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Research Article

Green House Gas Mitigation – A Scientific Approach for Sustainable Agriculture

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Abstract

Agriculture is although not a major source, it releases significant amounts of CO_2, CH_4, and N_2O to the atmosphere. The agricultural activities like crop cultivation, animal husbandry and deforestation produce 24% of total global greenhouse gas emissions. Agricultural operations with different best management practices can reduce greenhouse gas emissions by nearly a third. The increased practice of resource conservation agriculture, crop land and livestock grazing area management for soil carbon sequestration and bio-energy plantations in degraded lands poses great potential for GHGs mitigation. Many such climate-smart agro-technologies are becoming popular among the farmers and are offering good opportunities for enhancing food production and GHGs emission.

Keywords: Greenhouse gases, Agricultural emissions, Mitigation options, Sustainable management, Government initiatives

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Introduction

The major greenhouse gases (GHGs) in the atmosphere are carbon dioxide, methane, nitrous dioxide, water vapor, ozone and fluorinated gases which has greater global warming potential. These gases evolve from various sources including agriculture. The agricultural activities such as land operations, crop cultivation, livestock production, fisheries and aquaculture have a considerable effect on GHGs emission and results in climate change. Although not a major source, agriculture releases significant amounts of CO_2, CH_4, and N_2O to the atmosphere. According to IPCC, electricity and heat production were major contributor of GHGs emission (25%). Almost 24% of GHGs from agriculture activities and deforestation followed by industry (21%), transportation (14%), other energy (10%) and buildings (6%) were reported [1]. Worldwide, 14.5 percent greenhouse gas emission is from livestock and human-induced greenhouse gas emissions accounts for 18 percent.

Options for mitigation of GHG emissions in agriculture are more. Various management practices in agricultural operations can reduce nearly one third of greenhouse gas emissions. Several technologies to reduce GHG emissions with sustainable crop and livestock management have been developed under the National Initiative on Climate Resilient Agriculture. The government has also proposed complementary actions to reduce methane emissions from ruminants, including modifications of diet, and from rice paddies. Adaptation to resource conserving technologies in agricultural operations could be helpful for improving food production and also crop land and grazing area management, restoring degraded lands with bio-energy plantations has enormous potential for GHGs mitigation.

GHGs from Agriculture

Agricultural activities contribute approximately 25-30 per cent of total greenhouse gas emissions, mainly due to the use of chemical fertilizers, pesticides and animal wastes. This rate is bound to further rise as a result of an increase in the demand for food by a growing global population, the stronger demand for dairy and meat products, and the intensification of agricultural practices. Agriculture not only contributes GHGs, it also become victim in many cases. The main gases emitted by agricultural activities are: Carbon dioxide (CO_2), which is released during soil cultivation; Methane (CH_4), which is associated with cattle and livestock manure; and. Nitrous oxide comes from using fertilizer and manure. Agriculture represented 9 percent of all emissions when measured by economic sector in 2017 [2].

Methane

The microbial decomposition of organic matter in soil under anaerobic conditions produces CH_4. The sources of methane production are from

- Rice fields submerged under water

- High organic C content
- Use of organic manure in puddled soil

Moreover, crop residues burning and crop residues application as organic manure also added sources to global methane budget [3]. The mechanism of methane emission from ruminants is depicted in **Figure 1**.

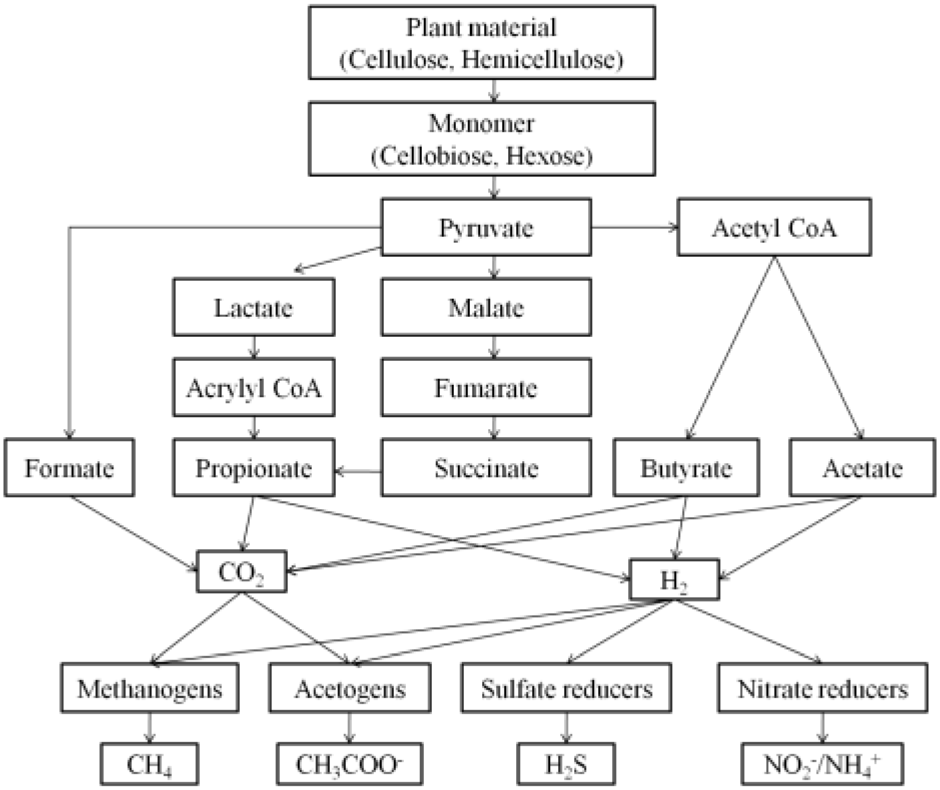

Figure 1 Mechanism of methane emission from ruminants

Nitrous oxide

Nitrous oxide emission from agricultural soils is mediated through nitrification and denitrification process [4]. Nitrification is the aerobic process in which microbial oxidation of ammonium to nitrate takes place while denitrification is the anaerobic process wherein anaerobic microbial reduction of nitrate to nitrogen gas occurs. N_2O is the intermediate gaseous compound produced in denitrification process and ultimately into the atmosphere. The factors affecting N_2O production are

- The availability of inorganic N contents in soil.
- Addition of synthetic or organic fertilizers, crop residues, organic manures and other nitrogen inputs like sewage sludge to soils.
- Mineralization of nitrogen in soil organic matter
- Drainage/management practices of organic soils
- Cultivation/land-use change in mineral soils

Carbon dioxide

The soil management practices in cultivable land are major sources for carbon dioxide production. Soil tillage activity breaks the soil aggregates and augmenting oxygen supply triggers biological decomposition of organic matter. Burning of crop residues and fuel emission during various agricultural activities are the additional sources CO_2 emission. Further, manufacturing of farm implements, synthetic fertilizers and pesticides also produces carbon dioxide.

GHG emission status: World

Agriculture emissions of GHGs estimated to be 5.1 to 6.1 $GtCO_2$-eq/yr. It accounted for 10-12% of total anthropogenic greenhouse gases emissions in global level. With annual exchanges between atmosphere and agricultural lands, net flux of CO_2 is approximately balanced and emissions estimated around 0.04$GtCO_2$/yr. Methane contributes 3.3$GtCO_2$-eq/yr, accounted for 50% of total global anthropogenic greenhouse gases while N_2O contributes 2.8 $GtCO_2$-eq/yr, accounted for 60%. Globally, CH_4 and N_2O emissions from agricultural sources increased by 17% from 1990 to 2010, in terms of increase in annual emission estimated upto 60 $MtCO_2$-eq/yr.

GHG emission status: India

According to the GHGs emissions status in 2010, global emissions estimated around 50,101 Mt CO_2eq, in which India contributed about 2,691 Mt CO_2 eq. i.e., 5% of total emissions. Global agricultural activities contributed about 5,677 $MtCO_2$ eq. i.e., 11% and Indian agriculture sources contributed about 403 Mt CO_2 eq. i.e., 7% of total emissions.

According to the World Resources Institute Climate Analysis Indicators Tool [5], India's 2014 GHG profile was dominated by emissions from the energy sector, which accounted for 68.7% of total emissions. Among, the energy sector, 49% of emissions were due to electricity and heat generation. Agriculture was the second highest source (19.6% total emissions), with enteric fermentation contributing 45% of agriculture emissions followed by industrial process (6.0%), land use change and forestry (3.8%) and waste (1.9%) [6]. The WRI CAIT shows energy to be the highest GHG emitting sector in India, followed by agriculture.

Agriculture emissions increased 25% from 1990 to 2014, driven by emissions from synthetic fertilizers (47%) and enteric fermentation from livestock (30%). Across the Indian states, GHG emission per ha was highest in rice (3188 kg CO_2e/ha) and sugarcane (3187 kg CO_2e/ha). Emissions from other upland crops ranged from 69 to 2773 kg CO_2e/ha. Similarly for livestock, GHG emissions per head were highest in buffalo (909 kg CO_2e/head) and cattle (761 kg CO_2e/head) whereas average emissions for small animals ranged from 141 to 295 kg CO_2/head.

Crop and livestock production contributed 42% and 58% to total agricultural emissions, respectively. Cattle production was the next important source of emission followed by rice, buffalo, small ruminant and wheat production. Over 52% of total crop-related emissions is contributed by rice followed by wheat, cotton and sugarcane, which in total constituted about 80% of total crop emissions. Of the total livestock emissions, cattle constituted the highest share followed by buffalo and sheep/goat. Cattle, buffalo, sheep and goat constituted 99% of total livestock-related emissions. Taking crop and livestock emissions combined, Uttar Pradesh was the highest GHG emitter followed by Andhra Pradesh, Madhya Pradesh, Maharashtra, Rajastan and West Bengal. Total emissions from crop production were highest in Andhra Pradesh, Uttar Pradesh and Maharashtra followed by West Bengal, Madhya Pradesh and Punjab. Total emissions from livestock were highest in Uttar Pradesh (~46Mt CO_2e) [7].

Causes for increased GHG emissions in Agriculture

The main causes of agricultural GHG emissions results from

- Increasing population
- Food and energy security
- Globalization
- Increased per-capita income
- Altered dietary trends
- Water and labour shortage
- Technology development
- Climate change
- Increased fertilizers application
- Increased usage of agricultural inputs
- Increased livestock population are major drivers for increasing GHGs emissions.

Tools for Agricultural GHGs Monitoring, Reporting and Verification

Though several agricultural practices available to mitigate GHGs emission, lack of awareness and low confidence in implementation and monitoring of interventions inhibited the addition of agricultural activities in climate change policy and emissions offset markets. Monitoring, reporting and verification (MRV) system is important to encourage altered agricultural practices and livestock management towards climate-smart agriculture. Focus on methodologies and data requirements for the MRV helps to estimate reduced GHGs emission from agricultural activities. Moreover, quality of the data collection in mitigation practices and adoptions of evaluation process are important components of MRV. With increasing challenges in agricultural GHGs mitigation projects due to rising standards of integrity and rigidity in the emissions offset markets can be strengthened by using remote sensing technology and using modeling tools. At field level, remote sensing technique used as a best tool for monitoring land-use and land-cover change, which also used to track change for several decades.

Nuclear technology

Nuclear techniques present substantial advantages over conventional techniques for measuring GHG emissions. Stable isotopes, which do not emit radiation like nitrogen-15 and carbon-13, were used to measure the impact of integrated crop-livestock practices and green manuring. This allows them to track and analyze how efficiently crops consume nitrogen and how well carbon accumulates or is stored in the soil. By adding nitrogen fertilizers labelled with stable isotope nitrogen-15 as a tracer, here we can track the isotopes and determine how effectively the crops are taking up the fertilizer. The amount of nitrogen that crops can acquire from the atmosphere through biological nitrogen fixation process can be quantified by isotope technique.

Using the nitrogen-15 technique, scientists can identify the source of nitrous oxide production, which is important to find ways to reduce the emission of the gas. Based on this farmers are advised on exactly how much animal manure and/or chemical nitrogen fertilizer they need to apply to their crops. The only technique which precisely quantifies the pathways of N_2O and N_2 under field conditions is the stable isotope of nitrogen-15.The 15N technique identified 2 more microbial processes of N_2O production which include co-denitrification and conversion of organ N to mineral N [8].

The carbon-13 stable isotope technique, allows researchers to evaluate soil quality and sources of carbon sequestered in the soil and this technique uses natural abundance of carbon-13 in the environment. Various combinations of crop rotation, tillage and ground cover can enhance productivity and improve the efficiency can be identified using the isotope studies. The movement and origin of carbon dioxide and methane can be determined by Carbon-13 tracking. To improve animal productivity and protect the environment from overgrazing, nuclear and related techniques can help formulate feed supplementation strategies. The hydrocarbon and natural C-13 on plants eaten by ruminants and in their faeces, which helps estimate their intake under grazing or grassland browsing conditions can be identified.

Measurement of Greenhouse Gas Emissions

The closed-chamber method and micrometeorological method are generally used to measure methane and nitrous oxide emissions from soils (**Figure 2**). Concentration of methane and nitrous oxide in the gas samples is analyzed by Gas Chromatograph (GC) fitted with a flame ionization detector (FID).

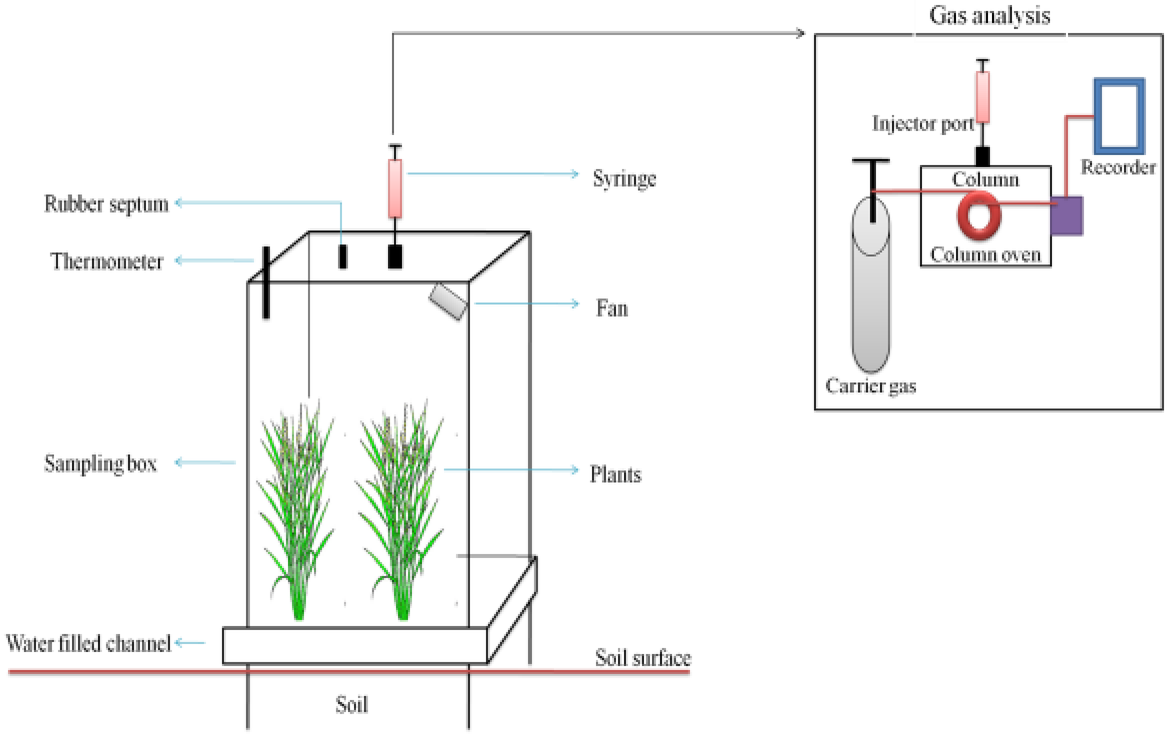

Figure 2 Closed-chamber used for collection of methane and nitrous oxide gas samples from field

Closed-chamber method, Soil respirator method and Infra-red gas analyzer method. Alkali trap method is the methods generally used to quantitative analysis of CO_2 emission from soil.

Measurement of methane by open circuit chambers

A pump is used to pump out air from the animal chamber, flow rate is measured either passing through a rotameter or a flow meter and concentration of different gases are measured by analyzers.

Measuring methane with the SF6 tracer technique

It is relatively a new technique and recent development on methane measurement. The main objective of the method is to investigate energy efficacy in free ranging cattle. The basic principal of the method is that methane emission is proportional to the emission rate of SF6 tracer gas from the rumen. For this purpose SF6 a non-toxic, physiologically inert, stable gas is used and the gas mixes with rumen air in the same way as methane.

Mitigation options in Agriculture

The development of agricultural activities that mitigate GHGs includes
- Cropland and livestock management
- Grazing land management
- Management of agricultural organic soils
- Restoration of degraded lands
- Manure management
- Bio-energy productions are the prominent options in agriculture [9, 10].

Also, adoption of low carbon in agricultural management practices and technologies are also the potential mitigation options [11] (**Figure 3**). Three approaches for GHGs mitigation:

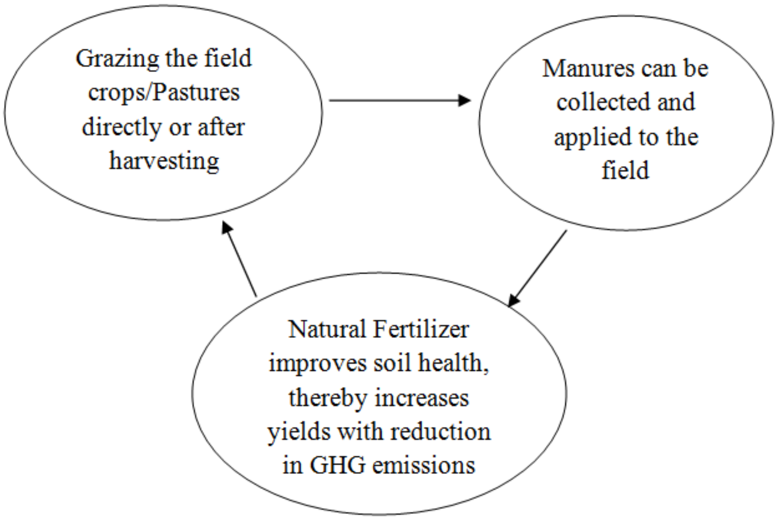

Figure 3 Recycling nutrients in animal manure and crop residues

Reduction in emissions

The CO_2, CH_4 and N_2O fluxes can be reduced by well-organized carbon and nitrogen flow management in the agricultural ecosystems. For example, efficient usage of nitrogen inputs to crops often reduces N_2O emissions. Conservation or zero tillage helps to reduce CO_2 emissions from soils

- Grass-based grazing systems reduces methane emissions from ruminant livestock
- Composting helps to reduce manure methane emissions
- Reduced use of inorganic N fertilizers (as manufacture is highly energy intensive), and adopting targeted- and slow-release fertilizers
- Using integrated pest management reduces pesticide use (avoid indirect energy consumption)

Enhancement of removals

The soil organic matter is the large carbon reserve in agricultural ecosystems. These systems have lost a large amount of C in the past, some of which can be recovered through improved management. Carbon sequestration by using plants which has high photosynthetic fixation rate and/or slow release of stored carbon in to the atmosphere. Perennial plantations and agro-forestry practices stored significant amounts of carbon in vegetative systems. Moreover, location specific carbon storage practices and land management also increase soil carbon sequestration. The sources from agricultural lands remove some amount of methane from the atmosphere via oxidation, however this effect is negligible compared to other GHGs fluxes.

Increase carbon sinks in soil organic matter and aboveground biomass

- Replacing inversion ploughing with conservation-tillage and zero-tillage systems
- Adopting mixed rotations with cover crops and green manures to increase biomass additions to soil
- Increasing above-ground standing biomass
- Minimizing summer fallows and periods with no ground cover to maintain soil organic-matter stocks
- Adopting soil conservation measures to avoid soil erosion and loss of soil organic matter
- Composts and manures application to increase soil-organic-matter stocks
- Perennial grasses (60-80% of biomass below ground) cultivation rather than annuals (20% below ground)
- Marginal agricultural land conversion to woodlands to increase standing biomass of carbon

Theoretically carbon storage can be increased in long-lived agricultural products. The products include leathers, wool, strawboards, bio-plastics, etc. but the quantity of carbon increase over the past 40 years has only from 37 to 83 MtC per year. A global potential mitigation of GHGs is estimated to be 770 MtCO$_2$-eq/yr by 2030 by practicing energy efficiency technologies in agriculture as well as in off-sites agricultural manufacturing sectors.

Avoiding emissions

Crop residues used as source of fuel. It can be used directly or after conversion to ethanol/diesel. Even though bio-energy feed stocks considered as green technology, it also act as additional source of CO$_2$ emission to the atmosphere. The net benefit of these green technologies is equal to the fossil fuel emissions. Further, converting new lands such as forest, grassland and other non-agricultural vegetation lands into agricultural lands could be avoided, it would notably reduce GHGs emissions especially CO$_2$.

Increase renewable-energy production to avoid carbon emissions

- Conserve fuel, reduce machinery use to avoid fossil-fuel consumption
- Substitute biofuel for fossil-fuel consumption
- Cultivate annual crops for biofuel production i.e., ethanol from maize and sugar cane
- Annual and perennial crops cultivation, such as coppiced trees, electricity generation, with crops replanted each cycle for continued energy production
- Use biogas digesters to produce methane, so substituting for fossil-fuel sources
- Use improved cookstoves to increase efficiency of biomass fuels

Integrated cropping-livestock systems are also a sustainable agricultural practice (**Figure 4**) supported by nuclear techniques. These practices are based on a simple concept: that crop yields can be maximized by recycling nutrients present in both animal manure and crop residues. It reduces the need for chemical inputs that release large quantities of greenhouse gases and thereby contribute to climate change. In this system, livestock may either graze the field crops directly or may be fed the crop after harvesting. Farmers then collect the manure from the farm animals and use it as fertilizer, thereby returning many of the nutrients to the soil.

The 119 countries that committed to mitigate greenhouse gas emissions from agriculture in the Paris Agreement are developing implementation plans that include sub-sectoral goals and strategies. Recently published agricultural greenhouse gas emission analyses from nine tropical, developing countries from a collaborative effort of the CCAFS (CGIAR Research Program on Climate Change, Agriculture and Food Security), FAO (Food and Agriculture Organization of the United Nations) and the United States Agency for International Development (USAID) can help prioritize agricultural practices that contribute to sustainable development goals in food security and climate.

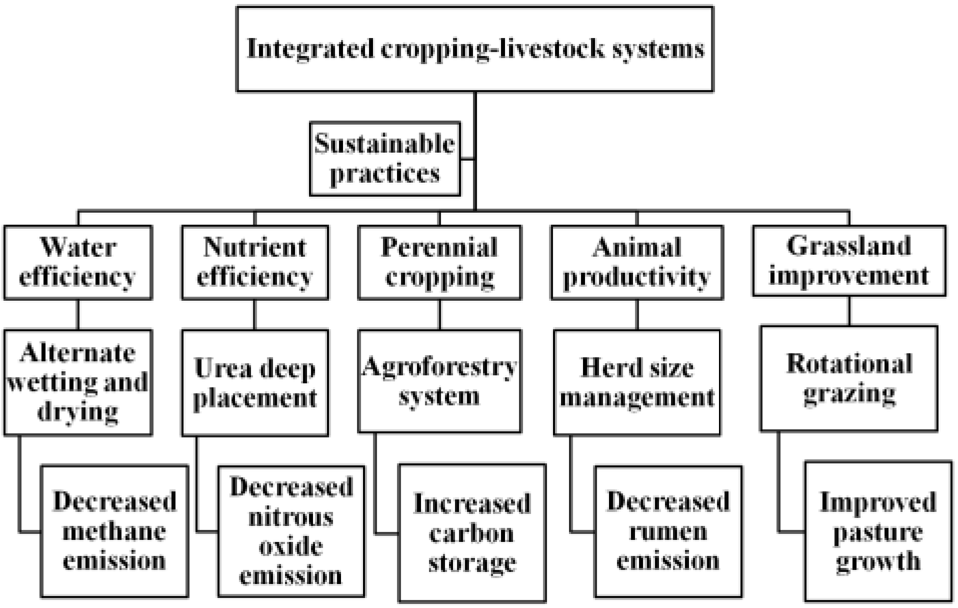

Figure 4 Integrated cropping-livestock systems

Alternate wetting and drying (AWD)

Releasing of methane from flooded rice paddies mediated by anaerobic decomposition organic residue which is a powerful greenhouse gas. Periodically drying the irrigated lowland rice fields reduced methane emission. Drying the paddy interrupts this process of methane emissions by up to half compared to continuous flooding. AWD also reduces water use by up to 30%, conserving the fuel required to pump it, decreasing operational costs. Though AWD delivers maximum climate change mitigation per area, barriers limit widespread adoption ie., it depends on identifying where and how to surmount these barriers. Hence, these practices followed in Bangladesh, Ghana and Haiti.

Urea deep placement (UDP)

A fertilizer management technology, improves nutrient use efficiency by placing urea briquettes into soil, instead of urea granules. Often used in rice paddies, UDP reduces GHG emissions like nitrous oxide and nitrogen loss caused by volatilization of ammonia and nitrate leaching. UDP decreases the amount of fertilizer needed as compared to surface broadcasting. Also emission reductions per hectare from UDP are small. In Bangladesh, Accelerating Agriculture Productivity Improvement project expected wide uptake of UDP and thus large emission reductions. Also farmers who use mechanization for UDP are more likely to adopt the practice, given the physical demands of manually placing briquettes.

Perennial crops and agroforestry

It stores atmospheric carbon in plant biomass and soil. Improving degraded land management, replacing annual crops with perennial crops, practicing agroforestry systems and managing soil fertility suggest climate change mitigation by plants and soil can store more carbon and reducing emissions. Emission reductions potential varies by practices. The projects need to consider which types of agroforestry systems make intellect in the particular context and pay attention to why farmers might or might not adopt and maintain trees in the fields. In Zambia, farmers adopted alley agroforestry systems and experienced increased annual crop productivity. Farmers also encouraged through growing and maintaining trees on their farms. Also the project connected them to consumer markets which offered premium prices to growers.

Mitigation of GHGs emissions from livestock

Various approaches have been reported for CH_4 emissions reduction from livestock without compromising productivity. CH_4 emissions mitigation measures can be applied at animal level, herd level, and production unit level [12]. At the animal level, emissions reduction can be achieved by optimizing feed digestibility, feed balancing, and selective breeding. At the herd level, emissions can be reduced by increasing the proportion of animals in the herd dedicated to reproduction only with production such as milk and meat not being considered.

Some other measures of reducing CH_4 emissions were by improving pasture and herd management [13]. Policy mechanisms such as

i. an emission tax on livestock products based on average national emissions and
ii. sectoral emissions trading scheme, which would impose minimal transaction costs on producers have also been proposed to reduce CH_4 emissions from livestock.

Canola oil-spraying of pasture was found to enhance feed intake and decrease CH_4 emissions. The CH_4 emissions can be decreased by 7–40% by making changes in livestock dietary patterns such as the use of legume-grass, an increase of starchy concentrate and more digestible forage, i.e. less mature and processed forage. Legume grass and processed feed and forage decrease methane emissions by 28% and 15–21%, respectively. Corn silage usage for livestocks instead of Napier grass decreases acetate production and increases propionate concentration which leads to decreasing production of methane [14]. The addition of organic compounds such as fumaric acid and secondary metabolites (saponin, tannins, edible oil such as fish oil, coconut oil, and sunflower oil) were found to be effective in reducing CH_4 emissions from livestock. The addition of organic acid not only decreases CH_4 production but also helps in weight gain of livestock. Use of bacteriocins, bacteriophages, and development of recombinant vaccines for archeal-specific genes and cell surface proteins for ruminant microflora are also some emerging CH_4 mitigation measures.

In tropical countries, use of trees and shrubs to supplement low-quality forages has been proposed as a measure for reducing CH_4 production and improving animal nutrition. Thus, overall an integrated approach considering increasing animal productivity, improving genetic potential of the animal through planned cross breeding or selection of high producing animal, improving the nutritive value of quality feed for ruminant diet, use of residual feed intake can result in reduced CH_4 emissions from livestock.

Livestock population stabilization is one of the CH_4 emissions mitigation approaches at the farm level. This can be achieved by reducing the number of non-productive livestock in herd and selection of more productive breed of livestock. Selective breeding, feeding management, and other management practices should be directed to increase livestock efficiency. The increase of mechanization in agriculture can also result in the reduction of draught animals which can positively influence the livestock population.

Mitigation Options in Livestock& Manure Management

- Select regionally appropriate forages.
- Practice rotational grazing.
- Choose high quality feed that will reduce methane released from enteric fermentation.
- Manage manure to reduce methane and nitrous oxide. Cover manure storage facilities. Optimize manure application to soil.

Herd size management strategies aim to reduction of herd size, maintaining the level of production of milk or meat also to increase productivity.

A project in Kenya focused to reduce total herd-size by 10% in two counties through quicker animal growth that allows slaughter at an earlier age. The project boosted producers' access to inputs (feed and veterinary services), improved market links between livestock producers and buyers and increased the availability of timely market information for livestock producers. The herd-size management strategy was appropriate for Kenya. Adapting strategies to to reduce herd size without facing production risks also to assess whether incentives or changes to enabling conditions (e.g., insurance, financial services). Managing grasslands to improve activities ie.,timing of grazing, planting or protecting species and/or adding nutrients and water to promote growth. A project in Ethiopia improved pasture quality and increased biomass and soil carbon sequestration by employing soil and water conservation measures, enclosing degraded pastures, selectively thinning bush and clearing the invasive plant *Prosopis*. In summary, potential of greenhouse gas mitigation options were described in **Table 1**.

Mitigation of GHGs emission rice–wheat system in Indo-Gangetic plains through tillage, irrigation and fertilizer management practices [16]

To evaluate different combinations of GHG mitigation technologies for rice and wheat and to find suitable low carbon options for Rice–wheat cropping systems (RWCS) in the Indo-Gangetic plains (IGP), a two year (2011–2012 to 2012–2013)field experiment growing wheat and rice in rotation was carried out at the experimental farm of Indian Agricultural Research Institute, New Delhi in the trans Indo-Gangetic alluvial tract. The adoption of direct seeding of rice and zero tillage in wheat along with residue application can significantly reduce GHG emission. This study indicated that, replacement of existing conventional system (CTW-TPR) by ZTW-DSR or ZTW + RR-DSR can reduce GWP of the system by 44–47% without any significant reduction in system productivity. NOCU can be effectively utilised for reduction of N_2Oemissionunder ZTW. The surface application of rice straw along with ZTW can also be a viable option for the reduction of N_2Oemission as well as an alternative practice to rice residue burning which is a major source of air pollution in this part of the IGP. In the longer term, this practice might also lead to an increase in soil organic carbon.

Table 1 Possible greenhouse gas mitigation options [15]

Option	Mitigation (%)	Constraints
1. Methane reduction		
Rice field		
Alternate wetting and drying	25-30	Efficient water usage
Method of direct seeded rice	30-40	Availability of machine, Herbicide usage
System of Rice Intensification (SRI)	20-25	Labour facility, Efficient water usage
Ruminants		
Balanced diet	5-10	Cost for balanced feeding, Grazing management
Feed additives	5-10	Cost for balanced feeding, Biosafety issues
Efficient and productive animals	10-20	Cost of purchase, Acclimatization to the environment
2. Nitrous oxide reduction		
Soil		
Location specific nitrogen use	10-15	Awareness among farmers, Fertilizer application strategy
Bioinoculants - Nitrification inhibitor	10-15	Cost of application, Encouraging farmers to adapt technologies
3. Carbon sequestration		
Soil		
Conservation options in agricultural activities	15-20	Adaptability, Continuity, Applicability in small scale land holdings
Organic farming practices	15-25	Availability of organic manure, cost for transport, Labour facility

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Identifying Low Emissions Development Pathways: Mahbubnagar District, Telangana, India [17]

A farm-level enterprise interventions and specific plot-level crop management strategies can increase profitability as well as mitigating climate change. Combined farm practices of reduced tillage, nitrogen management, crop-residue retaining, organic manure utilizisation, altered livestock feeding practices, adapting agro-forestry could added advantage to GHG abatement and improved profitability at Mahbubnagar District, Telangana.

Government initiatives

Indian government allotted Rs 65,000-crore project with an intention to reduce greenhouse gases from agriculture. The main goal of the project (2018-2025) is to implement improved agro-ecosystems has sequestering capacity of 49.9 million tonnes of carbon. This project covers the regions of Chambal (Madhya Pradesh), Dampa (Mizoram), Similipal (Odisha), Jaisalmer and Barmer (Rajasthan) and some wildlife corridor (Uttarakhand). In the Chambal region, 97,982 hectares of land cover were under threats include chemical-runoffs from agriculture, expanding ravines and sparse vegetation. In this case, mitigation proposals included organic farming and sustainable grazing land management for livestock. In Mizoram region, the project regions including 145,670 hectares of land which covered Dampa and Thorangtlang Sanctuary. In these regions, Jhum cultivation was noticeable threat to land degradation. Additionally, in Odisha, lands cover of 556,900 hectares including Simlipal Biosphere Reserve also included in the project. In Rajasthan, 316,200 hectares of Desert National Park and 324,696 hectares covering Corbett Tiger Reserve, Uttarakhand were included in this project [18]. The programme, involving the agriculture and environment ministries, is part of a global initiative of the Food and Agricultural Organisation (FAO) and the Global Environment Facility (GEF), a partnership 183 countries, including India [18].

Conclusions

Though agriculture is one of the major GHGs emission source, considerable mitigation options are available in this sector. Reduction in CO_2, N_2O and CH_4 emissions through adapting various conservation technologies and carbon sequestration practices mitigates GHGs emissions. However, limited awareness among farmers and low confidence in monitoring of adaptation practices in agricultural activities inhibited the enclosure of agricultural sectors in climate change policy as well as emissions offset markets. The possibility of agricultural sector's participation in emissions offset markets depends on real time demonstration of mitigation practices at field level and monitored using well established methodologies. Implementing suitable infrastructure, approved methodologies for establishing mitigation options at field level and facilitating financial incentives to farmers might encourage them to follow climate-friendly practices.

There is a need to identify soil management systems in Indian agricultural production systems. The climate friendly options with increased soil organic C in agricultural land reduces GHGs emission. Research and Development efforts on agricultural GHGs mitigation, adaptation, implementation, capacity building and land-use management would help in improved practicing of conservation technology in agriculture. Policies and incentives development by the government that would promote farmers to adopt GHGs mitigation options in agricultural activities undoubtedly improve soil health, efficient water and energy usage and ultimately reduce GHGs emission.

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