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TROPICAL DRY DECIDUOUS FOREST ACT AS METHANE SINKS

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Abstract – In the last few years exponential rise of greenhouse gas emissions is becoming a major challenge. These emissions cause the elevation of the atmospheric temperature leading to global warming. The Earth Summit held in Rio-de-Janeiro in June 1992 and Kyoto Conference on climate change in December 1997 made it mandatory for all countries to establish greenhouse gas emission budgets and develop mitigation strategies. Fluxes of Greenhouse gas methane, were measured in - situ monthly for two years from natural system Forest predominated by *Tectona grandis,* 20 km southwards from Indore (Madhya Pradesh) by using closed chamber technique. The study site is found to uptake methane showing annual consumption rates (mean - 20. 35 Kg ha $^{-1}$Yr^{-1}) Effect of different soil variables on methane fluxes like pH, Organic Carbon, soil moisture was also studied. Significant negative correlation was observed between soil organic matter Vs methane fluxes (r=-0.40, p<0.05, n=36). The study concludes that natural plant community forests should be maintained as they have potential to absorb methane, an important greenhouse gas to combat global warming leading to climate change mitigation.

INTRODUCTION

Forests are a dominant feature of the global carbon (C) cycle and play an important role in regulating climate and climate change (Bonan, 2008; Pan *et al*., 2011). Research on forests in the context of the global C cycle is focused primarily on carbon dioxide (CO_2) dynamics, because the fluxes are large and C sequestration in wood and soil organic matter influence centuryscale projections of radiative forcing (Canadell and Raupac, 2008). Less attention is directed toward forests as sources and sinks of other C trace gases such as methane (CH_4).

The presence of methane (CH4) in the atmosphere has been known since the 1940' s, when strong absorption bands in the infrared region of electromagnetic spectrum were discovered which were caused by the presence of atmospheric methane (Cicerone and Oremland, 1988). Methane (CH_4) is a trace gas with a global warming potential 21 times greater than that of carbon dioxide (CO_2) and participates in chemical reactions producing tropospheric ozone (Forster *et al.,* 2007; Topp and Pattey, 1997). Oxidation processes are the main sink of atmospheric CH_4, with the reaction of hydroxyl-radicals (OH) in the troposphere accounting for approximately 90% of annual CH_4 removal (Prather *et al*., 2001). Although soils can act as sinks and sources for CH_4, microbial oxidation (methanotroph) in aerated upland soils is the primary biotic sink for atmospheric methane. Global CH_4 uptake by upland soils has been estimated to range from 9 to 51 Tg CH_4 year$^{"1}$ (Dutaur and Verchot, 2007; Ghosh *et al.,* 2015; Kirschke *et al.,* 2013), with tropical forest and grassland soils contributing approximately 58% to this uptake (Yu *et al.,* 2017). CH_4 fluxes of upland soils are the result of two processes: methanogenesis (production) under anaerobic conditions and methanotrophy (consumption/oxidation) in aerobic soils (Trotsenko and Khmelenina, 2002). Depending on soil aeration, upland soils can act as a sink or source of CH_4. Gas diffusion into the soil is affected by soil water content and soil texture and these two factors have been regarded as primary controls of CH_4 uptake in upland soil ecosystems (Verchot *et al.,* 2000). In upland forest soils, soil conditions favor the activity and growth of methanotrophs and therefore the methane oxidation process is dominant compared to production (Kravchenko, 2017), as a result forests soils usually act as methane sinks. In the present study an attempt is made to measure trace gas (methane) fluxes on landscape basis, periodically in dry deciduous forest in relation to carbon and nitrogen dynamics. Also,the effect of different soil property variables on methane fluxeswas analyzed.

MATERIALS AND METHODS

The study site Simrol Forest comes under Indore forest division of Madhya Pradesh situated about 110 km away from Ujjain. The forest is Tropical Dry Deciduous Type and is mostly confined to hilly terrains of Deccan plateau. The soil is deep to moderately black cotton soil in plains and valleys. The density of teak forest is moderate varying from 0.6 to 0.8 through stocking of 0.9 densities and above is also noticed in valleys and banks of streams. The average height of the tree varied from 19 to 20 meters. *Tectona grandis* enjoys the status of dominant species. Other associates include *Hardwickiabinata, Acacia caesia, Sehimasulcatum,* etc. The climate of Ujjain and Indore area is typically monsoonal with hot summer (May-June) and cold winter (January-February). The year can be divided into summer, Rainy and winter seasons.

Sampling Technique

Gas samplings were carried out using closed chamber technique as standardized by National Physical Laboratory (NPL), New Delhi (Parashar *et al.*, 1993). In the forest aluminium base (54L × 33W × 10H cm) with internal groove size (48L × 27W × 2H cm) were installed manually. The base was embedded in the soil a few hours in advance to ensure that ambient soil atmosphere was maintained in a stabilized condition. The airtight Perspex chamber (50L × 30W × 50H cm) which fitted into the groove of the aluminum base was put in place at the time of sampling covering an area of $0.1765m^{-2}$. The air inside the chamber was isolated from the outside atmosphere and the system was made airtight by filling the groove in the aluminum base with water. Flux measurements were made in the late morning at 10 am and afternoon by 3 pm on each sampling day. The temperature inside the Perspex chamber was recorded at the time of sample collection (0, 10, 20, 30 min) using a thermometer (10 to 1000 ^{0}C range, Co Immersion Zeal, England) fixed on the inside wall of the chamber for calculation of box volume at STP. The collected gas samples in 100 ml glass vials were brought to the laboratory and analyzed for CH_4 on a gas chromatograph (Nucon series 5700, India) equipped with a Flame Ionization Detector (F.I.D) and a column of stainless steel 1/8'' O.D.× 6 feet length packed with molecular sieve 5A, 60/80 mesh column. Injector and detector temperature were maintained at 80,110 and 110^{0}C respectively. The gas chromatograph was attached with an integrator (Oracle 3). Ultrapure nitrogen served as carrier gas (flow rate 30 ml min^{-1}). Hydrogen was taken as the fuel gas and zero air as the supporting gas with flow rates of 30ml min^{-1} and 300 ml min^{-1} respectively. The chromatograph was calibrated by repeated injections of methane standards in the nitrogen and ambient air samples. After confirming the peak and retention time for methane in ambient samples, collected gas samples were analyzed for methane. Gas chromatograph was also calibrated before and after each set of measurement. Samples analyzed at Vikram University were authenticated (in aliquot) at NPL for reconfirmation. CH_4 Fluxes were calculated as:

CH_4 flux F (mg $m^{-2}h^{-1}$) = $BV_{STP} \times \Delta CH_4 \times 16 \times 1000 \times 60/10^6 \times 22400 \times A \times t$

Where BV_{STP} (Chamber air volume in cc at STP) = BV ×B. P×273/ (273+ T) × 760

Box Volume (BV)= [(H-h) LW-Biomass volume inside box)

Where H= Chamber height, h= channel above soil /chamber above water level

L= chamber length (cm), W=chamber width (cm), B. P= Barometric pressure (mm hg)

T= chamber air temperature at the time of sampling (^{0}C) ΔCH_4 = change in CH_4 concentration in ppmv from zero minute to the t minute sampling A= area covered by the box (m^2), t = time in minutes

The physico-chemical characteristics of soil were also analyzed. Organic carbon in soil samples was estimated by dichromate oxidation and titration with ferrous ammonium sulphate. pH was measured using a pH meter equipped with glass electrode (1:25 soil: water ratio, w/v)

RESULTS AND DISCUSSION

Methane fluxes in forest base and slope ranged - 7.78 to 4.88 and -9.58 to 3.82 mg m^{-2} d^{-1} (Fig. 1a). The results indicated that maximum methane consumption was observed in winter season (-11.66 to –14.52 mg m^{-2} day^{-1}) and minimum in summer. This is in contrast to its emission during the rainy

Table 1. Physico-Chemical characteristics of Forest soil

Forest Soil	Parameters	Summer	Rainy	Winter
	Soil Temp (^{0}C)	39.50 (5.75)	28.50 (0.52)	25.00 (1.51)
	Soil Moisture (% d.w.)	10.51 (3.84)	25.31 (1.81)	21.46(2.08)
	Organic Matter (%)	1.29 (0.02)	1.03 (0.01)	1.13(0.02)
	Microbial Biomass C (mg C100g^{-1}ODS)	32.17 (5.06)	24.88 (1.24)	-102.98(1.32)

ODS Oven Dry Soil, Values in parenthesis are Standard Deviations

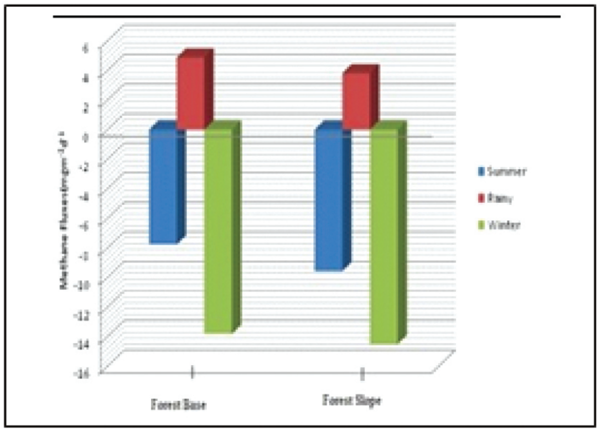

Fig.1 (a)

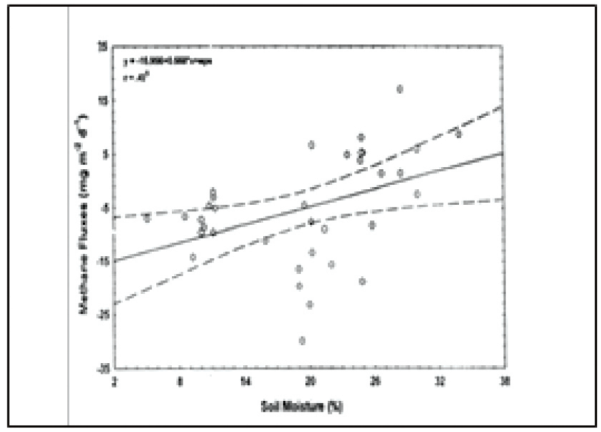

Fig.1 (b)

Fig. 1 (a). Seasonal variations in methane fluxes in forest soil. Positive values revealing the emission trend and negative the methane consumption

Fig. 1 (b). Relationship between Soil moisture (%) and methane fluxes. Dotted curve shows the 95% confidence interval for the regression

season (4.88, 3.82 mg m^{-2} d^{-1}) due to anaerobic condition developed on account of days continuously raining for several times, a condition favorable for the methane producing bacteria. Soil remained dry and oxicduring summer and winter season, a condition favorable for the functioning of methanotrophs. Following wetting in the rainy season, methane consumption is suppressed by a restricted diffusion in wet soil. As soil dries, methane consumption increases to a maximum as diffusion rates rise. If the soil becomes very dry, consumption rate will fall as direct effects of moisture stress pull down biological demand (Mosier *et al.*, 1997). Forest slope showed higher methane consumption than base. Significant negative correlation was observed between soil organic matter Vs methane fluxes (r = -0.40, p<0.05, n=36) (Kuldeep Kaur, 2017)while significant positive correlation was observed between microbial biomass carbon, NH_4^+N, NO^{-3} N Vs methane fluxes (r=0.47, p<0.05, n=36; r=0.35, p<0.05, n=36; r=0.47, p<0.05, n=36) respectively. In the forest, methane uptake has been attributed to oxidation of methane by methanotrophic bacteria to methanol by the enzyme methane monooxygenase which is further oxidized by means of dehydrogenases and the bacterial electron respiratory chain to CO_2 (Conrad, 1989). The climax tropical dry deciduous Simrol forest soil is a drained soil silty clay loam to silty clay. The clay content is 36%. The soil pore spaces in forest sites being replaced by rain water during the rainy season on account of days receiving rains and idealistic for an anaerobic condition. Soil water content increased to 25.31% during the rainy season. Organic matter received on the forest floors in the form of litter during earlier seasons started decomposing during the rainy season. This decreases the oxygen concentration in the soil atmosphere. Rainfall also stimulates heterotrophic activity in soils, decreasing the soil oxygen concentration which is an important regulator of methane. A decrease in soil oxygen concentration, results in anaerobic conditions. The methane producing bacteria becomes active in anoxic environment hence leading to methane emission during the rainy season as compared to negative fluxes during the summer and winter season. The overall results point out the importance of natural plant communities as key players to act as an absorber for methane. Thus natural systems such as forest should be maintained because they have the potentiality to uptake methane and in turn leading to fall in global warming.

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