Methane Emissions from the Rice Cropping System

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Introduction

The increasing demand of the growing population requires enhancement in the production of rice. This has a direct bearing on the global environment since rice cultivation is one of the major contributors to methane emissions. This increase is attributable largely to increased anthropogenic emissions arising primarily from agriculture (e.g., livestock production, rice cultivation, biomass burning), fossil fuel production and use, waste disposal, and alterations to natural methane fluxes due to increased atmospheric CO_2 concentrations and climate change. With India being the world's second-largest cultivator of paddy, it is very important that the extent of the methane emissions is estimated, and measures are taken to minimize these emissions. Peninsular India is a prime rice-producing region; however, no significant information is available on the contribution of this region to methane emissions, nor are there available studies that show the effect of cultivars, growth seasons, soil characteristics, etc., on methane emissions. One of the attempts to cover this knowledge gap is emissions of methane from paddy fields.

Green House Gases and Non-Green House Gases:

GHGs	Non-GHGs
CO_2 - 64.3%	Nitrogen - 78%
Methane - 17%	Oxygen - 20%
Nitrous oxide - 6%	Argon - 0.9%
Fluorinated gases - 0.8%	Other remaining gases
Water vapour	

Agriculture (GHG) Source

- Enteric fermentation in livestock (CO_2, CH_4, N_2O)
- Manure management (CO_2, CH_4 N_2O)
- Rice cultivation (CH_4)
- Agricultural Soils (N_2O)
- Burning crop residue (CH_4, N_2O)

Methane - (CH_4)

- Methane (CH_4) is the second most prevalent GHG (Nearly 17%) from human activities. CH_4 is more efficient in trapping radiations than CO_2. Evolved from the methanogenesis process. Anaerobic condition type – Methylobacter. Agricultural activities, waste management, energy use and biomass burning all contribute to CH_4 emissions.
- 7% of Agriculture's non- carbon-di-oxide GHG emissions are a result of rice farming.
- Agriculture: Rice cultivation

- CH_4 concentration in atmosphere - 0.00017%.
- 1 ton of CH_4 28 times as much heat as 1 ton of CO_2.
- The unit weight of Methane is 714 g/ sq.m.
- $1CO_2$ = 16% of heat absorbed.
- $1CO_2$ =11/3 kg heat produced.
- CH_4 is 80 times as much heat as CO_2.

Instruments needed for collection of gases

Methane (CH4) is an invisible and odourless gas that is a primary component of natural gas. Natural methane is found beneath the ocean floor and underground. It is also present at 1,800 parts per billion (ppb) in the earth's atmosphere. Methane is a byproduct of various industrial processes and may be emitted into the atmosphere if it is not treated or combusted (flared). Methane is a potent greenhouse gas that can persist in the atmosphere. It is important to reduce methane emissions and monitor its atmospheric levels. It may also be important to measure CH_4 in some industrial processes for quality or productivity reasons.

- Gas Chamber
- Dispo van and Needle
- Lock Needle
- Gas Chromatography

Measurement and Modelling of Methane Emission

- Observed CH_4 emissions were compared against modeled emissions from four different approaches:
  i. Yan et al. (2005)

ii. IPCC (2006) EF, (Intergovernmental Panel on Climate Change)

iii. Wang et al. (2018)

iv. IPCC (2019) EF models

According to the Intergovernmental Panel on Climate Change

IPCC, 2006 (Intergovernmental panel on climate change)

EFi = EFa X SFp X SFw X SFo …. (1)

IPCC, 2019

EFi = EFb X SFp X SFw X SFo …. (2)

Where,

EFi = Daily emission factor (kg CH_4 /day/hr.)

EFa = Baseline emission factor for continuous flooding, short drainage pre-season without organic amendment.

EFb = Scaling factor accounting for differences in regions for baseline emission factor (continuous flooding, short drainage pre-season without organic amendment).

SFp = Scaling factor accounting for the difference in water regime during pre-season

SFw = Scaling factor accounting for the difference in water regime during the growing season.

SFo = Scaling factor accounting for the difference in organic amendment application.

For the IPCC models, the daily CH_4 emission factors are calculated based on the region to which each country belongs, the water regime before and during rice cultivation, and the type and amount of organic amendment applied, a scaling and emission factor summary.

The Yan et al. (2005) and Wang et al. (2018) model also consider soil organic carbon (SOC), pH, and agro-ecological zone:

Yan et al. (2005)

Ln (flux) = Constant = a X ln (SOC) + pHh + Pwi +Tj +CLk + Omi Xln (1 + AOMm)

Wang et al. (2018)

Ln (flux) = Constant = a X ln (SOC) + pHh + Pwi + WRj + AEZk + Omi Xln (1 + AOMm)

Where,

Ln(flux) = Average CH_4 flux (kg CH_4 /ha/day) during growing season

Constant + a x ln (SOC) = Soil organic carbon (a is the effect of SOC)

pHh = The effect of pH in which h is for each class.

PWi = Effect of pre-season water regime (i is for each class)

WTj/WRj = Effect of water regime during the growing period (j is for each class)

CLk/AEZk = The effect of climate/agro-ecological zones (AEZ)

OMl x ln (1 + AOMl) = OM is the effect of added organic material while AOM is the effect of the amount applied (l is for each class/amount t/ha)

Methane escapes from the rice field to the atmosphere through

1. Ebullition.
2. Diffusion.
3. Transport through rice plant.

Ebullition

Dominates during the initial period and upon disturbance of soil due to weeding, harrowing, etc.

Diffusion

Due to partial pressure difference.

Transport through rice plant

Average about 95 and 89% at tillering and panicle initiation stages respectively.

Why methane emission is higher in rice?

- As a source of substrate for methanogenic bacteria, (*Methanobacterium formicarium, Methanobrevibacter sp., Methanosaarcina mazei and Methanosaarcina barkeri*),
- As a conduit for CH_4 through aerenchyma.
- As an active CH_4 oxidizing site in the rhizosphere by transporting O_2.

The path CH_4 through the rice plant includes

- Diffusion into the root,
- Gasification of CH_4 in the root cortex,
- Diffusion through cortex and aerenchyma,
- Released to the atmosphere through microspores in the leaf sheath.

Pathway of Methane Formation:

- Hydrogen trophic pathway

CH_4 +4H_2 □ CH_4 + 2H_2O

- De-nitrification pathway

NH_4^+ +NO_2^- □ N_2 + 2H_2

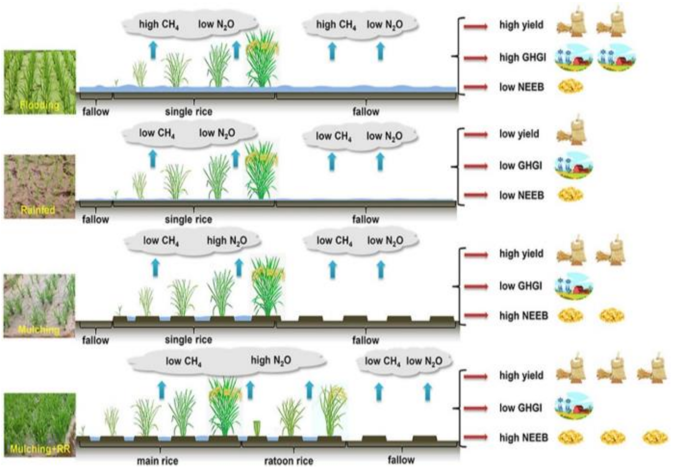

Fig. 1 GHGI was decreased while increasing the economic benefits of a rice cropping system in China. The results show that the yield in the rainfed fields was mainly affected by precipitation during the rice-growing seasons and was associated with a negative net ecosystem economic budget, although the amount of CH_4 and N_2O emissions was small. The continuously flooded practice was well received by farmers considering higher grain yield and net ecosystem economic budget. Compared with the continuously flooded paddy fields, Plastic mulching is considerable. Kaifu Song *et al.* (2021).

Global net anthropogenic GHG emissions 1990 to 2019 (IPCC report, 2022):

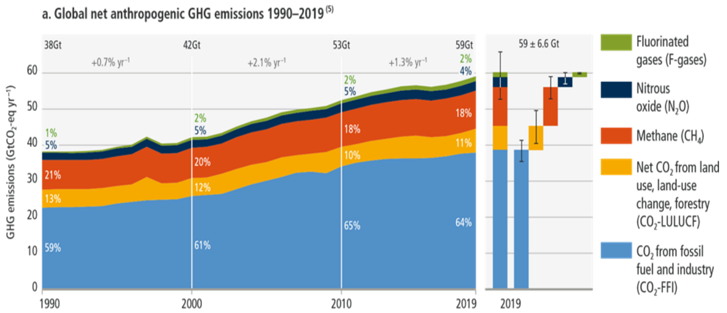

Fig. 2 Global net anthropogenic GHG emissions (Gt CO_2/eq/yr) 1990–2019 Global net anthropogenic GHG emissions include CO_2 from fossil fuel combustion and industrial processes (CO_2-FFI); net CO_2 from land use, land use change and forestry (CO_2-LULUCF)8; methane (CH_4); nitrous oxide (N_2O); fluorinated gases (HFCs; PFCs, SF_6, NF_3).

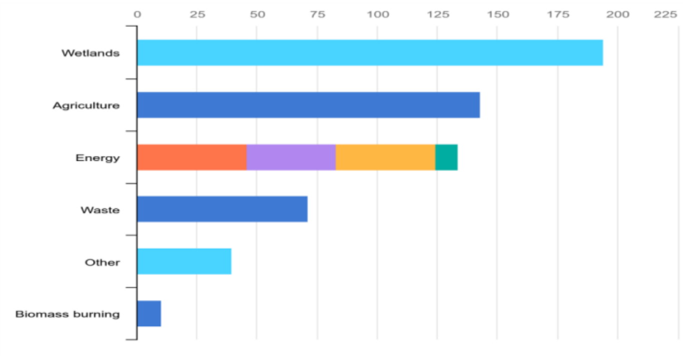

Fig. 3 Sources of methane emissions, 2017 and 2020

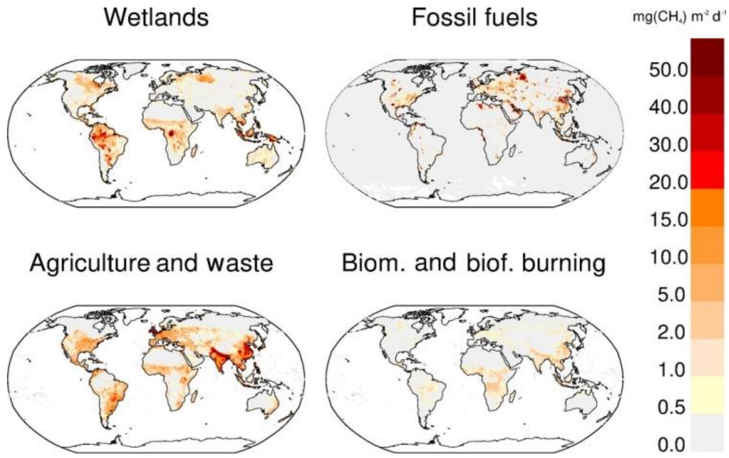

Fig. 4 Methane emissions from four source categories: natural wetlands (excluding lakes, ponds, and rivers), biomass and biofuel burning, agriculture and waste, and fossil fuels for the 2008-2017 decade (mgCH_4/m/day). The wetland emission map represents the mean daily emission average over the 13 biogeochemical models listed and over the 2008-2017 decade. Fossil fuel and agriculture and waste emission maps are derived from the mean estimates of gridded CEDS, EGDARv4.3.2, and GAINS models. The biomass and biofuel burning map results from the mean of the biomass burning inventories listed to the mean of the biofuel estimate from CEDS.

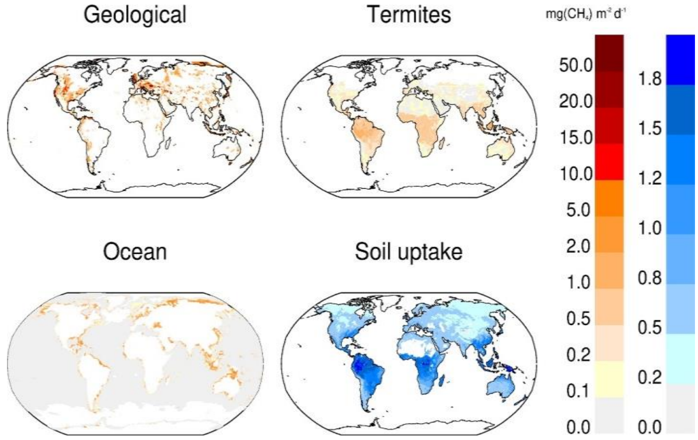

Fig.5 Methane emissions (mgCH_4/m/day) from three natural sources (left color scale): geological (Etiope *et al.*, 2019), termites and oceans (Weber *et al.*, 2019). Methane uptake in soils (mgCH_4/m/d) presented in positive units (right color scale) and based on Murguia-Flores *et al.* (2018).

- Methane is a natural gas and a fuel matter. It mainly produces heat and light energy.
- However excess methane production causes global warming.
- Anthropogenic methane emissions from livestock account for ~37% of total global emissions. Rice paddies are the primary source of methane in crop agriculture.

Climate change

- Water contamination
- Emission
- Oceanic changes
- Vegetation changes

Impact of Climate Change and GHGs on Agriculture

Climate change is likely to contribute substantially to food insecurity in the future, by increasing food prices, and reducing food production. Food may become more expensive as climate change mitigation efforts increase energy prices. Water required for food production may become scarcer due to increased crop water use and drought. Competition for land may increase as certain areas become climatically unsuitable for production. In addition, extreme weather events, associated with climate change may cause sudden reductions in agricultural productivity, leading to rapid price increases. For example, heat waves in the summer of 2010 led to yield losses in key production areas including Russia, Ukraine and Kazakhstan, and contributed to a dramatic increase in the price of staple foods.

- Reduction in crop yield
- Shortage of water
- Rise in sea level
- Decline in soil fertility
- Loss of biodiversity
- Problems of pests, weeds and diseases

Mitigation options for methane emission from submerged rice soil

Methane emission from rice fields depends on growing conditions with implications for the adoption of location-specific agronomic management practices. Meta-data analysis revealed that water, tillage, and fertilizer management practices are the most effective for CH4 emission reduction.

- Water management
- Changing of rice cultivation system
- Use of inorganic fertilizer
- Cultural practices
- Use of rice varieties

Conclusion

The present review of the study indicates that with the manner of irrigation remaining the same, the type of cultivar can play a major role in the extent of methane emissions from rice cultivation. Future works should assess the role of commonly used cultivars in conjunction with the impact of continuous versus intermittent flooding, to shortlist the varieties that emit the least global warming gases. To conclude, the emission of methane from rice fields is a major problem in many countries and it is mostly due to organic matter present in the fields. Mitigating CH_4 emissions from paddy fields cannot be fully controlled. However, it can be reduced using some of the mitigating options.

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