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SOURCES OF GREENHOUSE GAS EMISSION IN AGRICULTURE AND ITS MITIGATION STRATEGIES-A REVIEW

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ABSTRACT

Agriculture sectors considerably contribute 10-12 % of GHG emissions globally to the overall anthropogenic greenhouse gas emissions to the atmosphere. Depending on management, the agriculture sector can be both a source as well as net sink for carbon. This review explains the sources responsible for greenhouse gases emission in the agriculture sector and all the important strategies for lowering the greenhouse gas emission from agriculture like crop diversification, summer fallowing, tillage and irrigation management, N-use efficiency, soil carbon sequestration, bio-char application, organic farming, use of biofuel, livestock feed management and mitigation during rice cultivation etc. Utilizing these strategies can significantly reduce GHG emissions.

KEYWORDS Agriculture, Climate change, carbon footprint, CO_2 equivalent, Mitigation Strategies

INTRODUCTION

Global climate is rapidly changing, and for this, greenhouse gases are responsible; such gases are emitted by a variety of natural as well as anthropogenic sources. Greenhouse gases (GHG) act as a blanket around the planet, trapping the sun's heat and stopping it from escaping into space, resulting in Global Warming. Since the pre-industrial era, anthropogenic GHG emissions have contributed to significant increases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) concentrations in the atmosphere (IPCC, 2014). Worldwide, the effects of climate change are already being felt in various ways, including changing weather patterns, melting ice caps, agricultural losses, altered precipitation patterns, more frequent and intense floods and droughts, and severe ecological imbalances. Additional negative impacts include substantial economic losses (Stern 2006). Agriculture is one of the sectors which is not only significantly affected by climate change and variability but is also directly responsible for 14 % of global greenhouse gas emissions. As the food demand increases with the rising population, the proportion of GHG emissions from the agricultural sector is also increasing. Numerous climate pollutants cause anthropogenic climate change, with CO_2, CH_4, and N_2O being the three main individuals responsible for global warming

(Myhre *et al.*, 2013). "The total amount of GHGs (measured in carbon equivalent (C-eq) released by all agricultural processes is known as the carbon footprint of agriculture".

The primary sources of GHG emission in agriculture include tillage, ploughing, irrigation, chemical fertilizer, Rice cultivation, crop residue burning, wet land, deforestation, manure management, raising livestock, and using associated machinery, which produces a significant amount of greenhouse gases. Therefore, for reducing greenhouse gas emissions the agricultural sector can play an important part. The practices such as summer fallowing, tillage management, irrigation management, organic farming, nitrogen use efficiency, efficient use of fossil fuel and other non-renewable energy sources, diversified cropping system, enhancing soil carbon sequestration, rice crop management, manure and other waste management, improved ruminant digestion efficiency etc., may help to reduce the GHG emissions from the agriculture sector.

SOURCES OF GHG IN AGRICULTURE

- *Tillage:* Tillage is one of the most important agricultural practices used to create suitable conditions for seedbed preparation and plant growth and is among the most important primary sources of CO_2 emission. Soil tillage increases soil microorganisms' respiration and CO_2 emissions from soil. As the tillage depth increases, CO_2 emission from soil significantly increases; therefore, it is assumed that CO_2 emission from soil decreases by reducing the depth of tillage (Reicosky and Archer 2007).
- *Rice cultivation:* Rice cultivation has been linked to GHG emission, namely methane (CH_4), and nitrous oxide (N_2O) (Babu *et al*., 2005; Linquist *et al*., 2012; Reiner *et al*., 2000). Rice fields emit 32 to 44 Tg CH_4 yr^{-1} (Le Mer and Roger 2001). Due to the anaerobic characteristics of the soil, rice paddy contributes primarily to the CH_4 emission but also emits some N_2O when it floods (Pittelkow *et al*., 2013). Due to CH_4 emissions contributing 45% of the total carbon footprint, rice has the highest carbon footprint per unit output, 1.60 kg CO_2-eq (Zhang *et al*., (2017). Labile nitrogen and carbon concentrations rise in tropical low-land rice fields with high CO_2 and temperature, which is more responsible for CH_4 and N_2O emissions (Bhattacharya *et al*., 2013).
- *Fertilizer Use:* One of the main sources of CO_2 and N_2O emissions is nitrogenous fertiliser. In total agricultural GHG emissions, synthetic fertilisers contribute 13% of all those (FAOSTAT 2014). When nitrogenous fertilizers are applied on soil a portion is being used in plant uptake while remaining portion is utilized by microorganisms for producing N_2O, and lost through leaching or volatilization process (IPCC, 2019). The main greenhouse gas (GHG) released during production is CO2, whereas the major field contribution is N_2O emission (Rao *et al*., 2019).

- *Crop residue burning:* Burning straws both as fuel and on the field resulted in a significant loss of Carbon (Powlson *et al*., 2016). The carbon stored in residues is lost in the atmosphere as CO_2. 85 % of GHGs due to field burning of rice, wheat, and sugarcane residues (Sahai *et al*., 2011). In India, 488 million tonnes of crop residues were produced in 2017, and 24% were burned, emitting 211 Tg of CO2-e GHGs and other gaseous air pollutants (Ravindra *et al*., 2019).
- *Enteric fermentation:* Greenhouse gas (GHG) emissions from enteric fermentation consist of methane gas produced in the digestive systems of ruminants and, to a lesser extent, of non-ruminants. According to Hristov *et al.*, (2013), ruminant production produces 81% of the greenhouse gases (GHG) produced by the livestock industry, 90% of which come from rumen microbial methanogenesis (McAllister *et al.*, 2015). Compared to other ruminants or animals, beef and dairy cattle contribute more to the world's carbon footprint (Gerber *et al.*, 2013; Chhabra *et al.*, 2013).

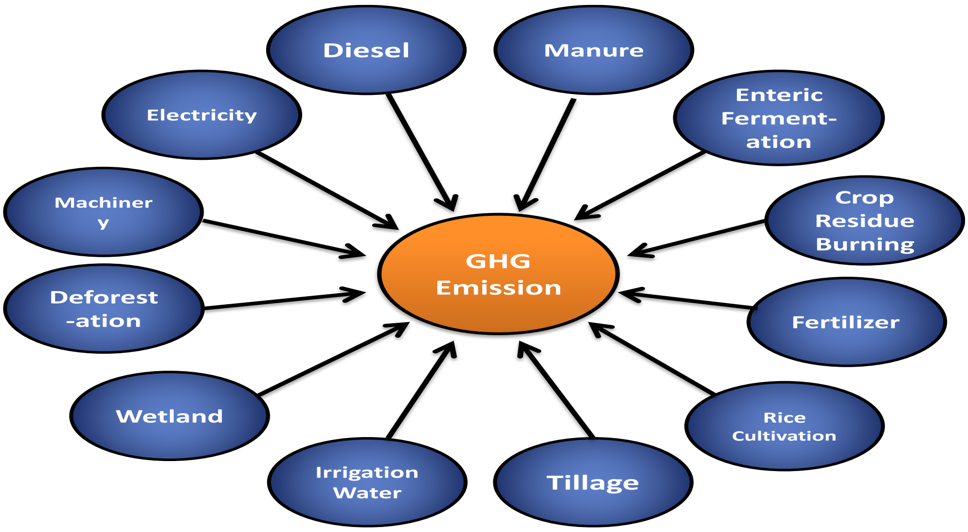

Fig 1. Sources of Green-House Gas Emission in Agriculture

- *Livestock Manure:* Manure contains organic matter and N, and as the organic matter decomposes, CH_4 and N_2O occur. Manure management in India accounts for 90 % of the total CH_4 emission (Chhabra *et al.*, 2013). The largest annual source of N_2O emissions in grasslands comes from animal faeces deposition (54%), followed by manure application (13%) and nitrogen fertilisers (7%) (Dangal *et al.*, 2019). Ruminant manure, of which 86% comes from cattle, is the source of 109 million tonnes of methane emissions to the atmosphere each year. The three main factors that affect the amount of CH_4 that manure exhales are the kind of storage, the climate, and the manure composition (Opio *et al.*, 2013).
- *Machinery:* Machinery is the major source of GHG emissions, as it uses energy in the form of fossil fuels. The greenhouse gas emissions of 160-200 kg CO_2-eq ha^{-1} from fuel consumption for field

operations for a non-irrigated corn-soybean-wheat rotation (Roberson *et al.*, 2000). In the cultivation of wheat and maize, machinery emissions from fuel use were 25% and 20%, respectively (Zhang *et al.*, 2017).

- *Diesel:* Diesel requires in the transport of fertilizers, pesticides, seeds, and other farm equipment, and major emissions occur during the tillage process. The diesel consumption depends upon the tractor's size, tillage depth, frequency, and type of tillage. In sunflower production, diesel consumption contributes to 12.24% of the carbon footprint (Yousefi *et al.*, 2017). Diesel contributed 6% and 19% to the total carbon footprint in mustard rice cultivation when using zero-tillage and conventional tillage systems (Yadav *et al.*, 2018).
- *Electricity:* The energy supply sector is the main global greenhouse gas (GHG) emission source. The second-largest contributor to greenhouse gas emissions is electric power. Approximately 60% of our electricity comes from burning fossil fuels, mostly coal and natural gas (USEIA 2019). Electricity used in agriculture contributed the most to carbon foot-printing (Yousefi *et al.*, 2017). In India, from 2000 to 2010, the emission from electricity use was 3% (Sah and Devakumar 2018).
- *Wetland:* wetlands are defined here as the land area that is either permanently or seasonally saturated, excluding small ponds, lakes, and coastal wetlands. Terrestrial wetlands are among the largest biogenic sources of methane, contributing to growing atmospheric CH_4 concentrations (Tian *et al.*, 2016). Wetland CH_4 emissions may, however, play a significant role in the atmospheric rise of methane due to the substantial reservoir of mineral and organic carbon held under anaerobic conditions. Furthermore, riparian wetlands emit more CO_2 to the atmosphere than CH_4 and N_2O because of higher plant and soil respiration (335-2790 mg m^2 h^{-1} in the wet season and 72-387 mg m^2 h^{-1} in the dry season) (Liu *et al.*, 2021).
- *Deforestation:* Deforestation is a significant contributor to climate change because plants absorb carbon dioxide (CO_2) from the atmosphere as they grow, and they store some of this carbon as aboveground and belowground biomass throughout their lifetime, when trees are burned, harvested, or otherwise die, they release their carbon back into the atmosphere. As estimated from 2015-2017 at global level, about 4.8 billion tonnes of carbon dioxide per year is lost due to deforestation of tropical forest (Annika Dean, 2019). In addition, forest land conversion to agriculture or pastures contributed 6-17 % of the world's total GHG emissions (IFOAM2016).
- *Irrigation water:* Irrigation is vital for achieving high crop yields in arid and semi-arid regions. However, irrigation is a very C-intensive process. According to Sloggett (1979), 23% of the energy required for agricultural production in the US was used for pumping on farms. Rainfed agriculture has

a lower carbon footprint than irrigated agriculture as the emission related to irrigation is reduced, and the areas are smaller, so the practices are done manually (Devakumar *et al.*, 2018).

MITIGATION STRATEGY

- *Crop diversification:* Crop diversity is growing multiple varieties of the same or distinct species of crops in a specific area through crop rotation and/or intercropping. Increased crop diversity increases productivity while reducing carbon emissions (Liu *et al.*, 2016). Due to the carbon and nitrogen sequestration in legume crops, they have a lower carbon footprint (Gan *et al.*, 2011). Crop diversification has been considered a vital cropping strategy for increasing agro-ecological produce and reducing greenhouse gas emissions. (Yang *et al.*, 2014; Minx *et al.*, 2009).
- *Summer fallowing:* The summer fallowing strategy lowers agriculture's carbon footprint by increasing nitrogen availability and decreasing the consumption of nitrogenous fertilizers. Additionally, summertime increases production (Liu *et al.*, 2016).
- *Enhancing soil C sequestration:* The most crucial method of lowering the quantity of GHGs in the atmosphere is soil carbon (C) sequestration. The SOC pool has a carbon content that is more than three times that of atmospheric CO_2: 1325 Pg C in the top 1 m and 3000 Pg C when assessments for deeper soil layers are considered (Kochy et.2015). Increased soil C sequestration can be achieved by keeping plant residues on the soil's surface, minimizing soil disturbance and erosion, using diversified cropping to create a continuous ground cover, and adding C-rich materials. (Lal and Follett, 2009). In addition, it is advised to use charcoal, mulch, cover crops, integrated nutrient management, conservation tillage, and diversified cropping systems to increase the SOC (Lal 2011).
- *Mitigation during rice cultivation:* Over half of the world's population relies primarily on rice as a food source. However, it is the main anthropogenic source of methane (CH_4) and nitrous oxide (N_2O). According to estimates, global CH_4 emissions comprise up to 19% of overall emissions, whereas rice fields are responsible for 11% of global agricultural N_2O emissions (IPCC, 2007). Because maize crops served as a weak sink for CH_4, switching rice with maize in a rotation lowered emissions. (Linquist et al. 2012). To lessen the high irrigation water requirement for paddy rice, the International Rice Research Institute (IRRI) has proposed a "safe alternate wetting and drying (AWD)" technology, which is also intended to reduce CH_4 emissions by 70%. (IRRI, 2013).

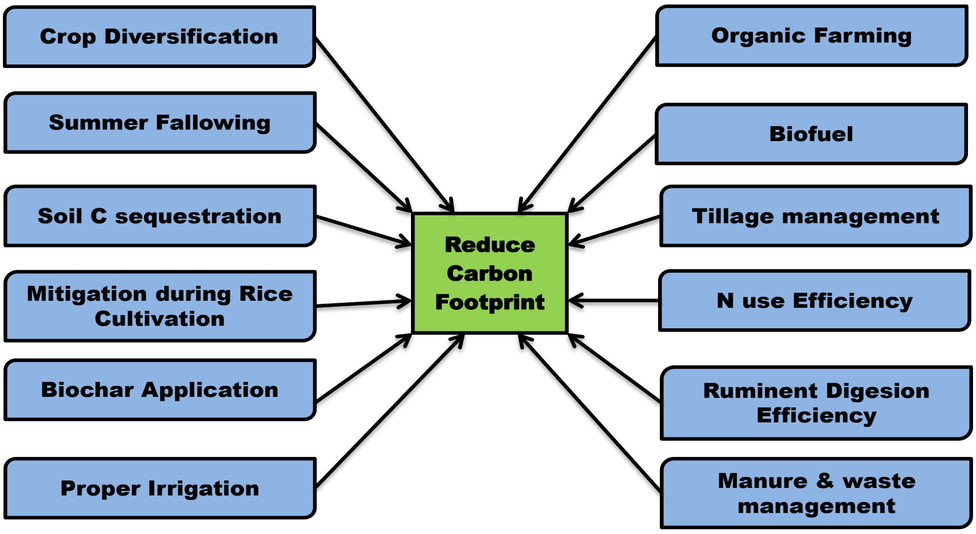

Fig 2: Mitigation measures to reduce GHG emission from agriculture

- *Bio-char application:* Bio-char is the solid product remaining after biomass is heated to temperatures typically between 300°C and 700°C under oxygen-deprived conditions, a process known as "pyrolysis. Biochar application has been widely reported to reduce N_2O emissions (Wu *et al.*, 2013; Cayuela *et al.*, 2013; Chang *et al.*, 2016; Hüppi *et al.*, 2016). Applying biochar to the soil has been shown to reduce denitrification and decrease N_2O emissions by 10-90%, indicating that biochar reduces N_2O emissions by facilitating the last step of the denitrification process and producing more N_2 rather than N_2O (Cayuela *et al.*, 2013).
- *Organic farming:* Organic farming uses less energy per unit area and yield than conventional techniques, lowering the environmental pollution. (Lynch *et al.*, 2012, Lee *et al.*, 2015). As a result, this approach is linked to less greenhouse gas (GHG) emissions and better soil carbon sequestration, making it an effective substitute for intensive farming in the face of climate change. According to Skinner *et al.*, (2019), organic farming can minimize N_2O emissions by 40.2%. Manure composting can reduce N2O emissions by 50% and CH_4 emissions by 70% in organic agriculture (IFOAM 2016).
- *Biofuel:* Fossil fuel usage makes a significant contribution to climate change. Due to their carbon neutrality, biofuels can reduce the amount of fossil fuels and the subsequent reduction in carbon dioxide emissions. Agricultural crops, along with their residues, can be considered as a source of fuel, either directly or after being transformed into fuels like ethanol or diesel. (Cannell 2003; Schneider and Mc Carl 2003). Burning crop leftovers that include lignin can also provide biofuel that minimizes overall emissions from electricity use (Liska *et al.*, 2014). By replacing electrical energy with solar-powered irrigation pumps, the agricultural carbon footprint decreased by 8.1%. Additionally, using machinery

driven by biofuels rather than diesel-powered equipment resulted in a 3.9% reduction in emissions during cotton cultivation. (Hedayati *et al.* 2019).

- *Tillage management:* Reduced tillage, minimum tillage, and non-inversion tillage are all terminology used to describe cultivation methods that do not use deep inversion ploughing and instead attempt to cultivate as minimally as possible, only to a depth of 15 cm. Tillage disturbs the soil, which tends to promote soil carbon losses through accelerated decomposition and erosion. (West & Post 2002; Gregorich et al. 2005). Crops left in a no-till situation after harvest enrich the soil with organic carbon (Powlson *et al.*, 2016; Nath *et al.*, 2017; Yadav *et al.*, 2018) and reduce the rate of oxidation of organic molecules due to soil cover (Lal 2004).
- *Improving N-use efficiency:* Crops don't always use nitrogen applied in fertilisers and manure effectively (Cassman *et al.*, 2003; Galloway *et al.*, 2003). Improving N use-efficiency can reduce N_2O emissions by soil microbes. Practices that improve N use efficiency include precision farming, slow-releasing fertilizer or nitrification inhibitors, right place and timing of N application (Dalal *et al.*, 2003; Monteny *et al.*, 2006). Several techniques, such as Green-Seeker and urea application based on leaf colour charts, make reducing emissions feasible by applying only the appropriate amount of fertilisers. For example, N_2O emissions in wheat farming systems can be reduced by 11-13% by adopting Green-seeker. (Nath *et al.*, 2017). The LCC-based urea application method boosts crop productivity and N use efficiency while reducing the emissions brought by fertiliser use. (Bhatia *et al.*, 2012).
- *Increasing ruminant digestion efficiency:* Methane (CH_4), a greenhouse gas that warms the globe and contributes to climate change, is released by cattle, sheep, and other ruminants. This methane is produced in the rumens of ruminants by the breakdown of cellulose by bacteria. It may be possible to reduce methane production by changing the rumen's fermentation process. Many variables, including cattle type, diet quality, and amount of feed consumed, affect methane emissions from ruminant animals. (Westberg *et al.*, 2001). Feeding extra concentrates, usually in place of forages, can lower methane emissions. (Blaxter & Clapperton 1965; Johnson & Johnson 1995; improved feeding practices (e.g., enhancing pasture quality), use of dietary amendments (e.g., edible oils, ionospheres (antibiotics), organic acids), and improved genetics (Kebreab *et al.*, 2006) and optimizing protein intake to reduce N excretion and N_2O emissions (Clark *et al.*, 2005).
- *Manure and other waste management:* During storage, animal manures can emit high quantities of N_2O and CH_4, although the actual amount of these emissions vary. Cooling or covering the sources or collecting the released CH_4 from the stored manure in tanks can reduce the emission (Clemens and Ahlgrimm 2001; Monteny *et al.*, 2006a; Monteny *et al.*, 2001b). Using CH_4 as fuel to produce on-site

power and heat energy, anaerobic digestion of manure results in the collection of biogases (CH_4, CO_2), improving industrial efficiencies (Kebreab *et al.*, 2006). Composting, covering stored manure, changing diet composition, adopting novel application techniques, and utilizing nitrification inhibitors are further options to lower GHG fluxes from manure (Kulling *et al.*, 2001).

- *Efficient irrigation method:* Eighteen per cent of the world's croplands now receive supplementary water through irrigation (Millennium Ecosystem Assessment 2005). Efficient water utilisation for crop growth will be essential in adapting to global climate change. However, irrigated agriculture is a major problem due to its high economic value comparative to rain-fed agriculture systems, significant output potential, and vulnerability to water supply constraints (Hatfield *et al.*, 2011). Adopting conservation measures that increase water storage and lowers evaporative demand is one of the methods for efficient water usage (Follett, 2012).

CONCLUSION

Various agricultural production processes and inputs share the major significant proportion of greenhouse gas emissions and climate change, and climate change can be mitigated by preventing the emission from multiple agricultural sources and reducing the current greenhouse gas level back to the pre-industrial revolution. Still, for this, no single option is sufficient by itself, a combination of various green-house gas offsetting strategies like crop diversification, summer fallowing, tillage and irrigation management, Fertilizer and manure management, bio-char application, soil carbon sequestration, organic farming, use of biofuel, improved ruminant feed efficiency, and mitigation during rice cultivation etc. can help reduce the carbon footprint of agriculture sector.

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