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Green House Gas Emissions from Paddy Field

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Introduction

Developing countries currently account for about three-quarters of direct greenhouse gas (GHG) emissions and are expected to represent the most rapidly growing GHG emission sources in the future. However, developing countries make up 70% of climate change mitigation potential for land use in agriculture. Agricultural soil acts as a source and sink of important greenhouse gases (GHGs) like methane (CH4), nitrous oxide (N2O), and carbon dioxide (CO2).

Rice paddies have major contribution and concern because they produce the threatening and long-lasting GHGs mainly CH4 and N2O. Around 30% and 11% of global agricultural CH4 and N2O, respectively, emitted from rice fields.

Share of Agricultural Emission

As per the national GHG inventory, the agriculture sector emits 408 MMT (million metric ton) of CO2 equivalent. Rice cultivation is the third highest source (17.5%) of GHG emissions in Indian agriculture after enteric fermentation (54.6%) and fertilizer use (19%). Paddy fields are anthropogenic sources of atmospheric nitrous oxide (N2O) and methane (CH4), which have been reckoned as 273 and 80-83 times more powerful than CO2 in driving temperature increase in 20 years. The amount of CH4 emitted from paddy fields of India is 3.396 teragram (1 teragram = 109 kilograms) per year or 71.32 MMT CO2 equivalent.

Issues in Rice GHG

Firstly, scientific evidence suggests that intermittent flooding can reduce water and methane emissions but increase nitrous oxide emissions.

This means that while controlled irrigation may lower methane emissions, it does not necessarily result in overall reduced emissions. Furthermore, there is a specific concern regarding India's national GHG inventories, as they do not include reporting of nitrous oxide

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(N_2O) emissions. This emission can lead to an incomplete understanding of the true extent of GHG emissions associated with rice production in the country.

The current scope of GHG emissions in rice production also fails to consider various important factors. These include emissions resulting from burning rice residues, the application and production of fertilizers used in rice cultivation, energy operations such as harvesting, operation of pumps, processing of rice, and transportation of the harvested crop. Another significant issue is the substantial water requirements for paddy fields, which necessitate around 4,000 cubic meters of water per ton of rice for irrigation. However, this excessive water usage leads to oxygen deprivation in the soil, creating ideal conditions for methane-releasing bacteria.

Methane formation

Flooded rice soils, where soil temperatures are 25-30 °C, methane production in alkaline and calcareous soils may start hours after flooding, in neutral soils it is delayed two to three weeks, and in acid soils methane may only be formed five or more weeks after flooding. Methane production is negatively correlated with e soil-redox potential and positively correlated with soil temperature, soil carbon content, and rice growth.

The rate and pattern of organic matter addition and decomposition determine the rate and pattern of methane formation. Methane production generally increases during the cropping season, although the population density of methanogens remains fairly stable Easily degradable crop residues, fallow weeds, and soil organic matter are the major source for initial methane production. At later growth stages of rice, root exudates, decaying roots, and aquatic biomass seem to be more important. Methane production is enhanced in the rooted soil zones

Rice & Global Warming

The baseline emission factor for methane in continuous flooding rice cultivation is typically 1.3 kg CH_4 ha/d. A portion of the methane produced in the rice soil is consumed by the oxidation process in the rhizosphere of rice roots or at the soil-floodwater interface. Soil bacteria also have the ability to consume methane. However, most of the methane escapes into the atmosphere, with a small portion leaching into groundwater and dissolving in water. Methane has a significant impact on the climate as it remains in the atmosphere for around 10 years or longer, contributing to its increasing abundance. Eventually, methane breaks down into carbon dioxide (CO_2), with approximately 95% of the methane produced in flooded soils

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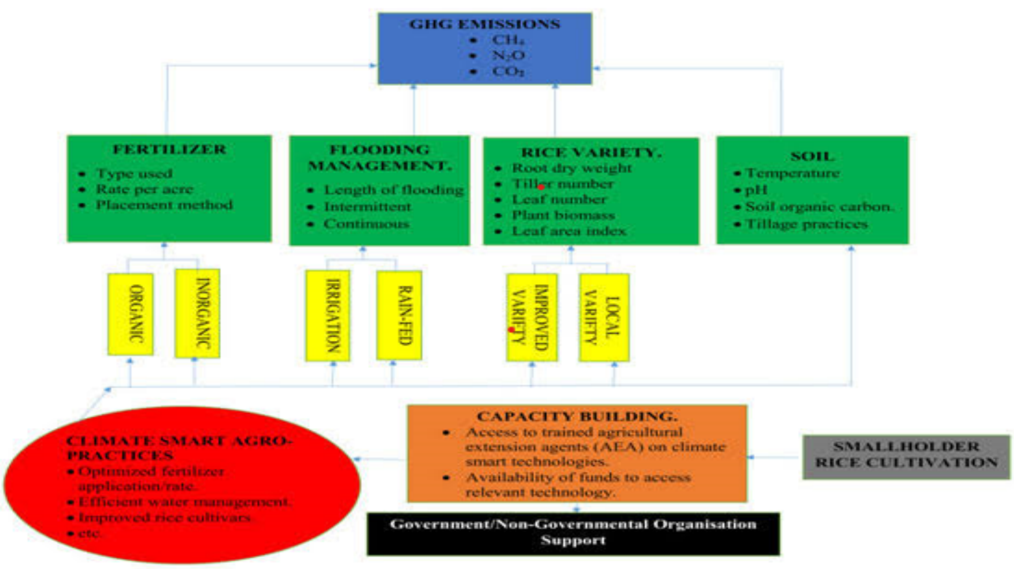
being oxidized to CO2 before being released into the environment. The exact amount of methane that converts to CO2 and the presence of other carbon-containing compounds with no significant climate impact are still not well understood.

When released into the atmosphere, methane participates in a chain reaction with ozone, leading to the production of CO2 and water vapor. Methane also contributes to the formation of ground-level ozone, which is harmful to human health and exacerbates climate change. Compared to CO2, methane is more effective at trapping heat, accounting for over 60% of its warming potential in the atmosphere. Recent years have witnessed record-high global temperatures, primarily caused by carbon emissions. These rising temperatures, coupled with changes in rainfall patterns, create favourable conditions for microbial methane production in flooded rice fields.

It is projected that the average global temperature will increase by 2°C by 2060. If this occurs, it will have severe implications for agriculture, leading to crop failures and widespread food scarcity, posing a significant threat to the world population. Additionally, rising temperatures will contribute to the rise in sea levels, resulting in devastating consequences such as the submergence of low-lying coastal areas and an increase in global homelessness.

Methane transportation from paddy soil to atmosphere



The process of methane (CH4) emissions from paddy soil to the atmosphere involves three main pathways: transport through rice plants, bubble formation and release (ebullition), and diffusion through the water layer in the paddy field. The majority of CH_4 (90%) escapes from the soil through the aerenchyma system in the rice plants, while a smaller portion is released through ebullition (10%) and diffusion through the soil and water (1%).

The transport of CH_4 through rice plants begins in the roots, where CH_4 diffuses through the outer layer of the roots and enters the plant during water uptake. Inside the root cortex, dissolved CH_4 is likely converted into gas and diffuses upward through intercellular spaces and the aerenchyma, which is a specialized system developed by plants to transport oxygen from leaves to roots. As CH_4 diffuses from the soil into the root system, oxygen diffuses from the roots into the soil, creating an oxygen-rich zone in the rhizosphere. In this oxygen-rich environment, methanotrophic bacteria oxidize a portion of the CH_4 to CO_2. The presence of oxygen in the rhizosphere suppresses methanogenesis, the process of CH_4 production.

The release of CH_4 to the atmosphere depends on various factors related to the rice plants. The movement of gases through the aerenchyma is influenced by permeability coefficients, concentration gradients, and the internal structure of the aerenchyma. Additionally, factors such as the number of tillers per square meter, root mass, rooting pattern, total biomass, and metabolic activity of the plants also affect the flux of gases.

Overall, CH_4 emissions from paddy soil to the atmosphere involve complex processes influenced by the characteristics and activities of rice plants, including their root systems and the presence of oxygen in the rhizosphere.

Conclusion

Rice cultivation is a significant contributor to methane emissions, accounting for approximately 19% of anthropogenic methane emissions globally, second only to ruminant animals. Unlike other major food crops that are grown in aerobic soils and sequester methane, rice production takes place in anaerobic conditions, leading to methane production. Methane emissions from rice cultivation are influenced by the rates of methane production, oxidation, and transportation. However, from a management perspective, two key options can help modify the amount of methane emitted.

The first option Involves managing the quantity of organic matter (such as farmyard manure, green manure, compost, and straw) added to the rice field. Increasing the inputs of organic matter leads to greater methane emissions. However, it’s important to note that the rice

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plants themselves contribute significantly to the production of methane, so reducing organic matter input can only have a limited impact on reducing methane emissions.

The second option involves water management. Changing the water management practices in rice cultivation can result in a reduction of methane emissions by over 100%. However, this approach often leads to increased emissions of nitrous oxide, another potent greenhouse gas. Understanding the trade-offs between methane and nitrous oxide emissions is crucial before advocating for different rice production methods based on climate mitigation.

While methane emissions receive most of the attention in discussions about rice's greenhouse gas emissions, nitrous oxide is also a significant contributor, particularly in rainfed systems and, to a lesser extent, in systems following the System of Rice Intensification (SRI).In addition to greenhouse gas emissions, the yield of rice is a critical factor to consider. It may be more effective to achieve high yields of rice from farming systems with higher greenhouse gas emissions per unit area, rather than lower yields from less greenhouse gas-intensive systems. The System of Rice Intensification (SRI) offers the potential to increase rice yields while simultaneously decreasing greenhouse gas emissions.

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