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Climate Smart Livestock Production - Call for Food Security: A Review

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ABSTRACT

Climate change is no more a myth but a reality supported by scientific evidence. The rapid change in environmental green house gases post industrialization is one such indicator responsible for global warming. Atmospheric concentrations of core GHGs carbon dioxide, methane and nitrous oxide have increased by 43%, 154% and 21%, respectively between 1750 to 2013. Similarly global average air temperature has increased from 0.74 in 1906 to 1.2°C in 2020 and sea level by 8 inches in last century, besides increased frequency in natural hazards like floods, draughts, cloud bursts, storms, typhoons and heat waves. The changing climate has negative impacts on human life as well as on livestock. However, livestock is believed to be the main contributor of methane, an important green house gas with 21 times more global warming potential in comparison to carbon dioxide. Since human population has tremendously increased and is further expected to increase by 33% till 2050 and at the same time due to urbanization, improved incomes and increased purchasing capacity, the demand for food of animal origin is increasing. In order to have food and nutritional security the production of livestock products is a necessity. Therefore, on one hand increase in livestock production and on the other hand minimizing the GHG emissions, the livestock sector warrants climate smart livestock production which will encompass climate resilient, environmentally sustainable, economically viable production of nutritious, safe, affordable livestock food and products.

Key words: Climate resilient, Food security, Greenhouse gases, Livestock management, Smart Livestock.

The world human population has exponentially increased post industrialization. In 1804 the world human population was 1 billion that doubled in a century and was 2 billion in 1927. It reached 3 billion just in a span of 32 years in 1960 and 4 billion in just 14 years in 1974. Thereafter, human population growth curve illustrates a spike and we have in 2021 global human population of 7.2 billion that is projected to be 9.6 billion by 2050 (FAO, 2009). To feed such a huge population, the exploitation of natural resources was rampant, industrialization, chemical fertilization and mechanization was brought in that resulted into emission of enormous quantities of green house gasses that subsequently lead to climate change and global warming. Along with the rise in population, world income has also shown rise and increased demand for agrifoods, particularly the foods of animal origin. The demand for agriculture products is expected to increase by 70% by 2050. The demand for meat and milk in 2050 is projected to grow by 73 and 58 per cent, respectively especially in developing countries and emerging economies. Population growth, urbanization, dietary changes and improved incomes are main drivers of increased food demand especially of animal origin (Nelson *et al*., 2010).

Livestock sector globally supports the livelihood of over 1 billion poorest people, employs 1.1 billion people, accounts for 40% of global agricultural gross domestic product, and provides over 33% of the world's protein intake and 7% of global kilocalorie consumption (The Word Bank, 2022). The livestock sector is one of the most important sectors in global food security. Crop agriculture provides energy security, livestock on the other hand provides protein and nutritional security. Livestock can play a vital role in improving the lives of millions by providing the sufficient and reliable supplies of meat, milk, eggs and dairy products, diversifying food basket with animal-source foods; helping to generate income and creating employment and strengthening the rural household assets thus improving the livelihood. Livestock production can also help improve children's cognitive and physical development as well as school attendance and performance, empower rural women, improve natural resource-use and support sustainable economic growth (Pampori, 2021).

As we understand, less than 1800 calories per day per person is hungry and some 811 million people in the world faced hunger in 2021 that means one person among nine go to bed hungry. 193 million people are acutely food

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insecure and in need of urgent assistance across 53 countries, 40 million people were facing emergency or worse conditions across 36 countries and 570,000 facing catastrophe (starvation and death) in 4 countries (Global report on food crises, 2021 and 2022). The main drivers of this food insecurity are conflicts and wars on the top, followed by economic shocks and weather vagaries/ extremes.

The Indian population has increased tremendously from 376 million in 1950 to 1380 million in 2020 and it is agriculture and its allied sectors that sustained such a huge population despite rapid decrease in landholdings. This population growth witnessed exponential increase during seventies and eighties with growth rate of 2.5 and has decreased to 0.99 in 2020. India has only 2.3% of the world's land with 17% of world's human population (2nd largest population in the world) posing a big challenge to food security for increasing population. India has increased its food production post independence through various revolutions including Green Revolution, White revolution, Red revolution or Blue revolution tremendously (Pampori, 2021). Among the agriculture and allied sectors, the livestock is an important contributor to the food and protein security and GDP of the country. In India livestock contributes 28.4% to the total agricultural output. However still India is a home to 1/4th of world's hungry. Over 20 crore Indians go to the bed empty-stomach every day, means around 14.5% of the Indian population falls beneath the underfed category. India stands at place 101 in global hunger index among 116 countries with score of 27.5 that is a matter of concern despite India being self-sufficient in food production (Fig 1). 35% children in India are stunted, 20% children underweight, 52% women of reproductive age are anaemic (NFHS-5) (Fig 2).

The increasing population and demands for food warrants sustainability and efficiency in production systems because of threat posed by climate change and natural resource depletion. Climate change is not now a myth but a reality that has been supported by indicators. GHGs have tremendously increased in the atmosphere post industrialization. Carbon dioxide has increased 43%, methane-154% and nitrous oxide-21% from 1750 to 2013. Similarly global average air and ocean temperatures have increased from 0.74°C in 1906 to 1.2°C in 2020. Widespread melting of ice and snow (13% reduction), rise in global average sea level by 8 inches, widespread retreat of mountain glaciers and increase in the frequency and intensity of natural hazards like floods, droughts, storms typhoons, heat waves are clear indicators of climate change.

Livestock, however, is caught in an argument, believed to be the major contributor to climate change through emissions of carbon dioxide and methane from enteric fermentation however; the other side of story is that livestock production has been suffering severely by the climate change because of increased physical environmental stress, feed, fodder and water scarcity. The primary livestock GHG emissions are CO_2, CH_4, and N_2O. CH_4 contributes the most to anthropogenic GHG emissions (44%), followed by N_2O (29%) and CO_2 (27%) (Gerber *et al*., 2013). It has been clearly demonstrated that non-CO_2 greenhouse gas emissions [(*i.e.*, enteric methane (CH_4) and nitrous oxide (N_2O)] are inversely related to animal productivity (Gerber *et al*., 2011). Around 14.5% (7.1 Giga tons of carbon dioxide equivalents) of total GHG emissions come from livestock sector (Fig 3). Out of total emissions of 7.1 gigatons, feed production contributes 3.3 gigatons, livestock products 3.5 gigatons and post farm transportation and processing 0.2 gigatons. Around 5.7 gigatons are produced from ruminants and 1.1 gigatons by monogastric animals. The contributors of the 14.5% of livestock GHG emissions are presented in Fig 4. Enteric fermentation is the largest contributor of the sector's emissions with 39.1%, followed by manure management, application, and direct deposit 25.9%, feed production 21.1%, land use change 9.2%, post-farm gate 2.9%, and direct and indirect energy 1.8% (Gerber *et al*., 2013). Deforestation, cultivated soils and land degradation due to livestock production are the main source of CO_2 emissions. The growth in livestock numbers drove the

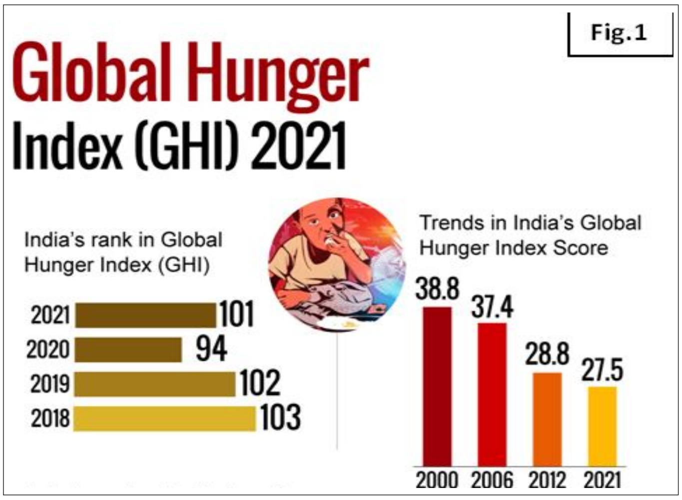

Fig 1: Global hunger index.

increase in the emissions from manure and from enteric fermentation. The livestock production has huge carbon foot prints that differ between the species with cattle and buffaloes contributing maximum. On an average, each kg of beef, cattle milk, buffalo meat, mutton, goat milk, pork, chicken and eggs contribute 295, 87, 404, 201, 148, 55, 36 and 35 kg of carbon dioxide equivalents respectively (FAO, GLEAM). The drivers of climate change are green house gases and its potential impacts on health, agriculture, forests, water resources, coastal areas, species diversity and natural habitats include weather related mortalities, infectious diseases, emerging and re-emerging diseases, respiratory illness, reduced crop yields, more irrigation demands, changes in forest composition, shift in geographic ranges of forests, forest health & productivity, changes in water supply, water table, water quality, competition for water, erosion of breaches, inundation of coastal lands, shift in ecological zones, loss of habitats and loss of species (Fleming *et al*., 2018; Lipton *et al*., 2018).

India has a huge livestock population of 535.8 million (20th Livestock Census) and ranks number one in cattle and buffalo population in the world. India although stands largest producer of milk, makes up to 23% of the world's milk annually yet the per animal milk production is too less as compared to developed countries. Because of this huge livestock population in India with low average production per animal, Indian livestock sector is tagged as the main contributor to the global climate change. The livestock sector is often associated with negative environmental impacts such as land degradation, air and water pollution, and biodiversity destruction (Bellarby *et al.,* 2013). It is well realised that the livestock production system in India is not much efficient, as it has a high proportion of low yielding indigenous livestock. 51 % of the cattle in India are non-descript with an average milk production of 3 kg per day, contributing only 21% of total milk pool (Fig 5). The average age at first calving is 60 months and long calving interval of 20 to 24 months are the indicators of not having an efficient system of livestock production. The exotic blood although very limited 13% of population yet contributes 27% to the milk pool. Increases in livestock production are expected to originate from a declining natural resource base, which will cause further environmental damage without proper natural resource management. Climate change affect livestock production through competition for natural resources, quantity and quality of feeds, livestock diseases, heat stress and biodiversity loss. Climate change severely threatens genetic resources, puts stress on and poses many risks to

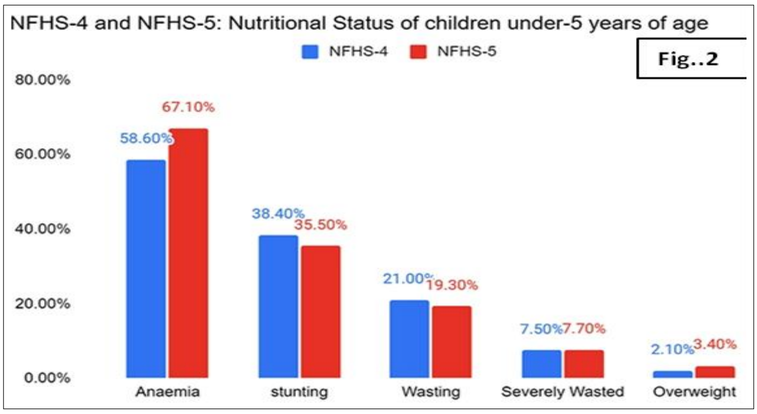

Fig 2: Nutritional status of children under 5 years of age in India.

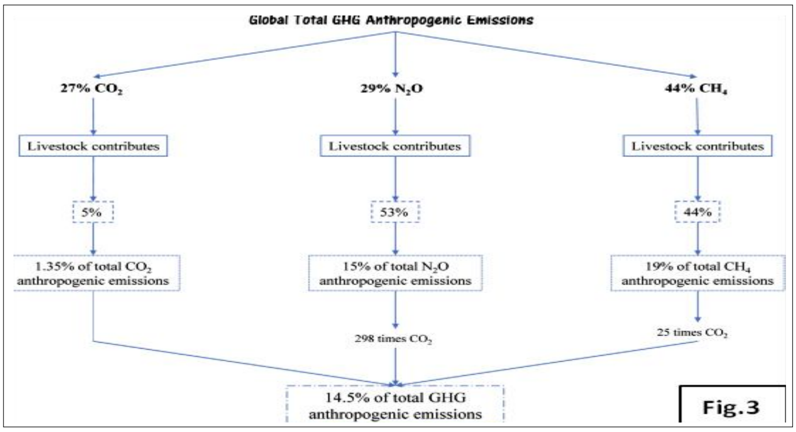

Fig 3: Global anthropogenic greenhouse gas emissions.

animal genetic resources. It is expected to change the distribution of species, population sizes, herd composition, temporal changes in biological events and the behaviour of many species (Steinfeld *et al.,* 2006). Extreme weather events can pose an immediate threat to the survival of livestock species. Changing climate increases livestock mortality in grazing animals as they are directly exposed to increased ambient temperatures and radiation. Climate change indirectly affects forage availability, production and quality that will translate into low animal productivity. Heat distress suffered by animals reduces the rate of animal feed intake and result in poor growth performance and production. Higher temperatures and changing rainfall patterns, could translate into the increased spread of existing vector-borne diseases and macro-parasites, accompanied by the emergence and circulation of new diseases in livestock. IPCC states that an increase of 2 to 3 °C above pre-industrial levels may result in 20 to 30% loss of biodiversity of plants and animals. In year 2000, 16% of livestock breeds (ass, water buffalo, cattle, goat, pig, sheep, and horse) were lost (TWB, 2022). In addition, the FAO, 2007, has stated that from 7,616 livestock breeds reported, 20% were at risk, and almost one breed per month was being lost. Animal genetic diversity is a precious and irreplaceable resource that needs to be conserved and used as it serves a great choice for the farmers to have climate resilient and disease resistant livestock species. Conservation and sustainable use of genetic resources will be critical for the development of climate-smart livestock strategies (FAO, 2007).

An efficient system of livestock production is inevitable wherein livestock products are produced with low carbon foot prints, wherein inputs are efficiently utilized by the animal to produce optimum with low GHG emissions. Climate smart livestock production has been defined the one that 'sustainably increases productivity, enhances resilience (adaptation), reduces/removes greenhouse gases (mitigation) and enhances achievement of national food security and development goals'. The climate-smart livestock approach is a comprehensive approach that works towards sustainable livestock production systems that fully support to climate change adaptation and mitigation activities, food security, sustainable incomes, animal welfare

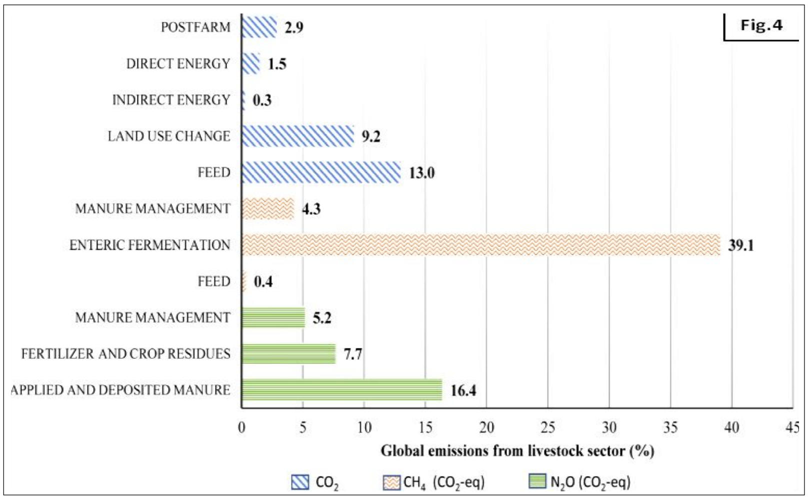

Fig 4: Global greenhouse gas emissions from the livestock sector.

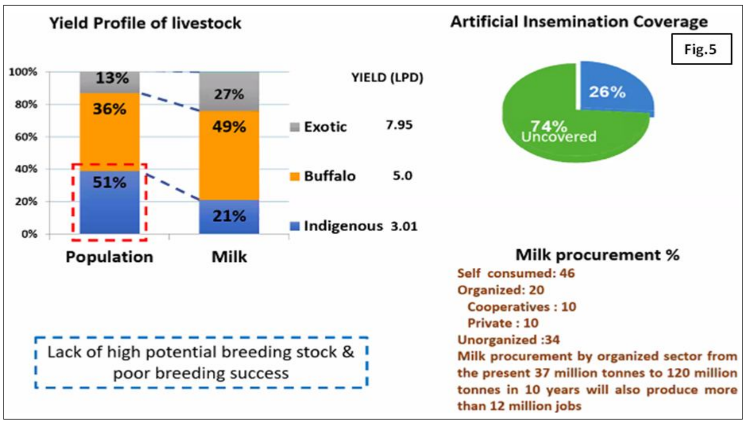

Fig 5: Livestock production system in India.

and reduce the environmental impacts. A climate-smart livestock necessitates strategies to prevent climate change *e.g.* mitigation, as well as adjust to climate change *e.g.* adaptation. The IPCC defines climate change adaptation as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" and climate change mitigation as the "anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gasses". Even though there are some differences between adaptation and mitigation, both are interlinked and critical in combating climate change. Adaptation strategies can improve the resilience of livestock productivity to climate change and mitigation strategies could significantly reduce the impact of livestock on climate change (Dickie *et al.,* 2014). Adaptation and mitigation strategies can make significant impacts in climate smart livestock production if they become part of national policies.

In order to feed rising population and increasing liking for food of animal origin, the livestock production has to be augmented efficiently, smartly with adoption of mitigation and adaptation strategies. The scale, purpose and nature of the livestock farming enterprise is known as the livestock production system. The different production systems are;

- ✓ **Land-based:** In this livestock system, more than 90% of dry matter fed to animals comes from pastures, rangelands, annual forages and purchased feeds whereas less than 10% of the total value of production comes from non-livestock farming activities.
- ✓ **Mixed farming:** In this livestock farming system, more than 10% of the dry matter fed to the animals comes from crop by-products and more than 10% of the total value of production comes from non-livestock farming activities.
- ✓ **Feedlot:** The system is feed-intensive and labour-extensive. In this livestock production system feed is mainly introduced from outside the farm system. The system is based on high-producing, specialized breeds and their crosses and key efficiency parameters are daily weight gains and feed conversion ratio.
- ✓ **Backyard:** The backyard system or subsistence system is used in monogastric species, mainly poultry and pigs. In the backyard system, animals are usually confined in simple structures, often within the homestead, and provided with some feed supplementation. The family labour suffices for all production activities.
- ✓ **Semi-commercial:** In this system monogastric species, mainly chickens and pigs are reared for home consumption up to 50% of the value of produce.
- ✓ **Commercial:** In this system monogastric species, mainly chickens and pigs are reared with more than 50% of livestock produce for sale.

The climate smart livestock production system will require efficiencies in various operations, plans and activities common to all systems of livestock production. It includes;

Proficient livestock productivity

Livestock productivity is measured as the ratio of outputs to inputs. Improving livestock productivity will lead to both improved food security and reduced GHG emissions. Productivity gains are recognized from an increased number of animals born and raised per breeding animal per year, increased growth rates and market weights of animals anticipated for slaughter, or increased amount of livestock products per animal per year. Europe, North America and the non-European Union countries produced 46.3% of ruminant meat and milk energy and only 25.5% of the enteric CH_4 emissions in 2005 (O'Mara, 2011). In contrast, Asia, Africa, and Latin America produced a similar amount (47.1%) of ruminant meat and milk energy for a large proportion of 69% of enteric CH_4 emissions. Production efficiency will lead to less emission per unit of livestock product. In Netherlands, milk production per cow increased from 6,270 kg/yr in Kyoto base in year 1990 to 8,350 kg/yr in 2008, with a concomitant decrease in CH_4 production from 17.6 to 15.4 g/kg milk, respectively (Bannink *et al.* 2011). Flachowsky (2011) estimated that a dairy cow producing 40 kg milk/d would produce 50% lower CO_2-equivalent (CO_2e) emissions per kilogram of edible protein than a cow yielding 10 kg/d. Similarly, GHG emissions would be about 70% lower from beef cattle gaining 1.5 vs. 1.0 kg/d, 40% lower from a growing or fattening pig gaining 900 vs. 500 g/d, and 60% lower from a laying hen with 90 vs. 50% laying performance. Proficient way of increasing livestock productivity is to employ all the available technologies, skills, strategies as per the production system to augment productivity.

- ✓ Selection and breeding of more productive animals shall be the foremost and effective strategy to increase productivity. Well-designed selection and culling strategies, cross-breeding programmes and artificial insemination programmes can all contribute to increase productivity, and thereby reducing GHG emissions.
- ✓ Cross-breeding programmes should be considered in such way that they address adaptation, food security and mitigation at the same time. Cross breeding for heat tolerance, disease resistance and better reproductive traits should be designed.
- ✓ Breeding management is a key strategy to increase livestock productivity by improving traits such as live weight gain, milk yield, disease resistance or fertility. However, selection for higher productivity in dairy cows should not decrease productive life or increase death rate or decline fertility (Hare *et al*., 2006; Norman *et al*., 2009).
- ✓ Use of marker-assisted selection for breeding, to identify genes that can enhance beneficial traits in livestock like controlled growth rate, resistance to disease, increased fertility, better FCR, tolerance of heat and cold conditions, lower cholesterol in eggs, and an increased lean-to-fat ratio in pigs.
- ✓ Selection for prolific breeds or introgression of fecundity genes. Prolific breeds or strains of animals can greatly increase the efficiency of production by increasing the

number of animals (or BW) weaned per female for each gestation.

- ✓ Improving the genetic potential of the animal is essentially important, but it is equally important not to import high genetic potential animals into climates and management systems where high-producing animals can never achieve their optimum potential and will rather perform worse than native breeds or crossbreeds due to management, disease, or climatic challenges.

Feeding management

Improving diets so that animals produce more protein with less feed and lower emissions. Balanced feed ration is of utmost importance to improve growth, reproduction and productive life. Imbalanced feeding leads to an increase in GHG emissions, either as CH_4 from enteric fermentation in ruminants or as CH_4 and N_2O produced from the manure. Waghorn and Hegarty (2011) reported that good quality pastures/ fodders reduce methane emissions and calculated that 20% increase in ME of fodders can reduce methane emissions by 50%.

- ✓ Improving the quality of feed, formulating appropriate feed rations with high-quality feed ingredients. Use of technologies that enhance forage digestibility like, chopping, soaking, urea treatment, enzyme treatments or silage and hay preparation.
- ✓ Targeted feeding/ strategic feeding with energy and nutrients as per the type of animal, species, age, production and its physiological state. Strategic use of available resources such as feeding a balanced diet based on the physiological needs of the animal, reducing feed wastages, increasing concentrate feed availability and improving animal genetics have a tremendous potential in increasing animal productivity and reducing GHG emissions (Makkar, 2013).
- ✓ Selecting better feed resources, including alternative feed products and feed additives along with supplementation of small amounts of concentrate feed and multinutrient blocks (mineral/urea/molasses) in diets to improve feed conversion. Due to increased human population associated with increased demand for grains, it is likely challenging to spare grains for livestock in long run but more sustainable solution is to produce concentrate by strategically mixing agro-industrial by-products that are rich in energy or proteins (Makkar, 2013).
- ✓ Introduction of insect-based feed products as a source of protein in animal feed rations. The most promising species for industrial feed production are black soldier flies, common housefly maggots, silkworms, locusts/grasshoppers/crickets and yellow mealworms (Harinder *et al*., 2014).
- ✓ Use of rBST (recombinant bovine somatotropin) in USA has been shown to increase milk production and decrease methane emissions significantly (Capper *et al*., 2008).
- ✓ Better animal husbandry and livestock support services.

Efficient manure management

Livestock manure management is a central issue because of its impact on water and air quality through carbon dioxide, methane, nitrites and phosphorus released from manure (van Dijk *et al*., 2016; Web *et al.,* 2012). However, globally, livestock manure supplies up to 12 % of gross nitrogen input for cropping and up to 23% in mixed crop-livestock systems in developing countries (FAO, 2019). The total nutrients from livestock manure exceed nutrients from synthetic fertilizers. Animal manure contains most of the essential micro- and macro-elements required for plant growth and represents a valid alternative to other fertilizers that release GHG emissions. Manure management refers to manure accumulation, its collection, storage, processing and application to crops (Hristov *et al*., 2013). Most methane emissions from manure derive from swine, poultry and beef cattle feedlots where production is carried out on a large scale and manure is stored under anaerobic conditions. Manure is linked to both CH_4 and N_2O emissions. Most of the nitrous oxide emissions come from the manure of pigs and poultry (Fig 6). Most of the manure-related CH_4 emissions are produced under anaerobic conditions during storage and very little following land application. Manure from grazing ruminants does not produce significant quantities of CH_4 because it remains largely aerobic. Solid manure is mainly stored in field heaps, very little in covered storages and slurry is spread over fields. Climate smart livestock provides solutions related to reducing GHG emissions and polluting air and water by the manure.

- ✓ The important step to minimize the water pollution is that the manure shall not be stored or spread in the vicinity of water resources and a minimum of 100 meter distance should be maintained. The spreading of slurry and solid manures should be forbidden closer than 35 m from the banks of rivers and streams unless there is a permanent vegetative zone.
- ✓ Livestock farmers must have adequate storage capacity (Cu mm for slurries or Sq.Mts for FYM), sufficient to enable storage for a minimum period (45 days) before land spreading.
- ✓ Land spreading should be forbidden on certain lands like bare soil, sloping ground, saturated land, frozen ground that would otherwise lead to environmental impact *via* run off or by leaching.
- ✓ Ammonia liberation and its nitrification from the manure is a big threat to environmental pollution. Acidification of manure during storage or field application is a proven method to prevent ammonia emissions from manure by up to 90% (Fangueiro *et al*., 2015). However, it requires trained handlers to handle strong acids. Treatment with urease inhibiting enzymes is effective in preventing the conversion of manure urea to ammonia and lower ammonia volatilization (Hagenkamp-Korth *et al*., 2015).
- ✓ Covering manure is also an effective method to prevent ammonia emission from manure.
- ✓ Solid–liquid manure separation allows for wastewater to be used in flushing feed alleys and for irrigating fields, whereas the solids can be used as animal bedding, composted or air dried for application to the field.
- ✓ Other manure storage and treatment systems include lagoons, anaerobic digestion, activated sludge, and

constructed wetlands. Lagoons must be constructed in such a manner that they have a very low permeability.

- ✓ Anaerobic digestion and activated sludge have been developed to recycle and reuse organic wastes more efficiently. Capturing and transforming the CH_4 that is produced in anaerobic conditions in anaerobic digesters (*e.g.* biogas systems) can increase farm profits by 10 to 20 per cent and help reduce the environmental impact of livestock production.
- ✓ Construction of biogas digesters and waste water treatment systems. Bio-gas systems are recommended as a mitigation strategy for CH_4 to generate renewable energy that can be used to run electric generators, milking machines, farm heating or lighting systems.
- ✓ Composting can effectively reduce CH_4 but can have a variable effect on N_2O emissions and increases NH_3 and total nitrogen losses.
- ✓ Vermicomposting has proved to be a successful strategy to produce wealth from waste.

Efficient herd management

To improve output, the herd management including herd health management with less dependence on antibiotics is a strategy to have climate smart livestock production. Improving animal health services, including disease prevention and management, has a strong impact on the efficiency of livestock systems, food security and adaptation to climate change. Apart from productivity, management practices, such as improved animal health and fertility can improve overall animal performance and lifetime productivity (Place and Mitloehner, 2010). Decreasing dry period, increasing lactation days can reduce the GHG emissions significantly. Improving animal health and reducing morbidity and mortality to improve efficiency of the livestock production system offer opportunities to reduce both CH_4 and N_2O from enteric fermentation and animal manure. The major focus of veterinary medicine remains in eliminating infectious diseases through individual animal treatment in small herd livestock production systems. However, as herd size and animal productivity increase, the focus shifts towards preventive veterinary medicine and greater emphasis is placed on subclinical disease and systematic health management that target increased productivity (LeBlanc *et al*., 2006).

- ✓ Establishing strong animal health institutions, formulating dedicated policies and initiating research programmes focused on changing conditions are essential to improve livestock efficiency and increase the preparedness against new risks, including those resulting from climate change.
- ✓ Proper animal health services will also lead to an increased lifetime productive performance.
- ✓ Animal disease surveillance, tracking, early warning and rapid response is a key to climate change adaptation option.
- ✓ Effective and smart surveillance and forecasting system could lead to adoption of preventive measures to reduce the losses and increase the efficiency of production system.
- ✓ At door services for health and insemination using mobile vans can be a strategy to increase clean productivity.
- ✓ Use of advanced techniques like telemedicine, livestock health mobile Apps can improve the health and reproductive status of animals thus efficient farming
- ✓ Careful management of transition period in dairy cows that involves careful attention to the metabolic status of cows in the pre- and postpartum period.
- ✓ Day light length management during lactation and dry period, increasing the roughage content and reducing energy in the diet of cattle during dry period could improve the productivity, reduce metabolic problems in early lactation and concomitantly reduce GHG emissions (Beever, 2006).
- ✓ Management strategies should be adopted to reduce stress. Provision of adequate access to shade and water can reduce heat stress and minimizing transport or herding of animals over long distances.

Management of grasslands

Globally, grazing lands comprise the largest and most diverse single land resource and represent an important component of terrestrial carbon cycling and sequestration. Globally grasslands (pasture, silage and hay) dominate major agricultural areas and contribute 20-30% to the SOC pool by sequestering atmospheric CO_2, thus mitigating climate change (Lal, 2004; Conant *et al*., 2001). For

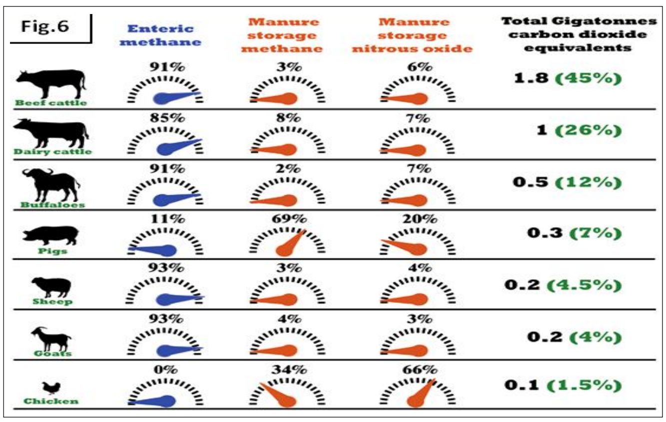

Fig 6: Species wise greenhouse gas emissions.

sustainable management of pastures and rehabilitation of degraded lands, tailored and site-specific grazing management is needed. By optimizing the grazing pressure on land and by improving grasslands for animal feed, more productive and nutritionally better quality of fodder will be available for livestock.

- ✓ A key grazing management strategy is rotational grazing, which will enhance the quality and digestibility of the forage. As animals will graze the forages in a relatively earlier growth stage, the quality and digestibility of the grass will be higher and will improve the quality of the diet.
- ✓ Implementation of successful rotational grazing may require some investment for fencing and the provision of drinking water, as well as some additional labour.
- ✓ Overgrazing can be prevented through controlled rotational grazing that will stop land degradation and increase soil carbon sequestration.
- ✓ Increasing livestock mobility, a traditional strategy of nomadic and transhumant herders for matching animal production needs with changing rangeland resources, can significantly enhance the resilience of these livestock systems to climate change.
- ✓ Better grassland management involves the sowing of improved varieties of pasture, typically replacing native grasses with higher yielding and more digestible forages, including perennial fodders, pastures and legumes like Tall fescue, Ray grass, Clover, Lucerne, *etc*. The introduction of legumes in pastures increases forage production and diet digestibility, thereby improving productivity and decreasing GHG emissions.
- ✓ The fertilization and nutrient management of pasturelands will improve the overall productivity of the land and the quality of animal feed. Aerial reseeding and fertilization with the use of drones can be done to highland pastures.
- ✓ Agroforestry is an important strategy in climate smart livestock production system, as trees can sequester carbon in the soil, provide shade and improve animal nutrition. It also improves the resilience of agricultural production to climate variability by using trees to intensify and diversify production and buffer farming systems against hazards like cold wind and snow in winter and from the hot sun and drying winds in summer.
- ✓ Integrated farming systems often provide a combination of good management practices. A number of integrated farming systems (IS) such as crop-livestock (agropastoral system, ICL), crop-forestry (silvoarable system, ICF), forestry-pasturage of livestock (silvopastoral system, ILF), and crop-forestry-pasturage of livestock (agro-silvopastoral system, ICLF) are reported to improve soil carbon sequestration and reduce farm waste.

Efficient use of natural resources

It include higher yields per hectare, higher water productivity, efficient use of low carbon energy, and the reduction of waste along the value chain. Natural resource use efficiency is measured by the ratio between the input of natural resources in the production process and the product output (*e.g.* litres of water used for one litre of milk). The amount of energy used in processed animal feed and fertilizer is particularly concerning. The efficient use of energy, including the use of renewable energy, is an important CSL strategy to minimize the use of fossil fuels. Solar energy, photovoltaic (PV) cells and solar thermal collectors, wind power, hydropower and other renewable energy sources can be used to minimize the need for non-renewable energy sources along the livestock value chains. The efficient use of energy can be achieved by using machinery and equipment with a higher energy efficiency on the farm and elsewhere in the livestock value chain. Some of the steps in this direction will include:

- ✓ Using natural ventilation in barns and sheds instead of cooling systems.
- ✓ Efficient systems for cooling milk at dairy farms.
- ✓ Variable speed drives on the milk pump, and refrigeration heat recovery units.
- ✓ Efficient systems for heating water.
- ✓ Replacing incandescent lighting with high efficiency lights like LED.
- ✓ Efficient livestock watering systems.
- ✓ Efficient heating systems for lambs, kids and piglets.
- ✓ Energy efficient equipment for feed manufacturing.
- ✓ Reduction of transport along the value chain.
- ✓ Using animal manure instead of fertilizer.
- ✓ Using conservation agriculture techniques instead of pesticides.

Similarly the climate change impacts water availability, variability in rainfall, evaporation rates and extreme weather events that indirectly affect feed production and water shortages. Increased ambient temperatures result in increased water requirements, degradation of water quality and increasing competition over water resources. Efficient use of water will include strategies like.

- ✓ Efficient water harvesting techniques.
- ✓ Weather forecasting, crop insurance.
- ✓ Use of drought-tolerant feed and fodder crops.
- ✓ Water management.
- ✓ Reduction of water waste.
- ✓ Increased water storage.
- ✓ Efficient and low-energy irrigation methods.
- ✓ Financing for water-smart investments.
- ✓ Development of policy and regulations related to efficient water use.

Reducing wastage along the value chain

A large volume of livestock products is wasted even before reaching the consumer. Food wastage from production to consumer is estimated to be 1/3rd of produce. In developing countries most of the wastage is at production source and little with consumer, however, in developed countries the wastage is majorly at table and little at production source. If the loss of food in value chain in India is reduced it can eliminate the hunger from the country alone (Pampori, 2021).

Waste reduction can substantially contribute to improving resource use efficiency such as land, water, energy, as well as other inputs such as nutrients. Therefore reducing wastage along the value chain will be an important strategy to a more efficient use of natural resources. The energy embedded in global annual food losses is thought to be around 38% of the total final energy consumed by the whole food chain (FAO, 2017). CSL options related to the reduction of losses and waste include;

- ✓ "There's enough on this planet for everyone take what you need and remainder is needed by others" is the sacred slogan to reduce waste.
- ✓ Ensuring proper sanitation at all stages of the value chain.
- ✓ Mechanized and hygienic processing units. Innovations in slaughter house waste collection, disposal and utilization.
- ✓ Higher payments for good quality products
- ✓ Appropriate processing, labelling and packaging, distribution, transportation and storage of livestock products to extend the product shelf life.
- ✓ Recycling of waste to strengthen the circular bioeconomy, *e.g.* using crop by-products as animal feed.
- ✓ Ensuring efficient manure management
- ✓ Behavioural changes at retail and consumer level.

Early warning system, disease surveillance and livestock insurance

The use of weather information to predict health and production risks and assist in risk management is a potentially effective option for climate change adaptation. Use of weather data to provide advisories and early warnings to the livestock farmers for better management of livestock Disease surveillance and assessment of association of different environmental conditions with different diseases can be a better tool to risk management in livestock farming. There is a need to improve upon weather warning and forecast system for effective application. Livestock insurance schemes that are weather indexed can be run by the private sector. Public-private partnership approaches to index-based livestock insurance in situations where risks are unacceptably high should be practiced.

Better integration of livestock in the circular bio-economy

It will contribute to reduced losses and lead to an overall decrease in GHG emissions. A circular bioeconomy minimizes the leaks of energy and materials from the system by re-circulating them in production, while a linear economy uses external inputs to produce outputs and waste. Crop residues and agro-industrial by-products such as bran, molasses or oilseed cakes represent nearly 30 per cent of the total livestock feed intake. These by-products will get produced more and more with the consumption of more processed food by the increasing human population and thus could become an environmental burden. Livestock play a critical role in adding value to these by-products. Increasing the share of by-products or waste that humans cannot eat in livestock feed, by recycling and recovering nutrients and energy from animal waste. Approximately one-third of all food produced for humans is either lost (not suitable for consumption) or wasted. Prevention and reduction of these losses, combined with alternate uses of food waste, including food recycling, can help reduce these negative impacts. Feeding food waste to animals is a sustainable solution and brings more co-benefits by reducing waste streams, greenhouse gas emissions and supporting circular bioeconomy. To ensure the safe use of food waste and food losses and their traceability, it is essential to develop innovative technologies, retailer standards and policies to frame their collection, treatment and usage.

Policy support

There is need to have policies and regulations in place that take climate-smart livestock solutions into account at all levels. In order to transition to a climate-smart enabling environment for the livestock sector, a coherent range of policies and regulations is must, besides that research programmes to support the implementation of the climate-smart livestock solutions needs to be promoted. An assessment of current policies related to livestock and/or climate issues is the first step into gaining a better understanding of the policy coherence. There is need to have more focus on the presence and detail of livestock sector-related climate change adaptation and mitigation strategies, approaches and activities. Schemes being framed and implemented in livestock sector should be supported by policies that take cognizance of environmental impacts, mitigation and adaptation strategies.

Next-gen technological interventions

Technology required for climate smart livestock depends on country, physical environment, infrastructure, climate, culture, literacy, economic conditions and governance and the technologies to achieve that goal span a wide range of subject areas, including land, soil and water management, Livestock management, pest and disease control, farm management, livestock product management like storage, processing, packaging, marketing and distribution of livestock products. Adoption of modern technologies and data analytics will provide the leads for smart livestock farming.

- ✓ Use of AI, IoT, ML, Robotics and ANN in livestock sector will be the game changer and are referred as the best innovative intervention in transforming every field of agriculture.
- ✓ Different farming parameters, farm monitoring, weather monitoring and air monitoring are used to generate data and real-time analysis of this data will help in making informed decisions regarding farming operations.
- ✓ Intelligence extracted from the data to build solutions for farmer's use will be a disrupting inclusion into livestock sector.
- ✓ Will equip with forecasting skills of the highest grade for prompt prediction of disease outbreaks, timing of various livestock practices. "smart cow-house". "WeSTOCK" a cow health tracker developed recently by Brainwired will be monitoring and tracking all the activities of animals and their health status. It will provide the leads to the farmer

for various farm activities that will increase productive life and utilization efficiency of livestock.

- ✓ Enable farmers to improve efficiencies, quantity and quality and ensure faster go-to-market for livestock products.
- ✓ Will help in formulating rations depending upon the production, functional state, weather, environment and behavior of livestock. In India NDDB has developed user-friendly computer software for advising milk producers to balance dairy feed rations with available feed resources. The software on hand-held devices enables small farm-holders to collect data and formulate appropriate feed rations for using local feed resources.
- ✓ Will help livestock farms accumulate and analyze data to predict consumer behavior, automate processes, reduce major costs and improve the quality of livestock products.
- ✓ Will favour environmental stability and sustainability.
- ✓ Implementation of robotic milking machines, brushes for added cow comfort, and automatic calf feeders on dairy farms will reduce the cost of production.
- ✓ Need to integrate different omics-branches *i.e.*, genomics, transcriptomics, metabolomics, phenomics and ionomics and use of next-gen biotechnological tools like CRISPR, nuclear transfer or transgenic technologies to have designed animals.
- ✓ Innovative use of smart phone technology can be quite helpful in disseminating farming knowledge to the livestock farmers for better returns and smart farming.

CONCLUSION

The increasing human population, urbanization, enhanced purchasing capacity and increased preferences for animal foods warrants increased production of foods of animal origin to have food security. However, the shrinking farm land, high cost of labour, exhausted soil and climate change are limiting factors, thus traditional farming practices and coping mechanisms are not enough to safeguard our livelihood and food security. Therefore, in order to cope with the challenges we need to have efficient, smart, sustainable and profitable livestock farming. There is need to adopt technological advancements in livestock, grass land, manure and feeding management. A wide array of options/strategies are available and are needed to be put in place for climate resilient, eco-friendly, smart and efficient livestock farming in order to achieve food security for a huge increasing population and livelihood security of the farmers.

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