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Climate Resilient Livestock Production

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Preface

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has overwhelmingly confirmed that climate change is real, irreversible, will become worse, and in large part, caused by anthropogenic activities. Climatic change in terms of increase in earth's near surface temperature, erratic changes in seasonal patterns, increase in frequency of extreme climatic events like heat waves, droughts, floods and precipitation are emerging as the new challenges for crop and livestock production. Climate change is projected to reduce renewable surface water and ground water resources in most dry subtropical regions, where livestock is the mainstay of rural economy. To achieve the Sustainable Development Goals adopted by United Nations, fruitful and efficient use of natural resources holds the key.

The climate change impacts are visible all over the world, but India is categorized among the most vulnerable areas. Almost 70 percent of livestock in India is owned by small and marginal farmers and landless labourers, and the animals of these resource poor livestock owners are more vulnerable to climate change and are at greater risk. Limiting the effects of climate change is necessary to achieve sustainable development and equity, including poverty eradication. The direct and indirect impacts that climate change will bring about are expected to exacerbate the vulnerability of livestock systems and to reinforce existing factors that are simultaneously affecting livestock production systems, such as rapid population and economic growth, increased demand for livestock food products.

To address the issue of impact of climate change on livestock production and health and work out the strategies and actions that can be pursued to move towards climate resilient pathways for sustainable livestock development, while at the same time helping to improve livelihoods, social and economic well being and responsible environmental management, the National Academy of Agricultural Sciences organized a Brain Storming Session on Climate Resilient Livestock Production. Useful recommendations have been made on climate resilient pathways, which are sustainable-development trajectories that combine adaptation and mitigation to reduce impacts of climate change. Adaptation-mitigation pathways and transformational approach to withstand the effects of climate change in short and long term have been recommended. Effective implementation of policies and actions that promote sustainable development and reduce poverty will improve adaptation pathways for livestock production and will also pave the way for more effective climate change mitigation.

The Academy appreciates the efforts of Dr Khub Singh for convening this important session. Grateful thanks are due to co-conveners, the participants, resource persons, reviewers and editors for their valuable contributions in the preparation of this policy document.

S. Ayyappan
President

Climate Resilient Livestock Production

1. INTRODUCTION

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 primarily dependant on crop - livestock production systems. Almost 70 per cent of livestock in India is owned by small and marginal farmers, and landless labourers. The animals of these resource poor livestock owners are most vulnerable to climate change and are at greater risk since they do not possess necessary means for adaptation and mitigation. Due to financial constraints and unawareness about latest technologies the livestock systems are even more vulnerable to impacts of adverse climatic conditions.

2. SIGNIFICANCE OF CLIMATE FOR LIVESTOCK PRODUCTION

Maintenance of homeothermy and homeostasis is mandatory for animals to survive, produce and reproduce. The animals are not able to maintain their optimum production even in the whole range of environmental temperatures of zone of homeothermy because some energy is wasted in using the thermoregulatory mechanisms. The animals can express their full genetic production potential only within a narrower range of environmental temperature *i.e.* zone of thermo-neutrality, within which metabolic rate is independent of environmental temperature. The range of environmental temperature for zone of homeothermy and zone of thermo-neutrality is different for animals of different species and of breeds within same species. The upper limit of the zone of thermo-neutrality *i.e.* upper critical temperature is of more significance in tropical and subtropical climate. The information on upper critical temperature for most of the species and breeds of farm animals in India is meagre. The upper critical temperature is lower in exotic breeds and their crosses with indigenous breeds in comparison to pure indigenous breeds. The upper critical temperature for Haryana bulls is 32.0⁰C but for its crosses having 50 percent exotic blood of Holstein Friesian, Brown Swiss and Jersey is 26.5⁰C, 27.5⁰C and 29.0⁰C, respectively (Singh and Bhattacharyya, 1991). Upper critical temperature is at lower level in high producing animals in comparison to that in low producing animals of same species / breed because of greater heat load of higher basal metabolic rate. Singh and Bhattacharyya (1985) reported higher resting metabolic rate in crosses of Haryana with exotic breeds in comparison to Haryana bulls. Increase in humidity at higher ambient temperatures is more stressful for the animals thereby lowering the upper critical temperature. Environmental temperature is the most important climatic factor followed by humidity, radiation and wind velocity in imposing stress and direct impact on livestock production. If the animal is not able to get rid of the access heat load even by exhausting thermoregulatory mechanism, it tries to reduce the internal heat production by curtailing the feed intake. Reduction in the feed intake affects production adversely. Temperature humidity index (THI) value up to 72 is optimum for milk production. In a situation where thermoregulatory mechanisms are insufficient to maintain homeothermy even survivability is threatened due to failure of homeostatic mechanism.

Indigenous breeds of cattle, buffalo, sheep, goat and other farm animals have adapted to tropical and subtropical climate through natural selection over generations and also man made selection. Breeds that are more heat tolerant are generally those that have lower productivity levels, which is likely the mechanism by which they are able to survive as a dominant regional breed. There is wide variation in heat tolerance between breeds and between animals within the same breed (Singh and Bhattacharyya, 1990, Singh et al., 1992, Singh and Saxena, 1995).

3. CLIMATE CHANGE

Anthropogenic GHG emissions have increased from 27 to 49Gt CO_2 eq. / year between 1970 and 2010 (IPCC, 2014). Cumulative CO_2 emission associated with agriculture, deforestation, and other land use (AFOLU) has increased from about 490Gt CO_2 in 1970 to 680Gt CO_2 in 2010. Total GHG emission from livestock in world increased from 1769 $\times10^9$ kg CO_2 eq. in 1961 to 2771$\times10^9$ kg CO_2 eq. in 2010. This increase in India was from 225 $\times10^9$ kg CO_2 eq. in 1961 to 392 $\times10^9$ kg CO_2 eq. in 2010 (Patra, 2014). The contribution of enteric methane emission from livestock in world was estimated to be 1537.5 $\times10^9$ kg CO_2 eq. in 1961 and 2372.5 $\times10^9$ kg CO_2 eq. in 2010. The corresponding values for India have been estimated as 209.5 $\times10^9$ kg CO_2 eq. in 1961 and 357.5 $\times10^9$ kg CO_2 eq. in 2010, respectively. Estimates of methane emissions from manure of world livestock were 170.25 $\times10^9$ kg CO_2 eq. in 1961 and 285.35 $\times10^9$ kg CO_2 eq. in 2010 and for India the respective values were 13.0 $\times10^9$ kg CO_2 eq. and 27.4 $\times10^9$ kg CO_2 eq. respectively. Of most concern in the anthropogenic factors is CO_2 emissions from fossil fuel combustion and industrial processes which together contributed 78% of total GHG emissions increase from 1970 to 2010.

In India there is an overall decrease in the seasonal mean rainfall. But an increase in extreme rainfall events has occurred over the central India and in many other areas. There are more land regions where the number of heavy precipitation events has increased than where it has decreased. Over the period 1901 to 2010, global mean sea level rose by 0.19m. Total anthropogenic greenhouse gas (GHG) emissions have continued to increase over 1970 to 2010 with larger absolute increase between 2000 and 2010, despite a growing number of climate change mitigation policies.

For South Asia the projected increase in temperature in both mid and late 21st century in most stringent mitigation scenario (RCP 2.6) is around 2ºC from that in late 20th century with the exception of change between 2ºC and 3ºC over the highest latitudes. The corresponding increase in temperature in worse scenario (RCP 8.5) is projected to be more than threefold *i.e.* global 3.7ºC and south Asia more than 7ºC. Virtually certain there will be more frequent hot extremes over most land areas on daily and seasonal time scale as global mean temperature increases. It is also very likely that heat waves will occur with a higher frequency and duration. Changes in the global water cycles response to warming over 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase. In many mid-latitudes and sub-tropical dry regions, mean precipitation is likely to decrease; while in many mid-latitude wet regions, mean precipitation is expected to become more intense and more frequent by the end of the century, as global mean temperature increases. Global mean sea level will continue to rise during the 21st century.

4. IMPACT OF CLIMATE CHANGE ON LIVESTOCK PRODUCTION

Progress made in understanding the climate change and its causes can help to develop a strong understanding of current and potential impacts on livestock production. This understanding is crucial for policy development. The risk potential for livestock production due to climate change depends on the levels of vulnerability, as influenced by animal performance and environmental parameters. When level of vulnerability is low with performance level and environmental influence combined, there is little risk. As performance levels (rate of body weight gain, milk production, egg production) increase, the vulnerability of the animal increases and, when coupled with adverse environment, the animal is at a greater risk. Combination of an adverse environment with high performance pushes the level of vulnerability and consequent risk to even higher levels. Inherent genetic makeup and type of management also play important role in deciding the risk level. In general, livestock systems under intensive management will be at lower risk than crop-livestock systems. Livestock managed in crop-livestock and pastoral systems will face more problems due to high sensitivity to climate change, low level of adoption of technology and lack of financial resources of livestock owners. Smallholder and subsistence farmers and pastoralists will suffer complex, localised impacts of climate change. Since livestock production in India is predominantly in small holdings and almost seventy percent of livestock is owned by small and marginal farmers, and landless workers, the livestock production will be more vulnerable.

4.1 Direct impact of weather and extreme events on livestock production and reproduction

4.1.1 Animal production

There does not seem to have been great deal of work done on the direct impacts of climate change on heat stress in animals and its impact on livestock production in India. A lack of appropriate physiological models that relate climate to animal physiology rather limits the confidence that can be placed in prediction of impacts (Easterling and Apps, 2005). It is, however, well established that increase in ambient temperature alter heat exchange between animal and environment and feed intake, growth, milk production, egg, wool production, reproduction and health are all affected potentially. Animals in production are more vulnerable to heat stress and further rise in temperature due to climate change will have additive impact. Although the animals will tend to get acclimatized to prolonged exposure to that particular temperature but this adaptation is at the cost of production. If the physiological and behavioural responses are insufficient to maintain thermal balance the animal try to restrict the feed intake to reduce the internal heat load.

Enteric methane emission is also influenced by environmental temperature. The methane emission per unit of dry matter intake reduced under moderate heat stress and increased under severe heat stress (Yadav, et al., 2012). An inverse relationship between rate of digestibility and rate of enteric methane emission per unit dry matter intake under heat stress of different magnitudes needs further investigations. Methane production from enteric fermentation was reported to be a function of rate of organic matter fermentation, type of volatile fatty acid production and efficiency of microbial biosynthesis (Shibata and Terada, 2010). Increase in enteric methane production under increase in air temperature will enhance the gross energy loss and will adversely affect the productivity.

Based on predicted climate outputs from Global Coupled Models (GCM), production and response models for future climate scenarios of 2040 and 2090, a decrease in milk production of 2.2 % and 6.0 % has been estimated in US. Days to market for swine and beef increased by 1.2 % and 13.1 % for 2040 and 2.0 % and 6.9 % for 2090 (Frank et al., 2001). Using Hadley model the respective changes in swine, beef and milk are 0.9 %, 0.7 % and 2.1 % for 2040 and 4.3 %, 3.4 % and 3.9 % for 2090 scenario. The work done under NICRA at NDRI revealed that increase of more than 4ºC above normal in maximum temperature during summer and decrease of more than 3ºC below normal in minimum temperature during winter had adverse effect on milk production in crossbred cattle and buffaloes. The decline in milk yield varied from 10 to 30 % in first lactation and 5 to 20 % in second and third lactation. Both the heat waves and cold waves caused short to long term cumulative effect on milk production in cattle and buffaloes. The decline and subsequent return of milk yield to normalcy after an extreme event was also influenced by maximum and minimum temperature in subsequent days. The estimated annual loss in milk production due to heat stress is nearly 2 % of the total milk production in India. The negative impact of temperature rise on total milk production for India has been estimated about 1.6 million tonnes by 2020 and more than 15 million tonnes by 2050 (Srivastava, A.K., 2010). The impact will be more on high producing animals. Commercial dairy farms have comparatively better housing facilities and feeding practices to minimize the impact of increase in ambient temperature.

Not only the intensity of stress, but also the length of daily recovery period is important in determining animal responses. Expected increase in daily stress hours will also adversely affect livestock production. In India average stress hours, *i.e.* hours above THI 72, during hot months of the year are likely to increase. The implications of such a change are that the already compromised summer livestock performance in terms of milk, meat and egg production could be further impaired. The increase in frequency of heat waves will also adversely affect the livestock production. During these heat waves heat exchange is affected. The animals fail to dissipate the extra heat load accumulated during days when THI and maximum temperature are above the threshold and little opportunity to recover. In a grazing system in Santa Fe the milk production in Holstein cows decreased by 10-14% after a three days heat wave. There was no recovery in these animals after the heat wave and they did not respond to the second heat wave recorded after one month even when it was more severe than previous one possibly because of low reduced milk production. Goat and sheep are more vulnerable to climatic extremes like heat waves as they are mostly reared under extensive and pastoralist system in India. Majority of cows and buffaloes in small holding livestock system are under semi-extensive system and thus will also be vulnerable.

4.1.2 Animal reproduction

Reproduction in most of the species of livestock in India is already affected by the prevailing climatic conditions during summer and rainy seasons. The fertility in female and male animals is affected by climatic heat directly as well as indirectly through feed and fodder and proneness to diseases. Conception rates in animals seem delicately balanced between both heat and cold. Abrupt environmental temperature changes above critical level reduce the conception rates. The drop in fertility when the maximum temperature of the day, after breeding, exceeds upper limit of zone of homeothermy is of concern in context of climate change. Stressful environmental temperature reduces the flow of blood to the uterine tract, damaging, or killing the developing embryos. Uterine blood flow is source of oxygen, water, nutrients and hormones for embryos. It also carries excessive, damaging heat away from the embryos. Zygotes are most vulnerable to heat stress in initial stages of cleavage.

Heat stress is a major cause of early embryonic losses. Such information is not available for Indian farm animals. Silent heat and low conception rates during summer in buffaloes is a serious problem in northern India. In males also the semen quality and libido get affected by heat stress. The problem of low libido and poor quality of semen is one of the major constraints even under existing climatic conditions. Further rise in temperature due to climate change will impose additional stress on these animals.

4.1.3 Poultry production

Compared to other species of domestic animals, poultry is more sensitive to high ambient temperatures as they do not have sweat glands, have a higher basal metabolic rate per unit body weight and body is covered with feathers. With further increase in air temperature due to climate change in future, the birds will face more stress and therefore air cooling, foggers and sprinklers on roof will be required to minimize the heat stress. This will require additional expenditure and will result in lower margin of profit and higher rates for the consumers. Poultry are more vulnerable to climate change because birds can tolerate comparatively narrow range of temperature. Heat stress during growth period of broilers has been associated not only with lower body weight but also quality losses. The transportation of broilers from farms to processing units under high temperature conditions has also been shown to cause meat quality losses. In layers, heat stress negatively affects the egg production and quality. The back yard poultry is more vulnerable to climatic variations and stress due to improper housing and feeding practices, lack of financial resources and erratic electric supply. Under heat stress when body activates thermoregulatory mechanism to maintain homeothermy and homeostasis, increased levels of reactive oxygen species (ROS) occur. As a consequence, the body enters a stage of oxidative stress, and starts producing and releasing heat shock proteins (HSP) to protect itself from the deleterious cellular effects of ROS. Recent work under NICRA has shown that supplementation of vitamin E, vitamin C or combination of both reduces the oxidative stress. Heat care mineral mixture has been developed, which help in ameliorating the stress in backyard and commercial poultry and increased body weight gain. Heat stress is also responsible to cause immune-suppression.

4.2 Impact on quantity and quality of livestock feed and fodder

The increase in climate variability and extreme climatic events like drought, heat waves, and cyclones are likely to put additional stress on fragile zone in arid and semi-arid regions in India. The beneficial effects of higher levels of carbon dioxide on yields of C3 crops, like wheat, rice, oat, barley, may be offset with rise in temperature and changes in rainfall in arid and semi-arid regions. There is much less information on possible impacts of climate change on either the quantity or the quality of crop residues, key feed resource in the mixed rain fed and mixed irrigated systems in India. Many regional staples like rice, millet and maize may suffer up to 10 percent loss in yields. The proportion of browse in rangelands may increase in future as a result of increased growth and competition of browse species due to increased carbon dioxide levels (Morgan et al., 2007). This will have significant impacts on the type of animal species that could graze these rangelands. Higher temperatures increase lignin formation in plant tissues and thereby reduce the digestibility and rates of degradation of fodder and crop residues in the rumen of animals. This will lead to reduced nutrient availability for animals and ultimately to a reduction in livestock production.

Shortage of feed and fodder to the tune of 40 % dry fodder, 36 % green fodder and 52 % concentrate on dry matter basis (DAHDF, 2014-15) and poor quality roughage, primarily crop residues, is already one of the major constraints in expression of full genetic potential in livestock production in India. The livestock population in India has registered a 3.3 % decrease from 2007 to 2012 (Livestock Census, 2012). The number of all farm animals except buffalo has decreased. But still there is a need to rationalize the number of large ruminants to overcome the shortage of feed and fodder and also reduce the total enteric methane emission. It is a big challenge to prepare the road map since almost 70 % of the livestock is owned by small and marginal farmers and landless labourers which is the source of livelihood security and sustainability for them. In view of this situation of feed and fodder availability the adverse impact of climate change on crop production will further increase the gap between availability and requirement of feed and fodder the situation.

4.3 Incidence and spread of diseases and disease vectors

Higher temperature may increase the rate of growth of pathogens and parasites during their life cycle outside animal host, leading to larger populations. Similarly, those pathogens and parasites that are sensitive to humidity level may be affected by changes in precipitation, soil moisture and the frequency of floods. Thus warming and changes in rainfall distribution may lead to changes in spatial or temporal distribution of diseases such as anthrax, haemorrhagic septicaemia and vector borne diseases. Changes in winds could affect the spread of certain pathogens and vectors.

Climatic changes could affect the frequency and extent of livestock disease outbreaks such as foot and mouth disease and haemorrhagic septicaemia in certain areas. Increase in frequency of extreme climatic events like floods and droughts will also affect the incidence of several parasitic, bacterial and viral diseases. Outbreak of infectious diseases in areas affected with floods is a major problem. Climate change may also cause new transmission modes. The immunity of animals is also lowered due to inclement weather conditions. Recent work done under NICRA at IVRI Izatnagar demonstrated that expression of cytokinase and TLR-2 under heat stress was higher in crossbred cattle than indigenous

Tharparkar breed indicating that former were under higher immune stress. The impacts of climate change on livestock diseases may be very complex, and studying them needs to go well beyond any simple assessment of rainfall and temperature effects on distribution.

4.4 Impact on water availability

The extent and nature of livestock role in water equation is the subject of considerable debate. Water use in the livestock sector includes not only the water used at farm level for drinking and the growing of feed crops, but also other services and product processing. Water requirement for different livestock systems varies from 1L per animal per day in extensive grazing system to 125 L per animal per day in commercial landless pig production system (Steinfeld et al., 2006). Irrigated area is continuously increasing and water use in other sectors is increasing even at faster rate. The key issue relating to water is its uneven distribution. The surface water bodies like ponds and lakes have been meeting the water requirement of animals in pastoral and semi-intensive system of animal rearing in India. The water bodies have been decreasing in many parts of India resulting in more pressure on ground water use for animals. The impact of such supply changes on livestock and livestock systems in India have not been well studied. But one thing is certain that the contribution of ground water to extensive grazing system and semi-intensive system will become even more important in future in the face of climate change. The increased reliance on ground water in future for livestock and crops in addition to human requirement could lead to problems associated with the sustainability of water resources in the country.

There is less uncertainty about the likely impacts of climate change on water demand by livestock. The impact of increased temperatures on water demand by different species of livestock in India is well studied. For indigenous cattle water intake increases from about 3 L per kg dry matter intake at 10^0C ambient temperature, to 5 L at 30^0C, and to about 10 L at 35^0C. Water intake for *Bos. taurus* cattle at the same three temperatures is about 3, 8 and 14 L per kg dry matter intake. Some of this water intake comes from forage, and forage water content itself will also depend on climate related factors in well understood ways With predicted increase in air temperature not only the demand of drinking water will increase but water will also be required for cooling of animal sheds during hot dry period in northern India. Most of these regions already face shortage of water. It will be a challenge to meet these demands in arid and semi-arid regions.

4.5 Impact on biodiversity

Drivers of the climate change are already having substantial impacts on biodiversity. Out of nearly 4000 breeds of cattle, buffalo, goat, sheep, horse, pig, and ass recorded in the 20th century, some 16% had become extinct by 2000, and 12% of leftover were rare.

A FAO report 2007 on animal genetic resources indicates that 20% reported breeds are now classified as at risk, and that almost one breed per month is becoming extinct (CGRFA, 2007). Much of this genetic erosion is attributed to livestock production practices and changes in production systems and local breeds. Several breeds of cattle, buffalo, goat and sheep in India have become extinct or have been declared threatened because of various factors including climatic factors. Cross breeding, changes in land use and animal husbandry practices have also played some role in extinction of breeds in India. The number of indigenous breeds have well adapted to harsh environment and diseases. Increase in environmental temperature may be stressful even for these animals. It is estimated that 20-30 % of all animal breeds assessed so far would be at high risk of extinction with a rise of 2.5^0C. Ecosystems and breeds are very likely to be vulnerable to climate change depending on exposure to critical thresholds. The data and models needed to project the extent and nature of changes in biodiversity and geographical distribution are not available. Animal genetic resources are non-renewable resource, once gone, they are gone forever. The pastoralists and small holders are the guardians of much of livestock genetic resources. This poses a challenge for conservation.

4.6 Socio-economic aspects of climate change

Livestock rearing is one of the most climate sensitive economic sector and rural poor communities are thus more exposed to the effects of climate change. Livestock systems in many parts of India are changing rapidly in response to variety of drivers, like population growth, increase in demand for livestock products related to rise in income, and urbanization. Climate change influences are more severely felt by poor people who rely heavily on the natural resource base for their livelihoods. Of course, pastoral communities are the most vulnerable communities. The management implications of livestock under heat stress involve adoption of measures to minimize the effects on production. These measures range from low, moderate to high cost adaptation measures. Low cost measure might be reducing overcrowding and maximizing provision of shade. Moderate cost measures include use of sprinklers for cooling animal shelters and improving ventilation. The high cost measures include construction of animal houses installed with air cooling system and providing high quality feed to animals. The capabilities of livestock owners to adopt these measures to cope with the projected rates of change in temperatures and related climatic factors are lacking in terms of financial resources and technological adoption. For rural communities losing livestock assets might lead to the chronic poverty with long term effects on their livelihood.

At present very few development strategies promoting sustainable livestock related practices have explicitly included measures to support small holder and landless livestock owners to adapt to or mitigate the effects of climate change. Activities aimed at increasing rural communities resilience will be necessary to support their capacity to adapt and to respond to new hazards.

5. ADAPTATION AND MITIGATION

The adaptation and mitigation potential is nowhere more pronounced than in developing countries like India where productivity remains low, poverty, vulnerability and food insecurity remains high, and the direct effects of climate change are going to be harsh. Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change. Sustainable development and equity provides a basis for assessing climate policies. Limiting the effect of climate change is necessary to achieve sustainable development and equity, including poverty eradication in India. Mitigation and adaptation raises issues of equity, justice and fairness. Countries like India who are most vulnerable to climate change have contributed and contribute little to GHG emissions. Current per capita CO2 emission of less than 2t in India is far less than world average of 5t.

Countries past and future contributions to the accumulation of GHGs in the atmosphere are different, and countries also face varying challenges and circumstances and have different capacities to address mitigation and adaptation. The evidence suggests that outcomes seen as equitable can lead to more effective cooperation.

5.1 Adaptation

Adaptation with reference to climate change is referred to as adjustment or preparation of natural, human or livestock systems to new or changing environment which moderates harm or uses beneficial opportunities. Adaptation can reduce the current risks of climate change impacts and can be used for addressing emerging risks. In the context of sustainable development, immediate adaptation actions will also increase future options and preparedness for sustainable development. The first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate and extremes. It is crucial to build adaptive capacity for effective selection and implementation of adaptation options. Adaptation to climate change is more than adaptation to heat but in Indian context elevated temperature and in particular extreme heat events are very important. It is difficult even with the most technologically advanced nations to select animals for extreme climatic conditions without a major reduction in performance. Therefore there is a need to focus on how changing climate impact the animal's overall environment. A number of interacting factors like precipitation (variation and extremes), soil moisture, feed resources, parasite exposure, solar load, temperature (variation and extremes) and water availability are also very important.

The role of the central government is to coordinate adaptation efforts of state governments, for example by protecting vulnerable groups, by supporting economic diversification and by providing information, policy and legal frame works and financial support. The role of local governments and private sector is critical through their roles in scaling up adaptation at community level, households and civil society in managing risk information and financing. Transformations in economic, social, technological and political decisions and actions can enhance adaptation efforts and promote sustainable development. Policies across all scales supporting development, diffusion and transfer, as well as finance for responses to climate change, can complement and enhance the effectiveness of policies that directly promote adaptation. International cooperation for supporting adaptation planning and implementation has received less attention, than mitigation. Incremental costs of adapting to continuously changing climate would be a major burden.

APPROACHES FOR ADAPTATION

5.1.1 Vulnerability and Exposure Reduction through Development, Planning and Practices

a) Feeding management

Modifications in nutritional management are used to reduce the internal heat load on animal. The animals use more energy for digestion of poor quality feed, like crop residues and proportionately higher amount of heat per unit feed intake is produced. This extra heat also is to be lost from body to maintain thermal balance. Similarly the particle size of fodder affect the amount of heat produced per unit weight of dry matter consumed because of higher specific dynamic action values. Several other simple and economically viable feeding technologies like wetting of straws, incorporation of good quality green during summer are available. Increasing the nutrient density by replacing poor quality roughage with concentrate, feeding properly chaffed dry fodder, hydration of dry straws during hot dry period and supplementation of good quality green fodder reduces the internal heat load on animal body and thus help in minimizing the impact of climate. Some of the feed additives like antioxidants, minerals and plant products are used in poultry and high producers. Even age old simple technology of chaffing the fodder, which reduce internal heat load, is not practiced in certain parts of the country.

b) Improved animal housing

In the intensive system of production the animals are mostly fully housed for attainment of maximum productivity. In tropical and sub-tropical climate animal shelters are designed to curtail the heat load on animals from external macro-environment and providing congenial micro-environment in animal houses. Design, height and orientation of shelters, choice of roofing material, provision of open space for ventilation and space per animal are some of the important aspects to attain cooler microenvironment. Shading and louvered roof are used for poultry housing. Lot of information is available on principles of housing in hot semi-arid region from the work done at CIRG Makhdoom in late eighties and early nineties of last century. This information can be used in adopting this approach.

c) Heat ameliorative measures

During the period of high temperatures the use of water can be used to bring down the micro-environmental temperature within the animal shelters and increase the evaporative heat loss from animal body. Use of air cooling systems is very efficient but more expensive. In India limited information is available on animal housing for different agro-climatic zones. The lack of knowledge on how to ameliorate the impact of changing climate on livestock production is one problem, but the major problem is the lack of financial resources. Proper housing is an obvious method to minimize the effects of climate.

d) Community animal shelters

The animals in arid zone are out in the fields for grazing during day and are exposed to peak heat. These animals are reared under extensive system of farming and there is scarcity of feed resources in grazing fields. If the community shelters are available in these areas the animals can take rest during peak hot hours. Similarly suitable shelters in flood and cyclone prone areas can save morbidity and mortality losses.

e) Weather forecasting and early warning system

Weather forecasting and early warning are very important to enable the farmers to take preventive measures to protect the animals from extreme weather events like heat wave, cold wave, heavy precipitation events including thunderstorm, cyclone, flood and disease outbreaks. In India presently this component is almost lacking. To make the adaptation measures effective to overcome the effect of climate change this should be brought to international level.

f) Coastal protection

The coastal low lying areas are vulnerable to rise in sea level and cyclonic disturbances. Since the climate change is resulting in rise of sea level and the frequency of extreme weather events is likely to increase, it is very important to construct well planned structures to safe guard these low lying areas.

5.1.2 Technological options

Bioclimatic zone based livestock production

India has well adapted breeds in different species of livestock and it is necessary to breed them in suitable bioclimatic zones to enable them to express their full genetic potential. The preference of the farmers should also be taken into consideration for prioritization of breeds. Some transformation is already taking place in this direction. Farmers in western Uttar Pradesh and Haryana have opted predominantly for buffalo rearing in place of cattle and buffalo earlier. There is also increasing preference for buffalo in parts of Rajasthan, Andhra Pradesh and Madhya Pradesh in place of cattle. In Punjab the farmers first opted for crossbred cattle and are now keen to rear pure Holstein Friesian. Similar changes have also taken place in small ruminant rearing. The population of sheep is decreasing in Rajasthan and increasing in southern part of country particularly Andhra Pradesh and Karnataka. The pig rearing is predominant in north eastern part of country.

There is a considerable variation, within and between breeds, for thermal tolerance and overall stress tolerance (Singh, 1990). The ability of livestock breeders to identify phenotypes, which carry specific genes, is difficult partly because phenotypic variance is due to the combined effects of genetic and environmental components. Therefore there is a reliance on selecting animals from within the environment or from a similar environment in which they are expected to live. Livestock need to be adequate in four key areas *i.e.* survivability, production, fertility and productivity. To further complicate things animal responses to acute and chronic stressors may be very different. Selection should probably focus on chronic environmental stress. Adaptation to hot environments is often at the expense of performance, and survivability is often better in low performance animals. In India almost 70 per cent of total livestock is owned by small holders and it is unlikely that they will be able to do much to enhance genetic change in their animals without financial and technical assistance

Transfer of technology and awareness

Transformation is required in mechanism of transfer of technology in livestock sector. The same extension techniques which have been very effective in crop production are either not easily adoptable or not effective in livestock sector. Each farmer has different situation as far animal are concerned. There is a need to have a village level decision support system to extend the help to farmers to resolve their day today issues regarding feeding, reproduction and other management practices. Participation of end users in development and refinement of area specific technologies for minimizing the effect of climate and climate change is very important.

5.1.3 Institutional

As majority of livestock owners are resource poor, economic instruments in the form of subsidies may be applied across sections, and include a variety of policy design such as financial incentives and microfinance, grants, loans and credit lines are required. The institutional support in the form of animal insurance, disaster contingency fund, community animal hostels may be made available with public private partners.

5.2 Mitigation

Fifth Assessment Report (IPCC, 2014) provides a comprehensive assessment of all relevant options for mitigating climate change through limiting or preventing greenhouse gas emissions, as well as activities that remove them from the atmosphere. There are multiple pathways that are likely to limit warming to below 2^0C relative to preindustrial levels. These pathways would require substantial reductions in GHG emissions over the next few decades and near zero emissions of CO_2, and other greenhouse gases by the end of the century. Implementing such reductions poses substantial technological, economic, social and institutional challenges in countries like India where one quarter of the population still lives below poverty line, almost 70% of population is dependent on agriculture and food and nutrition security is low.

In 2010, median per capita emissions for the group of high income countries was 13t CO_2 eq., which is almost 10 times that of low income countries level of 1.4t CO_2/capita. Per capita emissions GHGs in India at 1.9t CO_2 are well below the global average at 5T of CO_2/person (IPCC, 2014). The values for countries like USA, Brazil are very high at around 16-17t per capita. China has got CO_2 emission level of more than 7t/capita. Agriculture, forestry and other land use (AFOLU) sector accounts for less than a quarter of net anthropogenic GHG emissions mainly from deforestation, agricultural emissions from soil and nutrient management and livestock. Most recent estimates indicate a decline in AFOLU CO_2 fluxes, largely due to decreasing deforestation rates and increased forestation. In the future, net annual baseline CO_2 emissions from AFOLU are projected to decline, with net emissions potentially less than half the 2010 level by 2050 and the possibility of the AFOLU sector becoming a net CO_2 sink before the end of century.

Estimated GHG emissions from livestock during 2010 were 2771×10^9 kg CO_2 eq. for world and 392×10^9 kg CO_2 eq. for India (Patra, 2014). Thus the contribution of India in GHG emissions from livestock was only 14.1% of global value in year 2010 although it hosts more than 17% of the human population. Important greenhouse gases attributed to livestock are methane and nitrous oxide. The contribution of enteric methane emission from Indian livestock to total enteric emission from livestock in world was estimated to be 15.1% in year 2010. The contribution of manure methane and nitrous oxide from Indian livestock in year 2010 to total manure methane and nitrous oxide from livestock in world derived from values given by Patra (2014) was only 9.6% and 3.9% respectively. In view of the fact that India hosts more than 17% of the human population of world the per capita GHG emissions from livestock are also of lower level than the world average.

Strategies and actions are required for climate resilient pathways for sustainable development. Sustainable development and equity provide a basis for assessing climate policies. Limiting the effects of climate change is necessary to achieve sustainable development and equity including poverty eradication. Mitigation strategy raises the issues of equity, justice and fairness. India, one of the most vulnerable countries to climate change has contributed little to GHG emissions.

AFOLU plays a central role for food security and sustainable development in India as 70% of population depend on agriculture for their livelihood. The livestock sector contributes around 30% to agricultural GDP. Around 70% of livestock is owned by marginal and small farmers and landless labourers and improvement in livestock production is one of the most potent tool for poverty eradication and nutritional security. In such a scenario the mitigation pathways have to be such that the source of income and livelihood of poor is not adversely affected. India is a developing country and has enormous problems and so many things to focus. Mitigation can be more cost effective if using as integrated approach that combines measures to reduce energy use and the greenhouse gas intensity of end use sectors, de-carbonize energy supply, reduce net emission and enhance carbon sinks in land based sectors

Near term reductions in energy demand are an important element of cost effective mitigation strategies. Emissions can be substantially lowered through changes in consumption patterns, adoption of energy saving measures, dietary change and reduction in food waste

OPTIONS FOR MITIGATION PATHWAYS

5.2.1 Enteric Methane Emissions

- **Improvement in animal feeding:** Improper feeding leads to productivity losses and up to 12% energy loss in the form of enteric methane emission. Balanced feeding and good feeding management increase conversion of feed nutrients to animal products and decrease in emission of nitrogen and methane. Asynchrony between the rapid release of non-protein nitrogen from highly soluble plant proteins and slow rate of release of energy mainly from the forage results in low nitrogen use efficiency due to loss of nitrogen absorbed as ammonia from rumen. It is necessary to synchronize fermentation between feed having rapid rate of digestion, like fresh green fodder, concentrates and some by-products, and slow rate of digestion, like poor quality roughage. to improve the efficiency of feed utilization and reduction in enteric methane emission. Methane production tends to be lower when forages are ensiled than when they are dried. Grinding and pellet making of forages improves the utilization of feed and decrease the methane emissions. Grinding or pellet making of forages to improve the utilization by ruminants has been shown to decrease methane losses per unit of feed intake by 20-40% when fed at high intakes. The forage to concentrate ratio (F:C ratio) has an impact on the rumen fermentation and acetate: propionate ratio declines with F:C ratio. It has also been observed that higher proportion of concentrate in the diet leads to a reduction in methane emissions mainly as a proportion of energy intake mainly due to an increase in propionate production in rumen.

- **Use of feed additives:** Many compounds like chemicals, oils, plants and their extracts, condensed tannins, probiotics, acetogens, bacteriocins, organic acids and ionophore antibiotics have been used as feed additives to decrease the methanogenesis in rumen. Out of all ionophore antibiotic, represented by monensin, have been used widely as feed additive for ruminant livestock since the mid-seventies of last century. Methane synthesis is regarded as one of the cross feeding between hydrogen producing microbes and hydrogen consuming methanogens. Since the hydrogen producing microbes include fibrolytic fungi and bacteria, their co-association with methanogens allows efficient removal of hydrogen, which facilitates continuous fibre degradation. Methane production is the primary pathway followed by propionate production as the secondary pathway for hydrogen utilization in rumen. Other reductive reactions like nitrate, nitrite and sulphate reduction, synthesis of acetate from carbon dioxide and hydrogen play a relatively minor role in hydrogen consumption within the rumen. Stimulation of propionate production could be the best alternative hydrogen sink to methane production in the rumen. Therefore a strategy for abatement of methane production should be considered with a strategy to enhance propionate production.

- **New approaches:** New approaches for methane reduction such as vaccination of ruminants against methanogens and use of plant derived materials to divert the primary hydrogen sink channel without adversely affecting digestibility and production are still at a fundamental stage of development. Two potential materials, plant derived liquid (PDL) and yeast derived surfactant (YDS), have been found to reduce rumen methane production recently. Genetic selection of cows and buffaloes that have higher feed efficiency and low methane emission rates can be long term sustainable solution.

- **Heat ameliorative measures:** Enteric methane emission/kg dry matter intake has been observed to increase under severe heat. This might be attributed to lower organic matter digestibility and shift in methanogens and other microbial fermentation, due to alterations in rumen environment. An increase in rumen temperature also causes increase in enteric methane emission. Protection of animals from severe heat stress through proper housing and heat ameliorative measures will be effective in reducing methane emission.

- **Rationalization of livestock population:** Issue of large population of livestock in general and cattle and buffalo in particular in India, has been targeted for large amount of methane and nitrous oxide emission. This issue has been blown out of proportion without considering the ground realities. The contribution of Indian livestock to total enteric methane, manure management methane and nitrous oxide emission from livestock in world was 14.1, 9.6 and 3.9% respectively in year 2010 while India hosts 17% of world's human population and faces constraints of tropical and sub-tropical climate, like hot weather conditions coupled with shortage including poor quality of feed and fodder. The GHG emissions from animal feed production, processing and transportation of this feed is much higher in intensive and proportionately higher concentrate fed systems than the extensive and semi-intensive systems, which are mainly based on crop residue feeding ingredients. Similarly 39% of the total water used for agriculture is associated with livestock production in the intensive system. The use of water in livestock production in India is comparatively low. Therefore if all emissions due to these ancillary activities are also accounted towards livestock, it may turn out to be higher even to per unit production, in high income group countries.

  It is easy to work out ideal number of cattle and buffaloes required to fulfil the milk requirement of country. The road map and execution of any such proposal is not viable because of socioeconomic and political compulsions. The argument to drastically reduce the livestock population is not justified. India is, however, giving a high priority to improve the productivity of livestock which has direct bearing on population as reflected by successful reduction in livestock population by 3.3% from year 2007 to 2012. Further improvement in livestock productivity, reduction in poverty increase in urbanization will also result in judicious reduction of livestock population much quicker than expected from using any other approach.

- **Supplementation of protected fat in feed to lactating cows and buffalo:** Feeding of protected fat to by-pass rumen microbial degradation can improve production and decrease in emission of enteric methane.

- **Intensification of livestock and crops:** Intensification of livestock production and feed crop production can also help in reducing the enteric methane emission.

5.2.2 Emission of Methane and Nitrous Oxide in Manure Management

In India major amount of dung of cattle and buffalo and all faecal material of all other livestock species is used as manure in agricultural fields which does not under go much of anaerobic fermentation. Share of GHG emissions from manure management system was only 8% of the global GHG emissions from manure management. Improvement In disposal of farm yard manure and its use for biogas production and use of biogas slurry as fish feed and use of water from fish farms irrigation can reduce methane emission from manure.

5.2.3 Other GHG Emissions Related to Livestock

Promotion of conservation agriculture, agro-forestry, silvi-pasture, horti-pasture and integration of fodder trees and shrubs with cropped land and also on borders of water bodies can help in increased green fodder and reduction in enteric methane emission. In agriculture, the most cost effective mitigation options are cropland management, grazing land management, and restoration of organic soils.

5.2.4 Carbon Trading

The economic mitigation potential of supply side measures is estimated to be 7.2 to 11 Gt CO_2 eq./year in 2030 for mitigation efforts consistent with carbon prices up to 100 USD/t CO_2 eq. about a third of which can be achieved at less than 20 USD/t CO_2 eq. The first immediate global action is to develop carbon markets, with prices rapidly growing to over USD 100/ton of CO_2. There is need to deploy negative emission technologies in future which will involve removing CO_2 from the atmosphere and storing it in safe places like saline aquifers. These technologies are largely not available at present.

Box 1

NATIONAL INITIATIVE ON CLIMATE RESILIENT AGRICULTURE (NICRA)

Main programme includes centre at NDRI for livestock production and IVRI / NIVEDI for livestock diseases aspects. Work on sheep at CSWRI and on poultry at PDP has been taken up under competitive / sponsored projects. The objectives of the main programme on livestock include: (i) to understand the unique traits in indigenous livestock responsible for higher heat tolerance; (ii) to develop data base on genetic adaptation in cattle and buffalo; (iii) to identify molecular markers under different stresses; (iv) to develop adaptation and mitigation strategies to thermal stress through nutritional and environmental manipulation; (v) to develop models for disease forecasting; (vi) to identify markers for disease resistance; (vii) to carry out epidemiological studies; and (viii) technology demonstration and dissemination and farmers awareness.

There is need to expand the research and development work to different bioclimatic zones, for all economically important species of livestock and livestock management systems including backyard poultry. There is a need to strengthen the human resources and research facilities in different research institutes to take up work in identified areas. Work on animal housing, climate smart livestock village clusters, vulnerability mapping of whole country, demarcation of bioclimatic zones and identification of bioclimatic zone specific species and breeds needs to be taken either under NICRA or some other projects.

6. POLICY OPTIONS AND ACTIONS-WAY FORWARD FOR SUSTAINABLE CLIMATE RESILIENT LIVESTOCK DEVELOPMENT

Many adaptation and mitigation options can help to minimize the effect of climate change on livestock. Effective implementation, however, depends on policies and cooperation in execution actions at all scales. Policies and actions that promote sustainable development and reduce poverty will improve adaptation pathways for livestock production and will also pave the way for more effective climate change mitigation. These strategies will also take into account the co-benefits, adverse side effects and risks that may arise from both adaptation and mitigation options.

The policy options that emerged from the deliberations of the brain storming session are outlined in the sequence for consideration.

6.1 Mission on livestock feeding

Feeding component is most important not only because 70% of cost of livestock production goes on it but also for its role in mitigating the enteric methane emission. The livestock production in some areas like Punjab is fast changing to intensive system with use of high inputs. In major part of the country small holder livestock system will continue. Animal feeding interventions, based on what is locally available and acceptable, have potential to improve efficiency of feed utilization and productivity of animals, income of farmers and minimize enteric methane emission with integrated application of available technologies.

- ❖ Adoption of balanced feeding and location specific strategic feeding, feasible to local area and acceptable to farmers, as per need of the livestock production system.
- ❖ Use of tested technologies like chaffing of fodder, provision of green fodder, complete ration pellets, urea molasses mineral blocks, silage feeding and grazing schedule as per suitability.

- Proper utilization of protected nutrients like bypass protein, fat and amino acids in feed of high milk producing cows and buffaloes.
- Inexpensive densification and fortification of poor quality roughages through public private partnership.
- Exploitation of digestive manipulators like ionophores / antibiotics, propionate enhancers, archaeal inhibitors, nitrate and sulphate supplements, methanotraphs, acetogens, defaunation of rumen and probiotics, for raising animals producing enteric methane, depending of economic feasibility and biological needs. Indiscriminate use should be avoided.
- Creation and / or strengthening of village level decision support system to assist in adoption of improved feeding practices, least cost ration and feed improvement technologies.
- Supply of area specific mineral mixture at subsidized rates to livestock owners through public distribution system.
- Application of ICT and mass media in spreading awareness balanced feeding and climate resilient management practices.

6.2 Tackling the issue of feed and fodder shortage

The chronic problem of deficiency of feed and fodder is likely to aggravate due to competition in land use for food production and other uses. It will further impinge on availability of land for pastures and fodder production to meet the demand for large livestock population.

- Total ban on export of animal feed ingredients in general and oil cakes and soy bean meal in particular.
- Strict implementation of ban on burning of crop residues and farm wastes.
- Importance to improvement in quantity and quality of straws and stovers in breeding programs of cereal food crops.
- Establishment of fodder and seed banks and community feed processing plants with public private partnership.
- Incentives to farmers to integrate forage production with food and other crops, agro-forestry including agro-pastoral and agro-silvi-pastoral and conservation of natural resources.
- Strengthening of financial services, micro-financing and risk transfer for livestock owners at concessional rates.

6.3 Transformation in breeding policy to bioclimatic zone specific with incentives to farmers for rearing specified species / breed

The livestock breeding policy in country needs a transformation to withstand the impact of climate change in the long run. As of now the states are not bound to adopt the national breeding policy as livestock sector is a state subject and they have their own breeding policy. The livestock production is predominantly in small holder farming system owned by resource poor farmers. Obviously, in such a situation transformational option will require altered paradigms and alignment in breeding policies. This approach will pave the way for sustainable improvement in productivity of livestock, increase income of farmers, reduce the number of unproductive animals, will help in resolving shortage of fodder and increase resilience to climate change.

- ❖ Delineation of bioclimatic zones in the country on the basis of monthly / seasonal average, maximum and minimum temperature, average monthly humidity, solar radiation, feed and fodder situation and socioeconomic conditions.
- ❖ Prioritization of species and breeds most adaptable / suitable for each bioclimatic zone in consultation with livestock owners.
- ❖ Animal selection based on molecular genetics and biomarkers contributing towards high tolerance to environmental stress and production potential.
- ❖ Incentives to farmers for active participation in improvement programme of prioritized breeds in the form of artificial insemination services at farmers door without charge, health coverage, animal insurance at nominal charges and institutional credit at zero percent interest for procurement of animals of prioritized breeds.
- ❖ Establishment of mother bull farms of prioritized breeds of cattle and buffalo in major climatic zones with public private partnership.
- ❖ Capacity building of rural women and educated rural youth in improved feeding technologies and reproductive management.
- ❖ Setting up of regional demonstration units for climate resilient livestock production system and technologies with government support.

6.4 Net Work Project on Animal Housing and Management

Animal housing and management is the high priority adaptation measure to minimize the effects of climate and climate change on livestock production. The components involved include species of livestock, rearing / management system, climatic zone, financial status of farmer and economic viability of the measure to be adopted. Although only limited information is available on these aspects but we cannot wait for the ideal situation. While we need to generate more information on type of most appropriate housing and management for different species in different climatic zones and different management systems, we have to go ahead using present information available on principles of animal housing like, orientation, height, shape of roof and roofing material, open space in walls for ventilation and floor space.

- Scientifically designed animal housing with proper ventilation for protection of animals from heat in sub-tropical arid and semiarid and from heat and high humidity in tropical and subtropical wet zones and production system based provisions.
- Improved feeding and watering devices to minimize wastage and improved animal management to ameliorate stress on animals.
- Efficient waste and manure management provisions in animal housing.
- Sanitation and hygiene aspects for prevention of diseases.

6.5 Climate Smart Livestock Village Clusters

Climate smart livestock villages clusters programme may be taken up to sustainably increase productivity of livestock production, income of farmers, build resilience to climate change and reduce GHG emissions in different bioclimatic zones. Researchers, local government partners, farmers and private sector may collaborate to efficiently implement prioritized interventions, monitor and evaluate progress and disseminate outcome.

- Promoting stress tolerant species and breeds of livestock suitable and acceptable in different bioclimatic zones.
- Scientifically designed shelters and improved management of animals including health management. Community animal housing clusters in grazing areas in arid, semi-arid and coastal areas. Community livestock housing and management connect with value chain for small holder livestock reared in intensive and semi-intensive systems.
- Balanced / strategic feeding of livestock as per requirement of climatic zone, species and farming system.
- Weather information on near term and long term and timely warning for extreme climatic events.
- Integrated land use planning incorporating fodder crops, food feed crops, through cross visits to analogue sites and to other areas practising climate smart agriculture, agro-forestry and pasture management as per local area requirements and acceptability.
- Installation of community biogas plants for efficient use of dung for clean fuel and manure as well as waste to compost programme.
- Crop residue management, fodder conservation and socioeconomically viable community processing centres and fodder bank.
- Educating and facilitating farmers to cope with climate change and its impacts.

6.6 Priority Research Areas and Human Resource Development

- Generation of authentic data inventory on methane and nitrous oxide emissions from livestock sector.
- Molecular markers, allele mining and gene insertion / deletion for heat tolerance and water deprivation tolerance in ruminants and delineation of upper critical temperature in different breeds of cattle.
- Basic research on gut ecology, metagenomics, nutrient use efficiency, development of vaccine against methanogens and plant derived materials to divert primary channel of hydrogen sink in rumen.
- Development of simulation models, data base on impact of climate and climate change on milk, meat and egg production, and socioeconomic aspects in different regions.
- Generation and refinement of technologies for disaster management.
- District level mapping for vulnerability and hazards for livestock production.
- Human resource training in animal climatology needs to be strengthened / increased to take up the research work in this area at major research and teaching institutes / colleges.

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