involve the use of improved breed of dairy animals which have the ability to cope up with high temperatures, drier conditions etc. A wide range of measures are required to reduce the livestock sectors' climate change footprint. These include improving production and feed systems, developing new breeds of ruminants which produce less methane, introducing methods of manure management which reduce emissions, and integrating livestock with crops in order to reduce waste and improve soil fertility. Better grazing management could also do much to improve animal nutrition and reduce greenhouse gas emissions. There is also a need to consider changing feeding regimes and improving pasture management. Adaptation to short term climate variability and long term climate change also involves better risk management for example through insurance schemes and providing farmers with access to better weather forecasts.

The smallholder farming systems in India are characterized by low or fragmented land holding and livestock productivity due to unreliable, inadequate and troubled rainfall pattern, infertile soils, poor agronomic practices, undeveloped marketing channels etc. Climate smart dairy farming has the potential to provide a triple win of increasing productivity, improving resilience and mitigating climate change through the reduction of greenhouse gases (GHGs) emissions. Many practices exist, which can meet multiple demands and needs of livelihoods and agro-ecological systems whilst also contributing to an overall improved greenhouse gas balance in the dairy sector. Cows are a major source of the powerful greenhouse gas methane.

Most of this methane is formed in a cow's rumen (its first stomach) by microbes involved in the breakdown and fermentation of grass and other feeds. The bulk of it is then belched back into the atmosphere, with a single Dairy, the dairy cow, able to produce hundreds of litres of methane in a single day (over 100 kilograms over the course of a year). More emissions then arise from cattle manure and urine, from land use change and cattle feed production, and from the collection, processing and distribution of milk itself. The result is that each litre of fresh milk we purchase is responsible for the equivalent of 3 kilograms of greenhouse emissions - that's over half a kilogram per standard glass of milk. For most consumers, their direct role in this hefty footprint might seem minor. Yes, there's the transport of milk from store to home, and the electricity we use to power our refrigerators, but these amount to less than a tenth of the total. Where we can really dent the life cycle emissions of milk (and in this case it's a very deep dent) is through less waste.

Other than these all improved manure management practice also allows to reduce the loss of nutrients through vaporization and mainly helps in reduction of methane (CH_4) and nitrous oxide (N_2O) emissions. But main challenge of climate smart dairy farming remains in its implementation especially in case of small holder dairy farmers. Other major challenges in the area are the existing poor land management practices, knowledge and information gaps and missing training opportunities on good dairy farming practices as well lack of access to necessary inputs, tools, equipment and credit facilities. All kind of climate smart dairy farming practices are not suitable for every region as it largely depends on various contexts. However, for further, climate smart dairy farming practices needs to be put into practice with paid attention so that in this changing climate scenario also dairy farming can sustain with ensured food security.

Impact of climate change on livestock productivity

Livestock play a major role in the agricultural sector in developing nations, and the livestock sector contributes 40% to the agricultural GDP. Global demand for foods of animal origin is growing and it is apparent that the livestock sector will need to expand (FAO, 2009). Livestock are adversely affected by the detrimental effects of extreme weather. Climatic extremes and seasonal fluctuations in herbage quantity and quality will affect the well-being of livestock, and will lead to declines in production and reproduction efficiency (Sejian, 2013).

Climate change is a major threat to the sustainability of livestock systems globally. Consequently, adaptation to, and mitigation of the detrimental effects of extreme climates has played a major role in combating the climatic impact on livestock (Sejian *et al*., 2015a). There is little doubt that climate change will have an impact on livestock performance in many regions and as per most predictive models the impact will be detrimental. Climate change may manifest itself as rapid changes in climate in the short term (a couple of years) or more subtle changes over decades. Generally climate change is associated with an increasing global temperature. Various climate model projections suggest that by the year 2100, mean global temperature may be 1.1-6.4 °C warmer than in 2010. The difficulty facing livestock is weather extremes, e.g. intense heat waves, floods and droughts. In addition to production losses, extreme events also result in livestock death (Gaughan and Cawsell-Smith, 2015). Animals can adapt to hot climates, however the response mechanisms that are helpful for survival may be detrimental to performance. In this article we make an attempt to project the adverse impact of climate change on livestock production.

Cows, like humans, don't like it too hot. If the temperature begins to push up into the high 20s Celsius (80s Fahrenheit) then heat stress impacts may start to show. First the cow becomes lethargic and sweaty, her breaths becoming shallower and faster. As temperatures move into the 30s Celsius she may start to pant and her production of milk plummet. Without relief from the heat cow may die. Modern dairy cows tend to be more susceptible to heat stress, as their high feed intakes, sizes and growth rates mean they generate more body heat. Heat stress can also lead to a weakened immune system and the spread of diseases like mastitis. Historically these kinds of hot weather impacts were only a big problem for cows in warm and tropical climates, but increasing temperatures at higher latitudes including the US, Canada and Europe-have increased the risks to cattle there too.

The negative effects of increased temperature on feed intake, reproduction and performance on various livestock species is something that is reasonably well understood. For example, for most livestock species, such as cattle, sheep, goats, pig and chickens, temperatures between 10 and 30°C is when they perform the best. But for each 1°C increase above that, all species reduce their feed intake by 3-5 percent. Without a doubt, this will have far reaching effects on the quality and quantity of livestock species. Increase in temperatures will also spell widespread negative impacts on forage quality and as a consequence, livestock productivity.

Waterlogged soils may make pasture land less productive and much more vulnerable to damage by grazing. In very wet years farmers are forced to keep their herds indoors for longer, meaning more reliance on cattle feed. Availability and quality of forage and feed itself can also suffer in really wet years, with higher costs and lower milk yields as a result. Indeed, in many areas of the world there is a risk that future climate change impacts combined with a carbon dioxide-enriched atmosphere will mean big reductions in the quality of forage.

Direct effects of climate change on livestock

The most significant direct impact of climate change on livestock production comes from the heat stress. Heat stress results in a significant financial burden to livestock producers through decrease in milk component and milk production, meat production, reproductive efficiency and animal health. Thus, an increase in air temperature, such as that predicted by various climate change models, could directly affect animal performance.

Indirect effects of climate change on livestock

Most of the production losses are incurred via indirect impacts of climate change largely through reductions or non-availability of feed and water resources. Climate change has the potential to impact the quantity and reliability of forage production, quality of forage, water demand for cultivation of forage crops, as well as large-scale rangeland vegetation patterns. In the coming decades, crops and forage plants will continue to be subjected to warmer temperatures, elevated carbon dioxide, as well as wildly fluctuating water availability due to changing precipitation patterns. Climate change can adversely affect productivity, species composition, and quality, with potential impacts not only on forage production but also on other ecological roles of grasslands (Giridhar and Samireddypalle, 2015). Due to the wide fluctuations in distribution of rainfall in growing season in several regions of the world, the forage production will be greatly impacted. With the likely emerging scenarios that are already evident from impact of the climate change effects, the livestock production systems are likely to face more of negative than the positive impact. Also climate change influences the water demand, availability and quality. Changes in temperature and weather may affect the quality, quantity and distribution of rainfall, snowmelt, river flow and groundwater. Climate change can result in a higher intensity precipitation that leads to greater peak run-offs and less groundwater recharge. Longer dry periods may reduce groundwater recharge, reduce river flow and ultimately affect water availability, agriculture and drinking water supply. The deprivation of water affects animal physiological homeostasis leading to loss of body weight, low reproductive rates and a decreased resistance to diseases (Naqvi *et al.*, 2015). More research is needed into water resources' vulnerability to climate change in order to support the development of adaptive strategies for agriculture. In addition, emerging diseases including vector borne diseases that may arise as a result of climate change will result in severe economic losses.

Impact of climate change on livestock production

Animals exposed to heat stress reduce feed intake and increase water intake, and there are changes in the endocrine status which in turn increase the maintenance requirements leading to reduced performance (Gaughan and Cawsell-Smith, 2015). Environmental stressors reduce body weight, average daily gain and body condition of livestock. Declines in the milk yield are pronounced and milk quality is affected: reduced fat content, lower-chain fatty acids, solid-non-fat, and lactose contents; and increased palmitic and stearic acid contents are observed. Generally the higher production animals are the most affected. Adaptation to prolonged stressors may be accompanied by production losses. Increasing or maintaining current production levels in an increasingly hostile environment is not a sustainable option. It may make better sense to look at using adapted animals, albeit with lower production levels (and also lower input costs) rather than try to infuse 'stress tolerance' genes into non-adapted breeds (Gaughan, 2015).

Impact of climate change on livestock reproduction

Reproductive processes are affected by thermal stress. Conception rates of dairy cows may drop 20–27% in summer, and heat stressed cows often have poor expression of oestrus due to reduced oestradiol secretion from the dominant follicle developed in a low luteinizing hormone environment. Reproductive inefficiency due to heat stress involves changes in ovarian function and embryonic development by reducing the competence of oocyte to be fertilized and the resulting embryo (Naqvi *et al.*, 2012). Heat stress compromises oocyte growth in cows by altering progesterone secretion, the secretion of luteinizing hormone, follicle-stimulating hormone and ovarian dynamics during the oestrus cycle. Heat stress has also been associated with impairment of embryo development and increase in embryonic mortality in cattle. Heat stress during pregnancy slows growth of the foetus and can increase foetal loss. Secretion of the hormones and enzymes regulating reproductive tract function may also be altered by heat stress. In males, heat stress adversely affects spermatogenesis perhaps by inhibiting the proliferation of spermatocytes.

Impact of climate change on livestock adaptation

In order to maintain body temperature within physiological limits, heat stressed animals initiate compensatory and adaptive mechanisms to re-establish homeothermy and homeostasis, which are important for survival, but may result reduction in productive potential. The relative changes in the various physiological responses i.e. respiration rate, pulse rate and rectal temperature give an indication of stress imposed on livestock. The thermal stress affects the hypothalamic–pituitary–adrenal axis. Corticotropin-releasing hormone stimulates somatostatin, possibly a key mechanism by which heat-stressed animals have reduced growth hormone and thyroxin levels. The animals thriving in the hot climate have acquired some genes that protect cells from the increased environmental temperatures. Using functional genomics to identify genes that are up- or down-regulated during a stressful event can lead to the identification of animals that are genetically superior for coping with stress and to the creation of therapeutic drugs and treatments that target affected genes (Collier *et al.*, 2012). Studies evaluating genes identified as participating in the cellular acclimation response from microarray analyses or genome-wide association studies have indicated that heat shock proteins are playing a major role in adaptation to thermal stress.

Impact of climate change on livestock diseases

Variations in temperature and rainfall are the most significant climatic variables affecting livestock disease outbreaks. Warmer and wetter weather (particularly warmer winters) will increase the risk and occurrence of animal diseases, because certain species that serve as disease vectors, such as biting flies and ticks, are more likely to survive year-round. The movement of disease vectors into new areas e.g. malaria and livestock tick borne diseases (*babesiosis, theileriosis, anaplasmosis*), Rift Valley fever and bluetongue disease in Europe has been documented. Certain existing parasitic diseases may also become more prevalent, or their geographical range may spread, if rainfall increases. This may contribute to an increase in disease spread for livestock such as ovine chlamydiosis, caprine arthritis (CAE), equine infectious anemia (EIA), equine influenza, Marek's disease (MD), and bovine viral diarrhea. There are many rapidly emerging diseases that continue to spread over large areas. Along with the wetter winters and more extreme rainfall events may come the less visible but far more dangerous threat of disease. Dairy cows are valuable animals and farmers will try all they can to keep them well. Despite precautions, diseases like Foot and Mouth have devastated herds in recent years. In 2007, discovery of Blue Tongue in British livestock again caused widespread concern. This viral disease is spread by midges and had emerged in North Western Europe the previous year. It is spread most rapidly in warm and wet conditions, with its 2006 outbreak being attributed to the warming that has occurred in this region over the past 50 years. Outbreaks of diseases such as foot and mouth disease or avian influenza affect very large numbers of animals and contribute to further degradation of the environment and surrounding communities' health and livelihood.

Liver flukes are flat parasitic worms that mainly affect cattle and sheep. Even a light infection can damage liver function and reduce productivity-a heavy infection can kill the host animal. These parasites rely on a life cycle that starts off with eggs produced by the adult flukes in a cow's liver being excreted along with manure. If temperatures are high enough (over 10 degrees Celsius) the eggs develop quickly and produce the first microscopic mobile stage of the parasite. These then search out and infect the water snails common to many wet, low-lying grasslands. Within the snails the parasites grow and multiply fast (the warmer it is the faster they develop). After around 6 weeks the second mobile stage is released and these spread through the vegetation where they become infective cysts waiting for the next passing cow or sheep to chomp down on them. As several countries have experienced warmer conditions and more flooding of grasslands, so the liver fluke parasites and their water snail vectors have flourished. More intense summer droughts have the potential to limit them in some areas in the future, but a trend of higher temperatures and more extreme rainfall risks enhancing the spread and impact of liver flukes

Effect of climate variability and change on livestock status

Climate can affect livestock both directly and indirectly (Adams *et al.*, 1999, McCarthy *et al.*, 2001). Direct effects from air temperature, humidity, wind speed and other climate factors, influence animal performance such as growth, milk production, wool production and reproduction. Climate can also affect the quantity and quality of feedstuffs such as pasture, forage and grain, and the severity and distribution of livestock diseases and parasites. Indian livestock productivity has been severely affected by vector-borne livestock diseases which are known to be climate sensitive (Ford and Katondo, 1977). The direct effects of climate change could translate into the increased spread of existing vector-borne diseases and parasites, accompanied by the emergence and circulation of new diseases.

The climate change and variability may also affect the desirability of livestock. Livestock net revenues, number of livestock per farm, and earnings per livestock are all highly sensitive to climate as livestock income rises for small farms as temperatures rise but falls for large farms (Niggol and Mendelsohn, 2008). Loss of resources due to climatic extremes may heighten the vulnerability of livestock systems and reinforce existing factors that are affecting livestock production systems, such as rapid population and economic growth, rising demand for food (including livestock) and products, conflict over scarce resources (land tenure, water, biofuels, etc). For rural communities, losing livestock assets during climatic hazards could trigger a collapse into chronic poverty and have a lasting effect on livelihoods.

The impacts of climate change also depend on the rainfall which generally affects crop and grassland productivity, ultimately affecting livestock net income (Niggol and Mendelsohn, 2008). There are three plausible explanations. First, farmers shift to crops as rainfall increases; second, grassland shifts to forests as rain increases, reducing the quality and quantity of natural grazing for most animals; and third, increases in precipitation increase the incidence of certain animal diseases (Niggol and Mendelsohn, 2008).

Adaptation and mitigation strategies to climate change/variability

As a rule of thumb, where the welfare of dairy cows goes up greenhouse gas emissions come down. 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 climate change on animal responses and performance. Different managemental options for reducing the effect of thermal stress are:

I. Genetic Approach

Breeding cows that are all or mostly from Holstein stock makes sense for increasing milk yields. The downside is that more milk production may come at the cost of other desirable traits, like high fertility. The same large size and fast metabolism of Holstein cows that allows them to produce so much milk can also make them more susceptible to overheating and so more vulnerable to heat stress. Many local breeds are having valuable adaptive traits that have developed over a long period of time which includes

- Tolerance to extreme temperature, humidity etc
- Tolerance /resistance to diseases
- Adaptation to survive, regularly produce/ reproduce in low/ poor management conditions and feeding regimes.

Hence, Genetic approach to mitigate the climate change should include measures such as

1. Identifying and strengthening the local genetic groups which are resilient to climatic stress/ extremes
2. Genetic selection for heat tolerance or bringing in types of animals that already have good heat tolerance and crossbreeding the local genetic population with heat and disease tolerant breeds.
3. Identifying the genes responsible for unique characteristics like disease tolerance, heat tolerance, ability to survive in low input conditions and using it as basis for selection of future breeding stock will help in mitigating the adverse effect of climate stress.
4. Breeding management strategies: Changing the breeding animal for every 2-3 years (exchange from other district herd) or artificial insemination with proven breed semen will help in enhancing the productivity. This may be supplemented with supply of superior males through formation of nucleus herd at block level. Synchronization of breeding period depending on the availability of feed and fodder resources results in healthy offsprings and better weight gain. Local climate resilient breeds of moderate productivity should be promoted over susceptible crossbreds.

Further selection for and introduction of genetic traits - like heat tolerance, higher yields or disease resistance—all have the potential to deliver climate-smart milk. The real challenge is in finding the combination that works best for the specific locations and local circumstances of different dairy farms in a rapidly changing climate. In India, with small flock sizes, large fluctuations in rearing conditions and management between flocks, and over time within a flock, lack of systematic livestock identification, inadequate recording of livestock performances and pedigrees, and constraints related to the subsistence nature of livestock rearing (where monetary profit is not the most important consideration), the accuracy of selection will be much lower, resulting in even lower rates of genetic gain. However, locally adapted breeds are likely to be highly variable and the highest performing animals of such breeds can have great productive potential. Therefore, the screening of livestock populations previously not subjected to systematic selection is likely to give quicker results to provide high genetic merit foundation stock for nucleus flocks.

Genetic improvement, to be successful, usually needs to be accompanied by improvements in nutrition, health and management. However, while improvements in these other components of livestock production give short-term benefits and incur ongoing expenses, genetic improvement is permanent and is passed on from one generation to the next automatically so long as the improved animals are used for breeding and their progeny retained for further breeding.

II. Nutritional Adjustments

Beyond cow welfare and genetics, climate-smart milk relies on the whole dairy production system. If a new wonder feed wipes out livestock methane, but generates even bigger greenhouse gas emissions through its own production, then the climate benefit is lost. All cereals and crops have carbon footprints, so if they are then used to feed cattle this is added to the life cycle emissions of the milk we eventually drink. In most cases though, cuts in dairy cow methane from improved feed will still outweigh the emissions from the feed itself. For many rangeland cows in the developing world the food they forage is wild-grown and inedible to humans. These browsing herds are effectively creating milk from 'zero carbon' feed, but often with hefty methane emissions in between thorny bush and milk churn, and so a big overall carbon footprint. The feed intake by the livestock during thermal stress is significantly lower than those in comfort zone. Hence, the care should be directed towards providing more nutrient dense diet while will help to minimize production losses due to the high temperatures as well as those feed which generates less heat during digestion. This can be achieved by following measures:

- Feeding dietary fat remains an effective strategy of providing extra energy during the time of negative energy balance. Incorporation of dietary fat at level of 2 – 6 % will increase dietary energy density in summer to compensate for lower feed intake.
- Adjusting animals' diets to minimize diet-induced thermo genesis (low fibre and low protein diets). High-fiber diets generate more heat during digestion than lower fiber diets.
- Using more synthetic amino acids to reduce dietary crude protein levels. Excessive dietary protein or amino acids generate more heat during digestion and metabolism.
- Feeding of antioxidant (Vitamin A, C & E, selenium, Zinc) reduces the heat stress and optimize feed intake.
- Addition of feed additives/vitamins and mineral supplementations that helps in increasing feed intake, modify gut microbial population and gut integrity and maintain proper cation and anion balance.
- During lean/drought periods, shepherds migrate along with their animals in search of fodder. This migration sometimes creates social conflicts with local people for available scarce fodder resources. Further, this could invite new diseases and parasites which pose health problems in small ruminants. Protein is the first limiting nutrient in many grazing forages and protein availability declines in forages as the plant matures towards the end of winter season. When daytime temperatures and humidity are elevated, special precautions must be taken to keep livestock comfortable and avoid heat stress. Allow for grazing early in the morning or later in the evening to minimize stress.
- Concentrate mixture (18% DCP and 70% TDN) prepared with locally available feed ingredients should be supplemented to all categories of animals. When no green fodder is available, addition of vitamin supplement in concentrate mixture helps in mitigating heat stress.
- Further, in extreme conditions, energy intake becomes less compared to expenditure as the animal has to walk more distance in search of grazing resources which are poor in available nutrients. Hence, all the animals should be maintained under intensive system with cut and carry of available fodder. The concept of complete feed using crop residues (60%) and concentrate ingredients should be promoted for efficient utilization of crop residues like red gram stalk, etc. Further, productivity and profitability from ruminants can be increased by strengthening feed and fodder base both at village and household level with the following possible fodder production options.

III. **Managemental interventions:**

1. **Water supply:** Animals must have access to large quantities of water during periods of high

environmental temperatures. Much of the water is needed for evaporative heat loss via respiration to help them cool off. Hence, provision has to be made for supply of continuous clean, fresh and cool water to the animals. Cleaning the feeding trough frequently and providing fresh feed will encourage the animals to take more feed. Splashing the cool water over the animals at regular intervals during the hot period will reduce the heat stress.

2. **Feeding time:** Providing feed to the animals during cool period i.e. evening or night will improve the feed intake by the animals. Likewise, providing additional drinking water supplies and shifting feeding times, so that cows are not all feeding during the hottest parts of the day, will cut heat stress risks.
3. **Stocking density:** Reducing the stocking density during hot weather will help the animals in dissipating the body heat more efficiently through manifestation of behavioural adaptation. Just as heat wave warnings are now widely used to reduce risks to human health, so such warnings can help livestock farmers get plans in place to protect their herds. Reducing the numbers of cows held in confined spaces like milking parlours can be a good way to allow heat to disperse more easily. Even the cattle feed itself can be modified to make it more energy-dense and so reduce how much extra body heat is produced as it is digested. In fact, changing what cows eat has a peculiar strand of food and climate change science all of its own.
4. **Shade:** The use of shades is an effective method in helping to cool animals. Shades can cut the radiant heat load from the sun by as much as 40%. Shades with straw roofs are best because they have a high insulation value and a reflective surface. Uninsulated aluminium or bright galvanized steel roofs are also good. The best shades have white or reflective upper surfaces. Provision of trees at certain distance from the shed which will provide shade to the animals. Shifting the animals to cool shaded area during the hot climatic conditions.
5. Provision of vegetative cover over the surrounding area will reduce the radiative heat from the ground. The surface covered with green grass cover will reflect back 5-11% of solar radiation as compared to 10-25% by dry bare ground and 18-30% by surface covered by dry sand adding to thermal stress.
6. Provision of elongated eaves or overhang will provide shade as well as prevent rain water from entering the sheds during rainy season.
7. **Ventilation:** increasing the ventilation or air circulation in the animal sheds will aid the animals in effective dissipation the heat. The air circulation inside the shed can be increased by keeping half side wall i.e., open housing system, use of fan, increasing the height of the building etc.
8. Many introduced shading in feeding, drinking and corral areas to give cows plenty of opportunities to seek respite from the sun when they need it. Others use water sprayers and misters—as long as water supplies allow it—to cool the cows by evaporation. Some farms even employ large fans in the holding areas outside milking parlours, to keep air moving and temperatures down.

IV. Manure management

Cow manure is itself a globally important source of methane, while both it and cow urine are rich in nitrogen and so contribute to emissions of the powerful greenhouse gas nitrous oxide too. For dairy farmers, improved manure and urine management can turn this animal waste burden into a climate-smart blessing. In areas where cows congregate (e.g. in cattle sheds and outside milking parlours) the waste can be collected. This avoids the risk of it being washed into drainage waters by heavy rain or emitting large amounts of ammonia to the air on hot days. The collected waste is then a valuable feedstock for anaerobic digestion -the deliberate production and capture of methane for use as an energy source. Many farms already do this, using the biogas to heat buildings, generate electricity, or even to pump into the wider gas supply network. The residues from the anaerobic digester then make an excellent soil improver to apply back on the fields and substitute for artificial fertilisers. Even where anaerobic digestion is not an option, separating the manure and urine into covered storage often reduces air and water pollution problems. Methane will still be produced though, and aerating the manure, reducing storage times or even destroying the methane by flaring, have all been suggested as ways of reducing its climate impact. Cow diet can affect these waste emissions too. Ironically, the same nitrate supplements that inhibit gut methanogens may boost nitrous oxide production in the cow's manure and urine - potentially just swapping the climate change penalty of milk from one place and gas to another. The final big opportunities for climate-smart milk on the farm come in the way manures and fertilisers are applied, and the ways the cows use their fields. Getting the timing and amounts of manure and fertiliser right maximises how much of the nitrogen it contains is used by the grass or crops, and so minimises losses to air and water. For cow behaviour, keeping them away from waterlogged areas and streams, regularly moving feeders and drinkers about, and placing field gates at the top of slopes (where it's usually drier) can all help to reduce the compaction and 'poaching' of soils, and so the pollution and greenhouse gas emissions that result.

V. **Other interventions**

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

B. **Intensive fodder production systems**: Growing of two or more annual fodder crops as sole crops in mixed strands of legume (Stylo or cowpea or hedge Lucerne, etc) and cereal fodder crops like sorghum, ragi in rainy season followed by berseem or Lucerne etc., in rabi season in order to increase nutritious forage production round the year. Fodder crops like *Stylosanthes hamata* and *Cenchrus ciliaris* can be sown in the inter-spaces between the tree rows in orchards or plantations as horti-pastoral and silvo-pastoral systems for fodder production.

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

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

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

F. **Agro-forestry**: Out in the fields there is often an opportunity to use the natural shading and shelter provided by trees to increase hot weather resilience—dairy cows given such shaded areas have shown reduced panting and heat stress symptoms. Though, as we saw with Assam's tea gardens, the integration of trees with agriculture (agro-forestry) is most commonly associated with growing crops, trees are a successful part of livestock systems around the world too. Tree shelterbelts around fields can reduce the impacts of extreme weather events, including storms, intense rainfall, and extremes of heat and cold. For areas of intensive agriculture they also represent an important opportunity to sequester more carbon dioxide from the atmosphere without having to lose productive farmland. Some farmers have extended the benefits of livestock agroforestry to include extra forage for the animals, a source of biofuel for energy generation, and even as a natural filter for pollutants—the trees can help reduce nitrate leaching to drainage streams and capture ammonia emissions to the atmosphere.

Specific mitigation measures

Excess production of methane in the rumens of dairy cows is bad both for our climate and for dairy farmers. The microbes that produce the methane—methanogens—make use of the carbon dioxide and hydrogen generated as feed is fermented and digested. With harder-to-breakdown food, such as straw, more hydrogen is generated and so methane emissions tend to increase. Providing dairy cows with higher quality feeds and forages can therefore mean less of the food is converted into methane and more of it into milk. Scores of different feed and forage types have been assessed in terms of the methane penalties they incur. Improving feed quality remains one of the standout strategies in efforts to boost production and reduce the carbon footprint of livestock. Yet, many farmers either do not have access to better feeds or their cattle range far and wide, making controlling what they eat near-impossible. For those dairy farmers with closer control of the diet of their herds, and access to the latest feed mixes, there are some extra weapons in the methane-targeting armoury available. While higher quality feeds shift digestion away from the hydrogen production the methanogens rely on, a host of feed additives can also be used to divert the hydrogen supply or even to target the methane-producing microbes themselves. The impacts of adding tea, garlic, seaweed extracts, cinnamon, curry spice and oregano work by directly inhibiting the methanogens. Others, like nitrate and sulphate additives, work by competing with the methanogens for any available hydrogen in the cow's rumen can be impressive—cuts in methane of over three-quarters. They may also be short-lived. But, with prolonged exposure, the methane-producing microbes often become resistant to the effects of the additives. Too much use of nitrate additives can even prove toxic for the cows themselves. Fats, especially those rich in fatty acids like sunflower oil, are able to reduce methane and the amount of heat generated during digestion. These dietary fats can be derived from many natural sources, including algae. They also avoid many of the public health issues associated with artificial methanogen inhibitors like antibiotics—an antibiotic called monensin is widely used in livestock feed to boost growth and cut methane emissions, but is banned in Europe due to concerns around the spread of antibiotic resistance. Where antibiotics have a less controversial role in delivering climate-smart milk is in fighting disease. Together with improved veterinary care and animal health extension services, access to livestock medicines can vastly increase resilience to diseases and parasites that would otherwise attack cattle. So, a healthy and happy cow is usually a more climate-resilient and lower-emissions cow.

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