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FODDER FOR CLIMATE RESILIENT AGRICULTURE : A REVIEW

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SUMMARY

Climate change is a growing concern and its impacts are reflected in almost every sector and is mainly due to the increase in greenhouse gases. There is a leap in atmospheric concentration of carbon dioxide has observed from 1930 (278 ppm) to 2018 (408 ppm) and it expected to cross 1000 ppm at the end of the century (IPCC, 2019), which is a major warning to food-fodder security and climate change in 21^{st} century. Fodder production systems play a major role in mitigating climate change through improving carbon sequestration, reducing methane emission per unit livestock product and reducing nitrous oxide emission. Grasslands, pastures and forage crops contribute greatly in the global carbon cycle which stocks at least 30 per cent of world soil carbon. Many strategies can be adopted to enhance the carbon sequestration in fodder production system like implementation of pasture based agro forestry practices, restoration of degraded lands and inclusion of grasses and grazing management. Supplementation of suitable fodder in diet with high digestibility and high energy and protein concentrations will reduce the total methane emission per unit livestock. Certain pastures has a capacity to release biological nitrification inhibitors from their roots, which suppress nitrifier activity and reduce soil nitrification and nitrous oxide. Thus there is a need for strategies that will enable reduced GHG emissions through sustainable intensification of forage production systems to enhance productivity, income generation, climate mitigation and ensuring food-fodder security.

Key words : Carbon sequestration, enteric fermentation, methane, mitigation, adaptation

The increase in concentration of greenhouse gases (GHGs) in the atmosphere is a major threat to food-fodder security and climate change in 21^{st} century. The atmospheric concentration of carbon dioxide (CO_2) has increased globally by 40 per cent from 278 ppm in the pre-industrial era to around 408 ppm in 2018, and is expected to cross 1000 ppm at the end of the century (IPCC, 2017). In the recent years there has been a consistent and continuous increase in the emission of greenhouse gases into the atmosphere due to the anthropogenic activities *viz*. burning of fossil fuels for energy, deforestation, land use change, biomass burning and draining of peat and wetlands. The GHGs emission should be reduced by 50 to 80 per cent by 2050 to avoid adverse effect of climate change. Although oceans store most of the earth's carbon, soils contains approximately 75 to 80 per cent terrestrial carbon pool which is higher than the biotic pool (*i.e*. the increased amount stored in living plants and animals). Atmospheric enrichment of CO_2 can be moderated by reducing anthropogenic emissions and by adopting proper management practices in grassland and forage land which will enhance storing or sequestering carbon either in to plant or in to the soil.

Climate change and climate resilience

The challenge of agriculture within the global climate change context is two-fold, both to scale back emissions and to adapt to a changing and more variable climate. The primary aim of the mitigation options is to cut down emissions of methane or nitrous oxide or to extend soil carbon storage. All the mitigation options, therefore, affect the carbon and nitrogen cycle of the agro ecosystem in some way. Mitigation as technological change and substitution that reduce resource inputs and emissions per unit of output with respect to global climate change. Adaptation as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Nelson *et al*. (2007) defined climate resilience as the capacity for a socio-ecological system to absorb stresses and maintain function in the face of external stresses imposed upon it by climate change and adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future global climate change impacts.

Agriculture and livestock as major emitters of GHG

Green House gases (GHGs) are the major culprits which leads to climate change. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the main GHGs produced by agriculture including livestocks. Agriculture and allied sectors is a major contributor to climate change, producing 24 per cent of GHG emissions at the global level, with a further 10 per cent attributed to land use change and deforestation (IPCC, 2014). Globally livestock contribute 44 per cent of anthropogenic CH_4, 53 per cent of anthropogenic N_2O and 5 per cent of anthropogenic CO_2 emissions. All together livestock contributes 14.50 per cent of global anthropogenic GHG emission. Higher concentrations of those gases are often explained by lower efficiency and productivity of livestock system due to excess loss of nutrients, energy, and organic matter (Gerber *et al*., 2013).

Importance of forage based crop-livestock systems

Livestock production is the backbone of Indian agriculture which contributes 4.11 per cent of national GDP and 24.60 per cent of agricultural GDP. Livestock products contributes to global food security by providing 17 per cent of global kilocalorie consumption and 33 per cent of global protein consumption (Steinfeld *et al*., 2006). The livestock sector supports to the livelihoods of one billion of the poorest population in the world and employs close to 1.10 billion people.

Forage based systems include all systems that include forage plants as a component, including ley systems that include several years cropping before returning to pasture, agro pastoral systems, and rangelands. They all contain a substantial component of animal production. Forage grass is that the most consumed feed the planet (2.3 Gt in 2000), representing 48 per cent of all biomass consumed by livestock; of this, 1.1 Gt are used in mixed systems and 0.6 Gt in grazing-only systems. Grazing lands are by far the largest single land-use type, estimated to extend over 34-45 M km^2. Ranged ecosystem ranges from intensively managed pastures to savannas and semi deserts.

Reducing agriculture's GHG emissions and increasing C stocks in the soil and biomass could reduce global GHG emissions by 5.5-5.9 Gt CO_2 eq yr^{-1}. More than 89 per cent of the potential climate change mitigation of agriculture comes from terrestrial carbon sequestration, 9 per cent from CH_4 reduction, and 2 per cent from reduction of N_2O emissions (Scherr and Sthapit, 2009). Sown forages, through their effects on livestock systems and cropping systems, can contribute to the present potential altogether of them. Of the general carbon mitigation potential, 29 per cent are going to be from pasture land (Lal, 2010). There are various advantages for fodder that makes them adaptable to climate change. It has an ability to withstand moisture stress and dry conditions, tolerance to different soil related problems viz. alkalinity, acidity, water logging etc. Generally fodder crops are adaptable to low soil fertility conditions and lesser incidence of pests and diseases also help them to survive harsh conditions. Additional features like soil and water conserving characteristics. The fodder production in the country (1097 mt) is not adequate to feed the total livestock population (536 million).Thus there is a enormous gap between the demands and supply (63.50%). The demand of green and dry fodder will reach to 1012 and 631 million tonnes of by the year 2050. At the current level of growth in forage resources, there will be 18.40 per cent deficit in green fodder and 13.20 per cent deficit in dry fodder in the year 2050. To meet out the deficit, green forage supply has to grow at 1.69 per cent annually. Kerala require 232 mt fodder per annum. But the availability is very meager (94.5mt). Therefore a deficit gap of 59.20 per cent is noticed in Kerala.

Opportunities through fodder production systems to mitigate GHG emissions

Fodder production system can mitigate GHG emissions in three ways: by sequestering atmospheric CO_2, by reducing ruminant CH_4 emissions per unit livestock product and by reducing N_2O emissions (Scherr and Sthapit, 2009).

A. IMPROVING CARBON SEQUESTRATION

Carbon sequestration can occur several ways in plants, soil and deep in ocean. As per agriculture, carbon sequestration refers to the potential of agriculture lands to reduce the CO_2 from the atmosphere. Grassland including rangelands, shrub lands, pasture lands and forage crop lands, covered approximately 3.50 billion ha area, representing 25 per cent of global area and 70 per cent of the total agricultural area, and containing about 20 per cent of the world's soil carbon stocks (Conant, 2010). IPCC, (2014) reported that the land-use change from arable cropping to grassland leads to a rise of soil carbon of 30g C per m^2 per annum . There are several factor which define the capacity of the land to store carbon, that include climate, soil type, crop or vegetation cover and different management practices (Goh, 2004). Cultivation of forage crops leads to an accountable sequestration of atmospheric CO_2 and that will help the farmers to offset their own emissions and part of the emission from other industries. Improving carbon sequestration in agricultural soils and making soil a net sink for atmospheric carbon are often achieved by adoption of the scientific management practices like proper soil and nutrient management (Jiang *et al*., 2006).

Strategies for enhancement of carbon sequestration in grasslands

There are different management practice which will improve forage production and even have the potential to extend soil carbon stocks and that leads to increase the carbon sequestration capacity which mentioned as folows.

1. Adoption of pasture based agro forestry practices

Silvipastural system also offer excellent and economically viable potential for carbon sequestration in many situations (IPCC, 2000). When silvipasture systems are introduced in suitable locations, carbon is sequestrated in tree biomass and tends to be sequestered in soil also. Agroforestry system possesses optimum potential to sequester carbon than pasture or field crops (Kirby and potvin, 2007).

Shamsudheen *et al*. (2014) quantified carbon sequestration in both biomass and soil of two pasture systems (*Cenchrus ciliaris* and *Cenchrus setigerus*), two tree systems (*Acacia tortilis* and *Azadirachta indica*) and four silvipastoral systems (combination of one tree and on grass) in arid northwestern India. The silvipastoral system sequestered 36.30 per cent to 60.00 per cent more total soil organic carbon stock compared to the tree system and 27.10–70.80 per cent more in comparison to the pasture system.

A study conducted in AICRP on Forage Crops and Utilization, College of Agriculture, Vellayani, Thiruvananthapuram, documented that grass legume mixture of Hybrid Napier cv. Suguna (paired row) with fodder cowpea has recorded the highest carbon sequestration (211.44 q/ha) followed by intercropping of BN hybrid+ Agase (199.22 q/ha) and Guinea grass + Agase mixture (195.21 q/ha).

2. Restoration of degraded lands and inclusion of grasses

Retreating of degraded lands improves production, carbon inputs and sequestering carbon (FAO, 2010) and that will leads to greater forage production, more efficient use of land resources, enhanced profitability and rehabilitation of degraded lands and restoration of ecosystem services. Silvo pastoral system can sequester 1–3 tonnes C $ha^{-1}yr^{-1}$ under favourable condition. Introduction of grasses to arable land is a best method which improve organic matter content and reduce disturbance to the soil through tillage.

3. Grazing management

Conant and Paustian, (2002) estimated soil carbon in several grassland systems and concluded that 34.50 per cent average increase in soil carbon content was recorded under moderate grazing compared to heavy gazing. Improved grazing management (management that increases production) results in a rise of soil carbon stocks by a mean of 0.35 Mg/ha/yr. Universal rehabilitation of overgrazed grasslands can sequester approximately 45 Tg C yr^{-1}.

4. Direct inputs of water, fertilizer or organic matter

Application of fertilizer and other nutrients can improve litter production of the tall grass prairie and resulted in a rise in soil C of 1.60 $Mg^{-1}ha^{-1}$ (Rice, 2000). Application of irrigation can enhance water and nitrogen balances leading to increase in plant productivity and carbon inputs.

B. REDUCING METHANE EMISSIONS

Enteric fermentation is the largest contributor of the sector's emissions with 39.10 per cent, followed by manure management (4.30%) (Gerber *et al*., 2013). Feed production and manure emit CO_2, nitrous oxide (N_2O), and methane (CH_4), which consequently affects global climate change. Animal production increases CH_4 emissions. Processing and transport of animal products and land use change contributes to the increase of CO_2 emissions.

Methane from enteric fermentation in ruminants accounts for 25 per cent of GHG emissions from livestock, or 65 per cent of non-CO_2

emissions. Enteric CH_4 generated in the gastrointestinal tract of ruminants represents the greatest direct GHG released from the livestock sector and the single largest source of anthropogenic CH_4 at a global level (EPA 2012). About 75 per cent of total CH_4 emissions from livestock come from cattle and this is expected to increase in the next decades, especially in developing countries (Tubiello *et al.,* 2013). Over the last five decades, global enteric CH_4 emissions from dairy cattle grew by 12 per cent, with increases of 21.1 per cent in developing countries and decreases of 48 per cent in developed countries, thus highlighting a different contribution and a potential for reduction at a global level (Caro *et al.,* 2014). Interest in combating climate change has resulted in search for mitigation options to reduce GHG emissions from dairy cattle worldwide.

Enteric fermentation is a digestive process of ruminants where bacteria, protozoa and fungi contained in the rumen of the animal, ferment and break down the plant biomass consumed by the animal. Plant biomass in the rumen is converted into volatile fatty acids, which pass the rumen wall and go to the liver through the circulatory system. This process supplies a most important part of the energy needs of the animal and enables the high conversion efficiency of cellulose and semi-cellulose, which is typical of ruminants. Methane emission in the reticulorumen is an evolutionary adaptation that enables the rumen ecosystem to dispose hydrogen, which may otherwise accumulate and inhibit carbohydrate fermentation and fiber degradation (McAllister and Newbold, 2008).The methane emission from the cattle can be reduced by different strategies such as forage diets with high digestibility plus high energy and protein concentrations, inclusion of forage legumes in diet, ideal fodder preservation method, and use of forages in mixed crop-livestock systems (Herrero *et al*., 2008).

1. Forage diets with high digestibility, high energy and protein concentrations

Gurian-Sherman, (2011) reported that feeding cattle with high energy and protein contained fodder may reduce the methane emissions from beef production by 15-30 per cent. Forage with high proportion of easily digested carbohydrates like starches and sugars will move through the rumen faster than that of the feed with more roughages like cellulose, thus it will reduce the total methane production. Higher amount of dietary starch in the forage will favour the activity of amyolytic bacteria and that will leads to propionate production, Level of propionate in rumen inversely proportional to the rumen pH. Hence decreased pH generally unfavorable for the growth of methanogenic bacteria and the reduction in the population of methanogenic bacteria will reduce enteric methane production.

Benchaar *et al*. (2001) reported that utilization of slowly degraded starch rather than rapidly degraded starch as a potential strategy to reduce methane production in ruminants was simulated with a diet consisting of 30 per cent alfalfa hay and 70 per cent of either barley grain (rapidly degraded starch) or corn grain (slowly degraded starch).

2. Inclusion of forage legumes in diet

Legumes contain less structural carbohydrates and more condensed tannins than does grass, and adding legumes to the diet can further reduce methane emissions per unit livestock produce. Breeding of such legumes legumes with enhaced tannin like *Lotus corniculatus* (Birdsfoot trefoil) and *Lotus uliginosus* (Greater trefoil)will reduce the methane production considerably. Woodward *et al*., 2001 reported that cows offered with birdsfoot trefoil had a higher dry matter Intake (DMI) and milk production than those fed ryegrass and lower methane emissions per kg DMI. Cows fed ensiled birdsfoot trefoil produced 23 per cent less $CH_4{}^{-1}$kg DMI than cows fed ryegrass-based pasture silage. Benchaar *et al*. (2001) observed that replacing timothy hay with alfalfa hay substantially decreased (21%) methane production.

3. Ideal forage preservation method

Ensiled forage is a nutrient house for ruminants. Feeding cattle with ensiled forage will reduce the methane production to a greater extend. Evan (2018) reported that Adding maize silage in the diet will reduce the methane production by 10-20 per cent.

A study conducted by Benchaar *et al*. (2001) concluded that intake of Neutral Detergent Fiber (NDF) was lower by 11% with alfalfa silage than with alfalfa hay. Ruminal microbial efficiency was slightly enhanced by 9% by the utilization of alfalfa silage. Ruminal pH was higher for alfalfa silage. Total methane production was depressed by 33% by the utilization of alfalfa silage instead of alfalfa hay.

4. Use of forages in mixed crop-livestock systems

Introduction of forages in mixed crop-livestock systems could not only reduce methane emissions per unit livestock product but also add to the overall GHG balance of the system. Mosier *et al*, (2004) reported that well drained soils resulting from enhanced rooting capacity in improved forages can also work as a sink for methane as consequence of its oxidation by aerobic microorganisms (methano trophs) that use this gas as a source of C and energy. Kammann *et al.* (2001) emphasized the capacity of top soil aerobic layer for oxidizing methane and therefore cut down the amount of methane produced. Willison *et al*., (1997) compared the methane oxidation in arable land to that of grass land and found that methane oxidation rate of grassland was about 10 times that of arable land.

C. REDUCING NITROUS OXIDE EMISSIONS

At present globally, 17Mt N_2O is emitting per year and it expected to increase four-fold by 2100 and it is largely because of the increased use of N fertilizer (IPCC, 2014). Agricultural N_2O emissions are derived from three principal sources.

1. Direct emissions from soil nitrogen e.g. applied fertilisers (both manures and artificial), the mineralization of organic soils and crop residues
2. Emissions from livestock wastes in store
3. Indirect emissions from nitrogen lost to the agricultural system e.g. through leaching, runoff or atmospheric deposition.

The soil microbial processes of nitrification and denitrification drive N_2O emissions in agricultural systems. Nitrification generates nitrate (NO_3^-) and is primarily responsible for the loss of soil nitrogen (N) and fertilizer N by both leaching and denitrification. There are several strategies that help to reduce the nitrous oxide emission and fodder has an important role in this as follows.

1. Pasture as a Biological Nitrification Inhibitor

Subbarao *et al.*(2012) reported that some plants could release biological nitrification inhibitors (BNIs) from their roots that can suppress nitrifier activity and reduce soil nitrification and N_2O emission. This biological nitrification inhibition (BNI) is triggered by ammonium (NH_4^+) in the rhizosphere. The release of the BNIs is directed at the soil microsites where NH_4^+ is present and the nitrifier population is concentrated. According to Subbarao *et al.* (2007) tropical forage grasses, cereals and crop legumes show an extensive range in BNI ability such as *Brachiaria* spp which has high BNI capacity, particularly *B. humidicola* and *B. decumbens.*

2. Improving the nitrogen use efficiency of fodder crops

Nitrogenous emission from soil-plant-animal-soil cycle can reduce substantially by increasing the efficiency of plant uptake and by using nitrogen lower fertiliser application that could reduce the nitrogenous emissions. Nitrous oxide emission has both direct and indirect sources. Direct sources are straight Nitrogen inputs to soil e.g. animal excreta fertiliser, manure, crop residues, fixed nitrogen and also indirectly from nitrates.

3. Increasing the Nitrogen Use Efficiency in ruminant animal

Nitrogen Use Efficiency inversely related to the nitrous oxide emissions from ruminants. Major cause for N loss is due to rapid breakdown of herbage proteins in the rumen and inefficient incorporation of herbage nitrogen by the rumen microbial population. Breeding of improved forage grasses and legumes that constitute important components of the ruminant diet has the potential to reduce emissions to air.

Possible strategies can be suggested to improve the efficiency of conversion of forage-N to microbial-N as follows.

1) Increase the amount of readily available energy accessible during the early part of the fermentation and provide a level of protection to the forage proteins, thereby reducing the rate at which their breakdown products are made available to the colonising microbial population.
2) Develop forage species with enhanced balance between water soluble carbohydrate (WSC) and crude protein (CP) by increasing the WSC content of the grass or reducing the protein content of the legume.
3) Increase the content of compounds that affect protein breakdown in the rumen.

Opportunities are present within forages to select for other specific traits that can reduce protein loss. The emerging research on the enzyme polyphenol oxidase (PPO) is a good example for this kind. Owens *et al., (*2002) has conducted study in PPO and found that the activity is higher in red clover in comparison with other species and has a role in protein protection. This enzyme has a capacity to convert phenols to quinones which subsequently bind to protein and slow the rate of protein degradation.

Opportunities through fodder production systems to adapt GHG emissions

Combining soil conservation practices with fodder production is a way to adapt to the changes in climate. It give an opportunity to directly improve and diversify the farm productions through the integration of fodder and biomass production and also conserve soil and water resources, intensify farm production, preserve soil fertility and biodiversity and thereby paving a way to adapt the changes in climate.

Introduction of leguminous fodder like cow pea, stylo and rice bean will improve the soil fertility through nitrogen fixation. A study conducted by Varsha, (2015) on silvi pastoral system concluded that intensive silvopasture systems with high yielding grass species (HN) and densely planted fodder tree hedges (mulbery @11111 trees ha^{-1}), for maximizing fodder production, carbon sequestration and favorably influencing soil fertility in humid tropics of Kerala.

Legumes have the potential to improve soil fertility through the release of nitrogen from decomposing leaf residues, roots and nodules which results in increased sward productivity after nitrogen uptake by the companion grasses. The slow release of nitrogen may be better synchronized with plant uptake than other sources of inorganic N, thereby increasing nitrogen uptake efficiency and crop yields while reducing nitrogen loss through leaching. Thus integration of forage legumes into natural pastures is a viable option to improve soil fertility through addition of organic residues and soil nutrients.

The study conducted by Macharia *et al.*(2011) on effect of forage legumes on soil fertility at beginning and end of grass-legume integration experiment showed that the results showed that soil pH significantly increased from 5.23 at beginning of the experiment to 5.31 by end of the experiment. Leguminous fodder will add lot of organic matter to the soil through litter fall. Addition of organic residues, their decomposition and mineralization through action of soil micro-organisms may have resulted in increased soil pH. Less acidic conditions causes the release of major nutrients like C, N, P, K, Ca, Mg and S which becomes available for plant uptake, thereby decreasing in the soil.

About 75 billion tonnes of soil is eroded from the world's terrestrial ecosystems, most from agricultural land at rates ranging from 13 Mg/ha/yr to 40 Mg/ha/yr. About 6.6 billion tons of soil per year is lost in India (Lal, 1990). Conversion of cultivated lands to forage is a tool for conservation and stabilization of soil resources.

Diversified fodder cultivation practices like inclusion of leguminous fodder (fodder cow pea, stylo, rice bean), grass (napier grasss, para grass, guinea grass) cereal fodder (fodder maize, sorghum) and fodder trees (subabul, erythrina, agathi) will add to the farm profitability in one way and improve biodiversity in another way.

CONCLUSION

The increase in concentration of greenhouse gases (GHGs) in the atmosphere is a major threat to food-fodder security and climate change. Agriculture and livestock mainly fuels to it. Thus, there is an urgent need to develop certain strategies that will reduce GHG emissions like sustainable intensification of forage production systems without compromising the ability of ecosystems to re-generate and provide many ecosystem services. The strategies are mainly management of fodder production systems such grazing management, restoration of degraded rangeland, sowing of grasses and legumes and fertilization. These practices have the potential to increase forage productivity, income generation and climate mitigation that change the herder and farmers livelihoods.

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