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Estimation of methane emission from rice fields using static closed chamber technique in Tiruchirapalli District

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Abstract

Temperature and rainfall (climate) have mostly determined traditional agricultural practices on the Earth. Agriculture is the main source income for the majority of population living in the South and Southeast Asia. Agricultural activities are associated with the emission of greenhouse gases, notably methane (CH_4) and nitrous oxide (N2O), which are important for anthropogenically influenced climate change. Among all of atmospheric components, methane (CH_4) is a major greenhouse gases (GHG). According to the Intergovernmental Panel on Climate Change (IPCC), the warming forces of CH_4 are 25-30 times higher than that of CO_2 per unit of weight based on 100-yr global warming potentials (IPCC, 2007). Rice cultivation has been recognized as one of the major anthropogenic source for methane emissions (Li *et al*, 1999). Methane emission from rice fields is a microbial mediated anaerobic activity, mainly favoured by the flooded condition. In this regard, extensive rice cultivation may become a potential contributor to the enhancement of global warming. Therefore, initiatives to estimate country-specific contributions to the global methane emissions from paddy fields have to be undertaken. Gas samples were collected from the field using static closed chamber technique. The air samples from the sampling bags were analyzed for CO_2, CH_4 and N_2O. The Methane were estimated in a Shimadzu GC-2014 gas chromatograph. The obtained CH_4 concentrations were determined by peak area and flux were calculated based on the equation proposed by Rolston *et al.,* 1986) to estimate methane emission. In this study, present the distributions of CH4 emission from rice fields over the Tiruchirapalli District, Field chamber studies registered per day methane emission of 0.43 to 0.49 kg/ha/day and seasonal methane emission 40.8 to 48.5 kg/ha.

Keywords: Rice, greenhouse gas, anthropogenic source, anaerobic activity, methane emission, gas chromatograph

Introduction

Temperature and rainfall (climate) have mostly determined traditional agricultural practices on the Earth. Agriculture is the main source income for the majority of population living in the South and Southeast Asia. As the population increased so as the demand for food, during the green revolution during the 1940s through the 1970s, series of research and developments have occurred in order to increase agriculture production around the world. For instance, about 70%, 30% and 20% of the total land in South Asia, Southeast Asia and East Asia, respectively, are designated as agricultural land (FAOSTAT, 2010) [11]. Agricultural activities are associated with the emission of greenhouse gases, notably methane (CH_4) and nitrous oxide (N2O), which are important for anthropogenically influenced climate change. Among all of atmospheric components, methane (CH_4) is a major greenhouse gases (GHG). According to the Intergovernmental Panel on Climate Change (IPCC), the warming forces of CH_4 are 25-30 times higher than that of CO_2 per unit of weight based on 100-yr global warming potentials (IPCC, 2007) [12].

Rice cultivation has been recognized as one of the major anthropogenic source for methane emissions (Li *et al*, 1999) [17]. Methane emission from rice fields is a microbial mediated anaerobic activity, mainly favoured by the flooded condition. Rice fields are considered to be one of the important anthropogenic sources of atmospheric methane. Methane emissions from Rice fields, which depend on many factors arises due to the anaerobic decomposition of organic materials in the flooded soil and escapes to the atmosphere mainly by diffusive transport through the paddy plants (Nouchi *et al*., 1990) [21] during the growing season. World's rice production is expected to increase from the present 520 million tonnes to at least 880 million tonnes by expanding harvested areas by 70% by 2025 to meet the demand of the expanding human population. In this regard, extensive rice cultivation may become a potential contributor to the enhancement of global warming.

Therefore, initiatives to estimate country-specific contributions to the global methane emissions from paddy fields have to be undertaken.

There is an increasing interest in examining the greenhouse gas (GHG) contribution of rice production practices. Rice cultivation has received attention as a GHG emitter (IPCC, 2007) [12]. It was estimated that agriculture accounts for 10 to 12 per cent of total global anthropogenic emission of GHG, which amounted to 50 per cent and 60 per cent of global CH_4 and N_2O emission, respectively (Smith *et al.*, 2007) [28]. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) were important drivers of this anthropogenic greenhouse effect (Tans and Keeling, 2011) [29].

Rice cultivation resulted in an increased emission of methane to the atmosphere. The first field measurements of CH_4 emission from rice paddy fields were conducted in California by Cicerone and Shetter (1981) [5] and in India, measurements of methane emission from rice paddies were initiated by Saha *et al*., (1989) [25]. The rice plants influenced the methane dynamics in paddy soil by.

1. Providing substrate in the form of root exudates to methanogens and thus enhanced the production of CH_4.
2. Transporting CH_4 from soil to atmosphere (conduit effect) and.
3. Creating aerobic microhabitat in rhizosphere and making it suitable for growth and multiplication of methanotrophic bacteria (Dubey *et al*., 2000) [9].

Gupta *et al.*, (2008) had ranked the Indian States according to their cumulative emission in descending order and the relatively high emitting (>0.5 Tg yr^{-1}) States *viz*., West Bengal, Bihar, Madhya Pradesh and Uttar Pradesh were termed as ‘‘hot spots” and accounted for nearly 53.9 per cent of National CH_4 budget for 1994 (4.09 ± 1.19 Tg yr^{-1}). South East Asia emitted approximately 10,000 kg of methane per kilometer square or contributed to 90 per cent to the global rice methane emission chart (Yan *et al*., 2009).

Mechanism of Methane production

Methane, produced as the terminal step of the anaerobic breakdown of organic matter in wetland rice soils (Sahrawat, 2004) [26]. The processes involved in methane emission from flooded rice paddies to the atmosphere included methane production in the soil by methane-producing bacteria (methanogens), methane oxidation within oxic zones of the soil and flood water by methane-oxidizing bacteria (methanotrophs) and vertical transport of the gas from soil to the atmosphere. These methane producing microorganisms did perform well under anaerobic condition and responsible for harvesting organic carbon and transforming it into methane, the process called as methanogenesis (Bloom and Swisher, 2010) [4].

The major pathways of CH_4 production in flooded soils were the reduction of CO_2 with H_2, with fatty acids or alcohols as hydrogen donor and the transmethylation of acetic acid or methanol by methane-producing bacteria (Zang *et al*., 2011) [30]. Acharya (1935) [1] observed that in wetland rice fields, organic matter is degraded to the gaseous end-products such as CO_2 and CH_4. Methane is produced as the terminal step of the anaerobic decomposition of organic matter in wetland soils (Sahrawat, 2004) [26]. The two major pathways that produce CH_4 in submerged soils (Neue and Scharpenseel, 1984) [20] include:

i) Reduction of CO_2 with H_2 (deriving from an organic compound)

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

ii) Decarboxylation (transmethylation) of acetic acid

$$CH_3COOH \rightarrow CH_4 + CO_2$$

Various factors such as temperature, soil pH, and addition of organic materials influence the ratio between CH_4 and CO_2 produced (Aulakh *et al*., 2001) [3]. Methane production requires flow of carbon and electrons to microbial population of methanogens under reduced conditions in the strict absence of free oxygen (Sahrawat, 2004) [26]. It is produced in rice fields after the sequential reduction of molecular oxygen, nitrate, iron (III), manganese (IV) and sulfate, which serves as electron acceptors for oxidation of organic matter to CO_2 (Ponnamperuma, 1972) [22]. The final products of reduction in submerged soils are Fe (II) from Fe (III), H_2S from SO_4^{2-} and CH_4 from CO_2. In rice soils, root exudates provide important C sources for CH_4 production. On an average, 30 to 60 per cent of photosynthesized C by plants is allocated to the roots and a substantial portion of this C is released or secreted by roots in the form of organic compounds in the rhizosphere (Marschner, 1995) [18]. The organic acids in root exudates supply energy to soil microbial communities including methanogens (Aulakh *et al*., 2001) [3].

In the dry season scenario, much of the carbon was used for seeding and active rice production, thus, a lower methane emission and higher rice output came (Sass *et al*., 1990) [27]. The emission during rainy season was higher while at the same time a reduction in rice output was observed and also observed that the harvest index was lower in the wet season when methane emission was higher than in the dry season (Corton *et al*., 2000) [6]. A seasonal pattern of variations in methane emission were observed for paddy rice fields when compared to fields that were rice free. Rice plants stimulated methanogenesis under submerged condition in the wet season which enhanced methane production (Denier Van der Gon *et al*., 2002) [7]. Studies by Epule *et al.*, (2011) [10] had proved that during the wet season methane emission was high, while during the dry season, methane emission was low.

Materials and Methods

Study area

The Tiruchirappalli district of Tamil Nadu extends over an area of 4,40,383 hectares. It is geographically bounded by Salem district in the North, Thanjavur district in the East, Sivaganga and Madurai district in the South and Karur district in the West. Geographically it lies between 78° 10’ to 79° 5’ East longitudes and 10°15’ to 11°2’ North latitudes with an altitude of 90m.

Climate and Soil

The average annual rainfall is 842.6 mm. The contribution of South West, North East monsoons, winter rainfall and summer rainfall are 32.43%, 46.85%, 4.8% and 15.90% respectively. There are two cropping season *viz*., Kuruvai (June-July) and Samba (August) adopted by farmers.

Major portion of the district is covered by plain topography. Gneissic group of rocks of Archean period consisting of granitoid mica gneiss, granitic gneiss leptinites, mixed and composite gneiss are found at different places. The dominant minerals found in the district are limestone, gypsum, garnet sand and limonite. The crystalline lime stones of Precambrian age are mainly distributed in parts of Tiruchirappalli. Deep black is the predominant soil in the district accounting for 32.2 percent followed by the deep red soil with 25.12 percent. The major soil types are Red loam, Black cotton soil and Clay loam. The major crops grown in the district are paddy, banana, sugarcane, redgram, cotton, sorghum, groundnut etc,

Estimation of Methane emission using Closed Chambers
Fabrication of Closed Chambers

Gas samples were collected from the field using static closed chamber technique (Jain *et al.*, 1999) [13]. The gas chambers were fabricated as per the recommendations of several studies on trace gas measurements in field conditions (Mosier *et al.*, 1989; Adhya *et al.*, 1994; Denmead, 2008) [19, 2, 8]. Open-bottom perplex chambers using 4 mm acrylic sheets with a dimension of 50cm x 50cm x 100cm were fabricated. A battery (12V) operated fan was fixed for air circulation (avoid plant suffocation) to mix the air inside the chamber and draw the air samples into air-sampling bags (Tedlar®). The air samples from the sampling bags were analyzed for CO_2, CH_4 and N_2O.

Collection of air samples for Methane estimation

As described by Khosa *et al.*, (2010) [15] each chamber was placed on the soil surface with 4-5 cm inserted into the soil, 10 minutes prior to each sampling for equilibration to reduce the disturbance so as to minimize the disturbance to the sampling site. Care was taken not to disturb the vegetation during the whole measurement programme. After covering the plants with the chamber, four air samples were collected in Tedlar bags starting with zero time and subsequent sampling at an interval of 15 minutes using syringe and one way valve pump. As described by Rath *et al.* (1999) [13] and Jayadeva *et al.* (2009) [14], the air samples were collected in the morning (09:00-10:00 hours) and in the evening (14:00-15:00 hours) and the average of morning and evening fluxes were used as the flux value for the day. Gas samples were collected in five fields across the major rice growing blocks of Tiruchirapalli district at flowering in three locations of the monitoring fields and the average were reported as the average daily methane emission rate for the respective field.

Methane estimation

The Methane were estimated in a Shimadzu GC-2014 gas chromatograph equipped with FID available at Agro Climate Research Centre, Tamil Nadu Agricultural University. The gas samples were introduced into the analyzer by filling the fixed loop (1.0 ml) on the sampling valve. Samples were injected into the column system by starting the analyzer which automatically activated the valve and back flush the samples according to the time programmed. The GC was calibrated before and after each set of measurements using 1ppm, 2.3ppm and 5ppm of standards (Chemtron® science laboratories Pvt. Ltd., Mumbai) as primary standard curve linear over the concentration ranges used. CH_4 flux was expressed as mg m^{-2} hr^{-1} using the equation given by Lantin *et al*., (1995) [16]. The obtained CH_4 concentrations were determined by peak area and flux was calculated based the equation proposed by Rolston *et al.*, 1986) [24] to estimate methane emission.

$$f = (V/A)\ (\Delta C/\Delta t)$$

where f is equal to greenhouse gas emission rate (mg m^{-2} h^{-1}), V is equal to volume of chamber above soil (m^3), A is equal to cross-section of chamber (m^2), ΔC equal to concentration difference between zero and t times (mg cm^{-3}), and Δt equal to time duration between two sampling periods (h).

Results and Discussions

The weather condition prevailed during the experimental periods was presented in Appendix. I and illustrated in Fig.6. The rainfall received during *rabi* season (August 2015 to January 2016) 2014 was 92.1 mm in eleven rainy days. The mean maximum and minimum temperature were 33.8 °C and 23.7 °C, respectively. The relative humidity ranged from 85.8 per cent (7.22 hrs) to 59.3 per cent (14.22 hrs).

Soil Characteristics of the study area

The methane emission potential of soils is an important component for understanding site to site variations in methane budgeting. Soils are poor in organic carbon, low in cation exchange capacity and macro nutrients. Organic manures are not frequently applied due to unavailability as well as lack of time for application. Nitrogen losses through leaching and volatilization occur. As texture determines several physical and chemical properties of soil, it has influence on methane emission indirectly. The soil texture classes of rice growing areas of Tiruchirapalli district were collected and found to be ranging from clay, clay loam, sandy loam to sandy clay loam (Fig. 1.). Soil types of different taluks of Tiruchirapalli district is given below:

Different soil types in different taluks Tiruchirapalli District	
Tiruchirapalli	Black, very deep Fine soils with high clay content
Manapparai	Miscellaneous land type
Musiri	Coarse loamy Red soil Moderately deep
Thuraiyur	Fine (soils with high clay content) Black soil, Moderately deep.
Lalgudi	Fine loamy mixed alluvium, Black soil, very deep.
Kulithalai	Clay loam, sandy loam and red soil

Methane production in reduced soils is very sensitive to pH that varies with soil type. The soil pH map of Tiruchirapalli district was collected and presented in Fig. 2. In Tiruchirapalli district most of the soils were alkali or neutral in nature. Among the rice growing blocks, part of Manikandam and Anthanallur are characterized by dominance of alkali soils. Lalgudi block is dominated by soils with acidic pH of less than 6.5. In Pullambadi and Thiruverumbur blocks the soils were found to be neutral with regard to pH with a range of 6.5 to 7.5. These blocks are characterized by soils with a pH of more than 8.5 also to a smaller extent. Similar trend was observed in Musiri and Manachanallur blocks.

Field level Estimation of Methane emission

Five fields were continuously monitored for rice growth observations and estimation of methane emission at Manikandam, Lalgudi, Pullampadi, Anthanallur and Thiruverumbur blocks. Gas samples were collected at flowering stage in three locations of the monitoring fields and the average were presented as the average daily methane emission rate for the respective field in Fig.3. Among the blocks, Anthanallur recorded higher values for measured methane (2.02ppm) and per day methane emission (0.49kg/ha/day) followed by Thiruverumbur and Lalgudi (0.48kg/ha/day). Manikandam and Pullambadi blocks recorded comparatively lesser methane emission per day (0.44

and 0.43 kg/ha/day) respectively. However, considering the seasonal methane emission Thiruverumbur recorded the highest value of 48.5kg/ha followed by Anthanallur and Manikandam with 46.6 and 46.2 kg/ha methane emission during the season (Table. 1). Pullambadi block recorded the lowest value for field level methane emission in rice fields during Samba season (40.8kg/ha). Among the blocks Anthanallur, Lalgudi and Thiruverumbur recorded higher values for rate of methane emission and seasonal methane emission. The higher rates and quantity might have been attributed by the factor, that these blocks had early Start of the Season (SoS) and more days of flooding which favoured the cultivation of medium duration varieties. The tail end areas of Pullambadi recorded the lowest values for rate of methane emission and total methane emission. The reason for reduction may be attributed to the late SoS coupled with shorter duration of flooding which favoured the cultivation of short duration varieties.

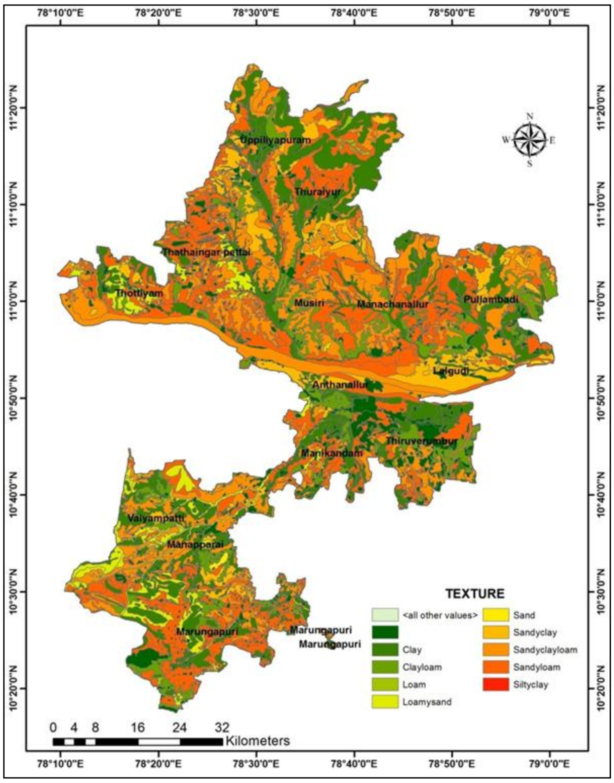

Fig 1: Soil Texture Classes of Tiruchirapalli District

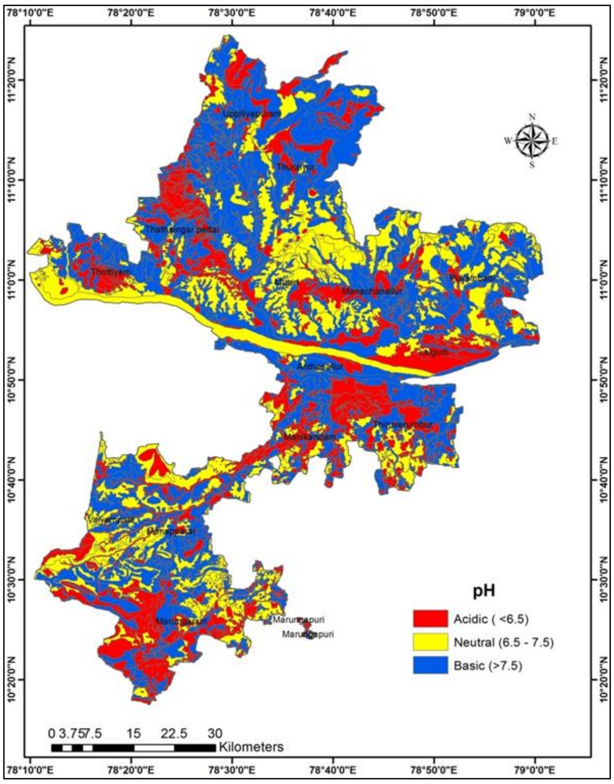

Fig 2: Soil Reaction (pH) of Tiruchirapalli District

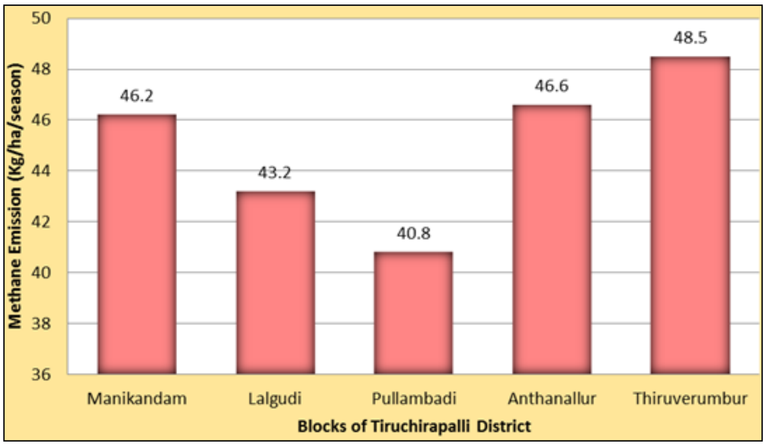

Fig 3: Blockwise Methane emission in Tiruchirapalli District

Table 1: Field level estimation of Methane emission

S. No	Blocks	Place	Latitude	Longitude	Methane measured (ppm)	Methane Emission (kg/ha/day)	Total Methane Emission (Kg/ha/season)
1	Manikandam	ADAC & RI	10.75456	78.60282	1.82	0.44	46.2
2	Lalgudi	Agalaganallur	10.90621	78.80905	1.98	0.48	43.2
3	Pullambadi	Irudhayapuram	10.93565	78.8948	1.79	0.43	40.8
4	Anthanallur	Ettarai	10.81974	78.59514	2.02	0.49	46.6
5	Thiruverumbur	Sozhamadevi	10.76496	78.77321	2.00	0.48	48.5

Conclusion

In this study, present the distributions of CH4 emission from rice fields over the Tiruchirapalli District, estimated using the field studies of emission rate, the seasonal methane emission Thiruverumbur recorded the highest value of 48.5kg/ha followed by Anthanallur and Manikandam with 46.6 and 46.2 kg/ha methane emission during the season. Pullambadi block recorded the lowest value for field level methane emission in rice fields during Samba season (40.8kg/ha). Field chamber studies registered per day methane emission of 0.43 to 0.49 kg/ha/day and seasonal methane emission 40.8 to 48.5 kg/ha.

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