Advances in Methods for Estimating Greenhouse Gas Emissions from Rice Soil

Saikat Ranjan Das[1,2]*, Bitish Kumar Nayak[1,2] and Dibyendu Chatterjee[1]
[1]ICAR-National Rice Research Institute, Cuttack, Odisha-753006
[2]Institute of Agriculture (Palli-Siksha Bhavana), Visva-Bharati, Sriniketan, West Bengal, 731 236, India
*Corresponding Author: saikatranjandas96@gmail.com

Agriculture contributes significantly to greenhouse gas emissions and plays an important role in climate change. As the world's population grows and demand for food increases, it is imperative to accurately assess and mitigate greenhouse gas emissions from agricultural practices. In recent years, there have been remarkable advances in methods for estimating these emissions that allow scientists, policy makers, and farmers to gain a better understanding of their environmental impact. These advances include a wide range of technologies, from improved measurement techniques and remote sensing to sophisticated modelling tools and the use of Big Data and machine learning. Using these innovative approaches, researchers can evaluate the effectiveness of mitigation strategies, identify emissions hotspots, and develop sustainable agricultural practices. In recent years, there have been significant advances in methods for estimating greenhouse ga emissions from agriculture. Accurately quantifying these emissions is crucial for understanding their contribution to climate change and developing effective mitigation strategies. In addition, standardization and harmonization efforts are providing consistent estimates of emissions, facilitating global comparisons and informed decision-making. This article reviews recent advances in methodologies for estimating greenhouse gas emissions from agriculture and highlights their importance in combating climate change and promoting sustainable agricultural systems. Here are some notable advancements:

Monitoring climate change in rice-agroecosystem

Climate change monitoring in the rice agro-ecosystem aims to understand and respond to the complex interactions between climate variables and rice production. Monitoring involves the systematic collection and analysis of climate data, including temperature, precipitation, humidity, and extreme weather events, to assess how changing conditions affect rice growth, yield, and quality. Remote sensing technologies such as satellites and drones provide valuable insights into crop health, water availability, and land use changes. Data collected through monitoring contributes to early warning systems that help farmers prepare for climate-related challenges such as droughts, floods and pest infestations. In addition, monitoring facilitates the identification of climate-resilient rice varieties and the development of adaptation strategies, including modified planting dates, modified irrigation practices, and improved pest management.

Greenhouse gas measurement at field level

Traditional methods of measuring greenhouse gas emissions in agriculture, such as manual chamber measurements, are labour-intensive and time-consuming. Newer technologies such as automated chamber systems, eddy covariance, open-path gas analyzers and laser-based spectroscopy enable continuous measurements of greenhouse gas fluxes in real time. These advancements provide more accurate and detailed data on emissions from agricultural systems.

Manual chamber method: Greenhouse gasses can be measured using the closed chamber method, in which the gasses are collected at the experimental site in a chamber made of acrylic plates and then analyzed using a gas chromatograph. However, the data obtained with this method is not real-time data and has its own limitations. The basic idea of this technique is to enclose a given volume of soil in a closed chamber that allows gaseous exchange between the chamber head and the soil below.

The greenhouse gas flux from the soil was assessed using closed chambers by taking regular gas samples from the chambers and measuring the change in gas concentration over the period of linear concentration change. Subsequently, the analysis was performed using a gas chromatography system equipped with a flame ionization detector (FID) as well as a methanizer for CO_2, an FID for CH_4 and an electron capture detector (ECD) for N_2O (Nayak et al. 2017).

Errors

- Disturbances of the physical and biological systems caused by the measurement procedures.

- The error regarding the volume of the chamber has been taken into account.
- Sample handling errors, improper chamber design, problems in sample analysis and inappropriate procedures for calculating the flux.

Advantages

- Inexpensive and can be used in remote locations because it does not require a power source.
- Used for large-scale greenhouse gas estimation for measuring emissions at the field and farm level.
- The chambers are simple, affordable, and easy to make and chamber's dimensions and size are adjustable.
- Even in small plots, treatment differences and even very small flux variations could be detected.
- Minimal disturbance to the crop during sampling.

Disadvantages

- Time-consuming process that requires a significant amount of manual labour.
- In other hand, limited in the sample volume that can be analysed at a time with limited accuracy, which can lead to variability in the results obtained.
- Also, limited in its ability to detect and count microorganisms that are smaller in size or present in low concentrations.
- Gas concentrations in the chamber may rise to the point of preventing normal emissions. However, short collection times can reduce this problem.
- Because of the turbulence of air flow that naturally exists at the ground surface, closed chambers alter atmospheric pressure variations. Therefore, an enclosed chamber may exaggerate gas flux. An appropriately designed vent that allows pressure equalisation inside and outside the chamber can solve this problem.
- Temperature fluctuations are possible both inside the chamber and in the soil. However, temperature fluctuations can be minimised by insulating the chamber and coating it with a reflective substance.

Ecosystem level measurements of greenhouse gas

Measurements of greenhouse gases at the ecosystem level are typically made using a range of methods, including direct and indirect methods. While indirect methods make estimates of GHG fluxes based on associated variables or processes, direct methods measure greenhouse gas fluxes at the ecosystem level. Direct methods include eddy covariance measurements of greenhouse gas fluxes and the measurement of ecosystem respiration. Modelling approaches including remote sensing that use satellite data to predict greenhouse gas fluxes based on ecosystem characteristics such as temperature, vegetation cover and moisture are some examples of indirect methods for estimating greenhouse gas fluxes at the ecosystem level.

Eddy Covariance: The eddy covariance method is based on a sensor-based real-time measurement of greenhouse gases (**Figure 1**). Basically, the air flow in the atmospheric boundary layer can be viewed as a horizontal flow of numerous rotating eddies containing the greenhouse gases, each of which has a 3-D component (Ux, Uy and Uz). The covariance between the concentration of a particular greenhouse gas or heat and the vertical wind component (Uz) is the flux of that greenhouse gas or heat. The EC measurements are based on high-frequency (10-20 Hz) data of wind speed, wind direction and CO_2, CH_4 and water vapour concentrations at a certain height above the canopy, obtained with a triaxial sonic anemometer and an infrared gas analyzer. Assuming perfect turbulent mixing, all high-frequency data are accumulated over half an hour to calculate carbon, water and heat balances on a daily to annual basis (Chatterjee et al. 2021).

Regional level measurements of GHG

There are several regional-level measurements of greenhouse gas emissions from agriculture, which can vary depending on factors such as climate, land use and agricultural practices. The development and improvement of a globally recognized methodology and software for the calculation and reporting of national greenhouse gas emissions and removals is the responsibility of the IPCC's Task Force on National Greenhouse Gas Inventories.

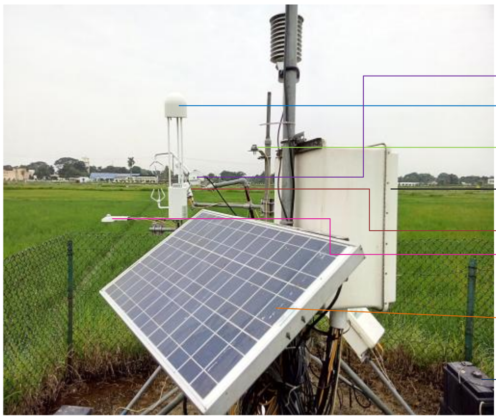

Fig. 1. Open path eddy covariance system

Life cycle assessment (LCA): Life cycle assessment is a method used to evaluate the environmental impact of a product or system throughout its entire life cycle. LCA has been applied to agriculture to estimate the greenhouse gas emissions associated with various agricultural activities, including crop cultivation, livestock farming and food processing. By accounting for emissions from inputs such as fertilizers, energy consumption and transportation, LCA provides a holistic view of the emissions associated with agricultural practices.

Global level measurements of GHG

Remote sensing and satellite imagery: Remote sensing technologies, including satellite-based sensors, offer a broader perspective on agricultural GHG emissions. These tools can be used to detect and measure various indicators such as vegetation condition, soil moisture and changes in land use, which are crucial for estimating emissions. The combination of satellite data with ground-based measurements and modelling techniques enables a more comprehensive assessment of agricultural emissions on a regional and global scale.

Modelling and simulation tools: Computer models and simulation tools are increasingly used to estimate GHG emissions from agriculture. These models integrate data on factors like soil properties, climate conditions, crop types, and management practices to estimate emissions. They can be used to explore different scenarios and assess the effectiveness of mitigation strategies. Improved models provide estimations that are more accurate and enable policymakers and farmers to make informed decisions to reduce emissions. Models such as CENTURY, DNDC, DayCent, DSSAT, TechnoGAS, ECOSSE, EPIC are widely used and validated globally for estimation greenhouse gas emission.

Climate change monitoring in the rice agroecosystem aims to understand and respond to the complex interactions between climate variables and rice production. Monitoring involves the systematic collection and analysis of climate data, including temperature, precipitation, humidity, and extreme weather events, to assess how changing conditions affect rice growth, yield, and quality. Data collected through monitoring contributes to early warning systems that help farmers prepare for climate-related challenges such as droughts, floods and pest infestations. In addition, monitoring facilitates the identification of climate-resilient rice varieties and the development of adaptation strategies, including modified planting dates, altered irrigation practices, and improved pest management. These advances in methods for estimating greenhouse gas emissions from rice soil have enhanced our understanding of the sector's contribution to climate change. They provide valuable insights for policymakers, researchers, and farmers to develop and implement sustainable practices and reduce emissions from agricultural systems.

References

Chatterjee D, Nayak AK, Swain CK, Tripathi R, Chatterjee S, Pradhan A, Swain P, Mohanty S. 2021. Eddy Covariance Technique for Measurement of Mass and Energy Exchange in Lowland Rice. NRRI Research Bulletin No.29. ICAR-National Rice Research Institute, Cuttack, Odisha, 753006, India. pp 34 + vi (March 2021).

Nayak AK, Bhattacharya P, Shahid M, Tripathi R, Lal B, Gautam P, Mohanty S, Anjani Kumar, Chatterjee D. 2016. Modern Techniques in Soil and Plant Analysis. ISBN: 93-272-7059-4, Kalyani Publisher. P.272.

* * * * * * * *