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GRASSLAND: AN ABSORBER AND AGRICULTURAL FIELD: A SOURCE FOR METHANE

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ABSTRACT

Methane (CH_4) fluxes were measured *in situ* monthly for two years from moderately grazed grassland situated behind the Zoology Department in the Vikram University and agricultural farm of Madhya Pradesh Oil Federation (Tilhan Sangh) situated near the kothi palace in Ujjain city. The crops grown in the agro ecosystem were Soyabean and Chick pea. The grassland harboured 18 plant species. The highest IVI was shared by *Iseilema laxum* (80%). Results revealed that the grassland act as sink for methane showing annual methane consumption rates (mean -11.02 kg ha^{-1} yr^{-1}) while managed agricultural field is found to be a source of CH_4 with annual methane emission rates (mean 5.09 kg ha^{-1} yr^{-1}). Several influencing factors like soil pH, inorganic nitrogen and organic carbon were studied concomitantly with CH_4 fluxes. CH_4 fluxes were positively and significantly correlated with NH_4^+ N, NO_3^- N while significant negative correlation was observed between organic matter Vs methane fluxes in both the sites. The study concludes the importance of natural system as key player to act as sink for methane. In contrast agricultural management practices favours emission of methane, the important green house gas.

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KEY WORDS : Agricultural field, Grassland, Methane, Sink, Source

Introduction

Methane is also known as Marsh gas, is a colorless and odorless gas with a molecular weight of 16.04 g/mol, a boiling point of -164^{0}C and specific gravity 0.55. The presence of methane in the atmosphere has been known since the 1940's, when strong absorption bands in the infrared region of the electromagnetic spectrum were discovered which were caused by the presence of atmospheric methane[4]. Methane is a chemically reactive trace gas and has 21 times more warming potential than CO_2 and contributes significantly to global warming[6].The first evidence for an increase of methane in the atmosphere reported[12]. The atmospheric concentration of this gas has more than doubled during the past 200 years, rising over the past 15 years by an average of 1% per year[13]. Although slowing down of this growth rate was reported[5]. The major sink for atmospheric methane is its chemical reaction with hydroxyl radicals in the atmosphere[7] uptake of ambient methane by some soils could be an additional significant sink[2]. Two microbial processes, methanogenesis and methanotrophy are involved in methane production, emission and consumption. The study addressed the following objectives

1. Quantification of biogenic emission / consumption of methane from grassland and agricultural field periodically.
2. Analysis of physico-chemical factors influencing methane flux in the soil interface.

Materials and Methods

For the study of CH_4 flux measurement, we considered moderately grazed grassland situated behind the Zoology Department in the Vikram

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TABLE- 1: Vegetation Characteristics of Moderately Grazed Grassland

Species	Relative Density%	Relative Frequency %	Relative Dominance Cover (%)	IVI (%)
Alysicarpus rugosus	1.75	5.82	6.12	13.69
Bothriochloa pertusa	9.20	6.64	4.16	20.00
Cyathocline purpurea	0.32	2.10	4.56	7.00
Cymbopogon martini	0.71	14.00	18.64	33.93
Dichanthium caricosum	16.6	14.90	13.50	45.00
Enicostema littorale	3.57	4.00	2.43	10.00
Iseilema laxum	35.60	26.00	17.40	80.00
Phyllanthus maderaspatensis	0.51	2.00	1.34	3.85
Setaria glauca	0.51	1.09	3.40	5.00

University, Campus, Ujjain. The grassland are differing in the grazing intensity. Once upon a remote time back the area was covered by the climax vegetation of dry deciduous forest. In course of time the forest were cleared for agricultural practices that lasted for many years. Consequently the land got converted into grassland on account of abandoned cultivation when the university came in to existence in 1955. Since then the grassland have been maintained under varying grazing stress and occasional burning and is thus seral in nature[1]. The soil of the area is vertisols, clayey loam to loamy in texture and black to brownish in colour and contains montmorillonite as the predominant clay mineral. The grassland covers an area of 150 hectares. Major plant species includes *Iseilema laxum, Setaria glauca* etc. The agricultural farm of Madhya Pradesh Oil Federation (Tilhan Sangh) situated near the Kothi Palace in Ujjain city. The cultivated area of this farm is 44 hectares. The soil type is medium black soil and the crops grown were mainly Soyabean *[Glycine max* Merrill] in Kharif [July to October] and Chick pea [*Cicer arietinum*] in Rabi (November to March) From April to June the field is kept without crop. Fertilizer added to agricultural field at the time of land preparation for seed sowing is P_2O_5 at a rate of 80 and 32 kg ha^{-1} (as single superphosphate), Urea-N at a rate of 30 and 8 kg ha^{-1} and potash at a rate of 20 and 8 kg ha^{-1} in Soyabean and chickpea field. The climate of the area is typically monsoonic with hot summer and cool winter. The mean maximum temperature varied from 21.0 (January) to 36.5^{0}C (May) and mean minimum temperature varied from 13.0 (January) to 29.5^{0}C (May). The year can be divided into summer, Rainy and winter season. The average annual rainfall is 1014 mm.

Sampling Technique

Gas samplings were carried out using closed chamber technique as standardized by National Physical Laboratory (NPL), New Delhi[11].

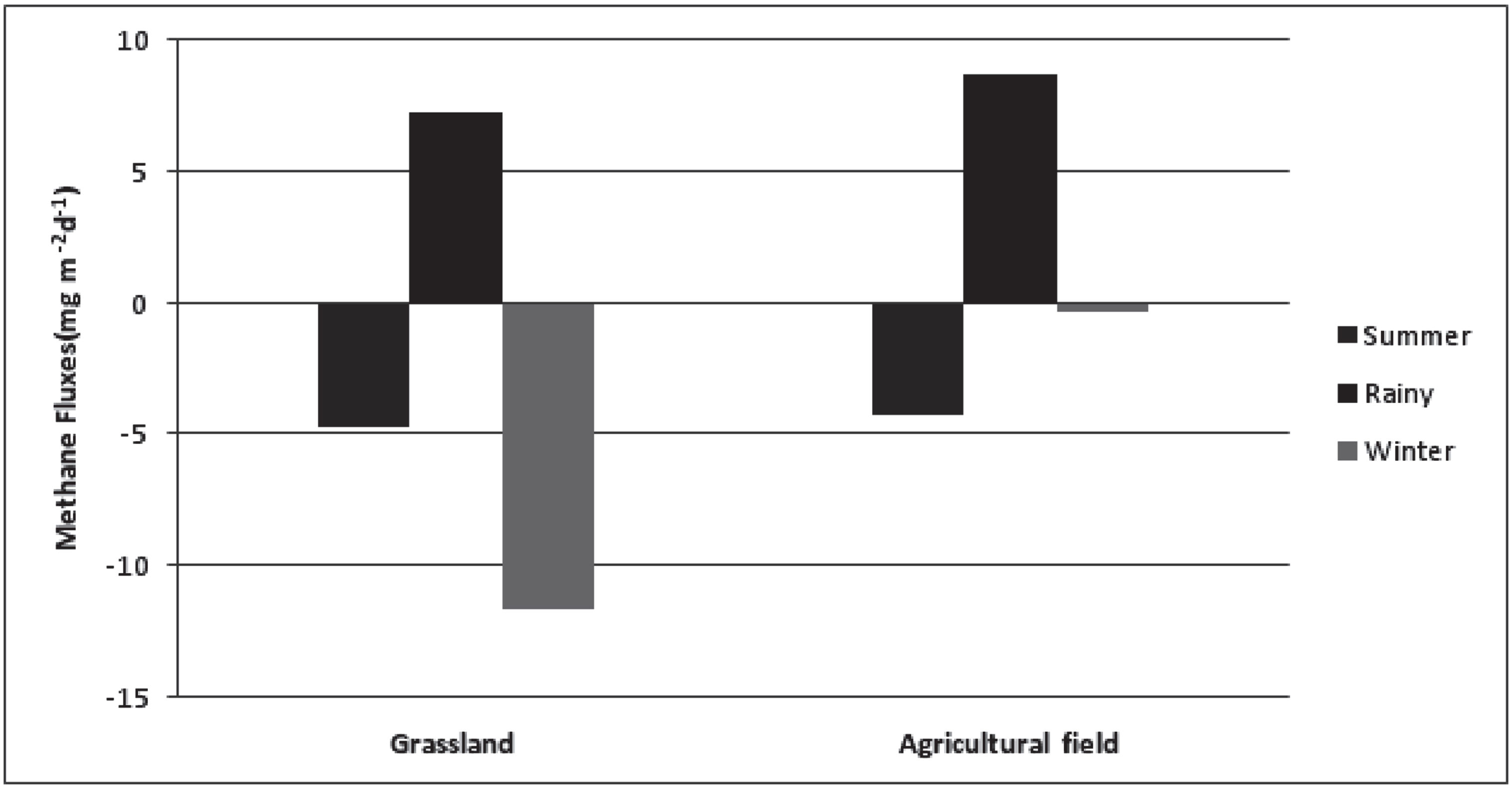

Fig. 1: Seasonal variation in methane fluxes from grassland and agricultural field. Positive values are revealing the emission trend and negative, the methane consumptions in soils.

TABLE -2: Physico-chemical properties of grassland and Agriculture soil

Site	Parameters	Summer	Rainy	Winter
Grassland	Soils Temp (°C)	33.00 (3.02)	27.50 (2.58)	20.50 (2.55)
	Soil Moisture (% d.w.)	10.18 (1.07)	30.62 (2.01)	20.43 (0.99)
	Soil pH	8.26 (0.19)	8.11 (0.16)	8.11 (0.16
	Organic Carbon (%)	0.60 (0.03)	0.50 (0.11)	0.64 (0.15)
	NH_4+ N (mg N $100g^{-1}$ ODS)	2.42 (0.14)	4.02 (0.08)	1.88 (0.25)
	NO_3 –N (mg N $100g^{-1}$ ODS)	1.89 (0.13)	3.83 (0.21)	1.96 (0.41)
Agricultural field	Soil Temp (°C)	33.50(3.67)	29.00(5.06)	24.50(1.54)
	Soil Moisture (% d.w.)	12.69(3.41)	30.21 (2.18)	28.00(1.96)
	Soil pH	8.60 (0.31)	8.28 (0.30)	8.54 (0.25)
	Organic Carbon (%)	1.07 (0.02)	0.87 (0.03)	0.97 (0.01)
	NH_4^+–N (mg N $100g^{-1}$ ODS)	1.15 (0.12)	3.87 (0.06)	2.04 (0.08)
	NO_3 –N (mg N $100g^{-1}$ ODS)	1.83 (0.03)	3.32 (0.29)	2.69 (0.37)

Values in Parenthesis are Standard Deviation

Transparent Perspex chamber made from 6 mm plexiglass sheet was used. The chamber cover was fitted with a sampling port and a port to which a plastic pressing pump was attached for uniform mixing of air inside the chamber. The sampling port is a hole plugged with a rubber septum through which a 50 ml glass syringe was inserted with hypodermic needle to collect gas samples from the chamber. Gas samples were transferred to pre evacuated, sealed glass vials of 100 ml volume at 0, 10, 20 and 30 min intervals and ambient air sample was also collected near the chamber to compare with 0 min flux at the time of calculation. The aluminium base (54L × 33W × 10H cm) with internal groove size (48L × 27W × 2H cm) was 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 aluminium 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 aluminium 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 (1, 10, 20, 30 min) using a thermometer (-10 to100^0C 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

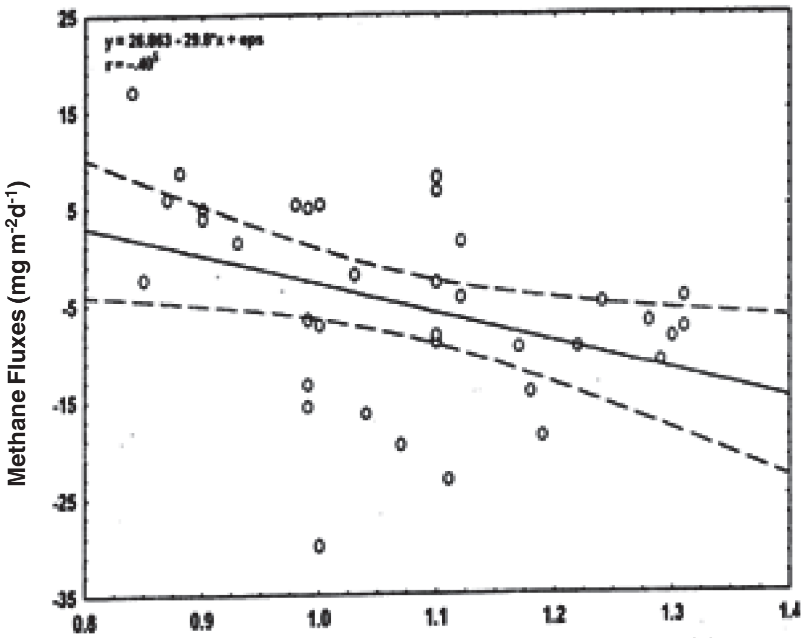

Fig. 2(a) : Relationship between CH_4 flux and soil organic matter.

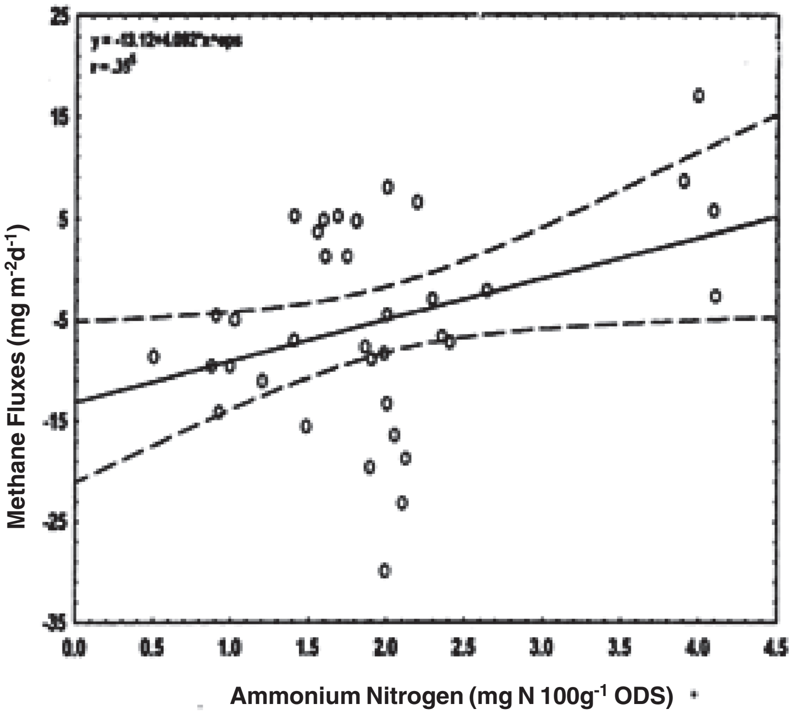

Fig. 2(b): Relationship between CH_4 flux and Ammonium Nitrogen. Dotted curves show the 95% confidence interval for the regression in Grassland.

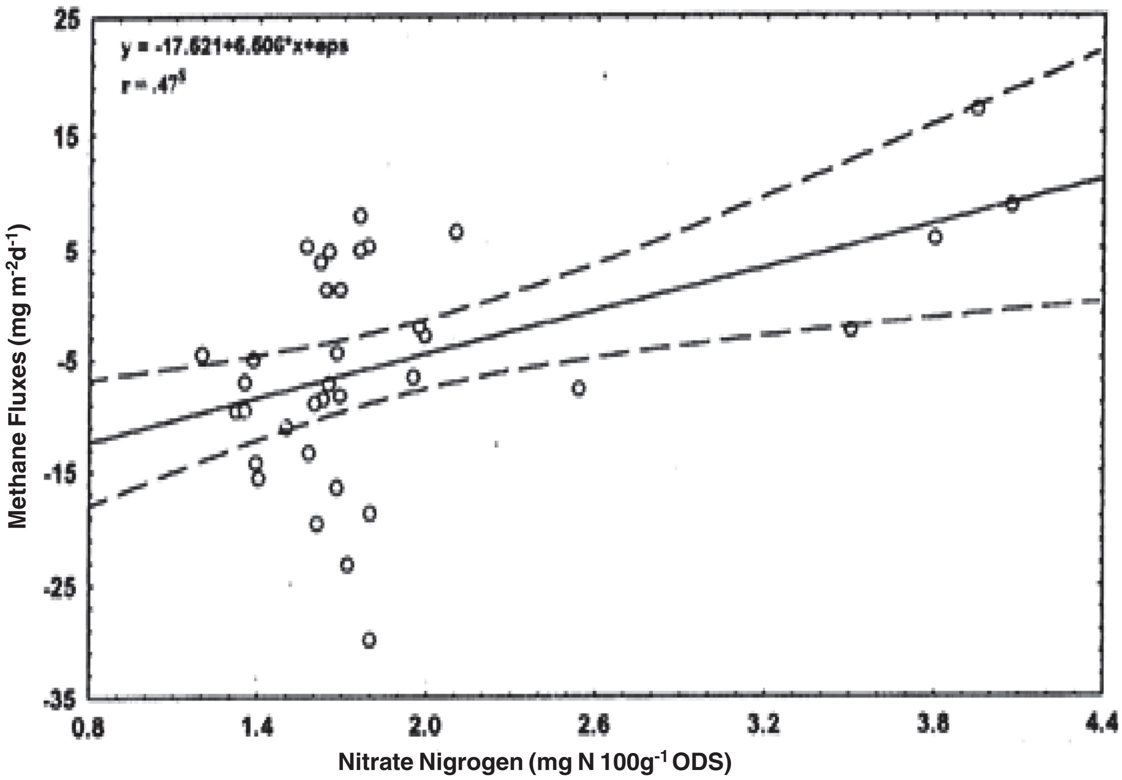

Fig. 2(c): Relationship between CH_4 flux and Nitrate Nitrogen. Dotted curves show the 95% confidence interval for the regression in Grassland.

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 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 30 ml min^{-1} and 300 ml min^{-1} respectively. The gas 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)

Ä CH_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. NH_4^+N and NO_3^-N was analyzed by distillation method[3], organic carbon by other workers.[15]

To study vegetation characteristics in the grassland 25 quadrats of 100 cm^2 were layed randomly.

Results and Discussion

Phytosociological analysis of a plant community is an essential prerequisite for the study of any piece of vegetation. The community structure can be expressed by the importance value Index (IVI) Grassland harboured following plant species during the rainy season (Table-1). The highest IVI was shared by *Iseilema laxum* (80%) and lowest by *Phyllanthus maderaspatensis* (3.85%)

In grassland and agricultural field soil organic carbon ranged from 0.50 to 0.64%; 0.51 to 0.62% NH_4^+N varied from 1.88 to 4.02 mg N $100g^{-1}$ ODS; 1.15 to 3.87 mg N $100g^{-1}$ ODS while NO_3^- N was found to be 1.89 to 3.83 mg N $100g^{-1}$ ODS; 1.83 to 3.32 mg N $100g^{-1}$ ODS (Table-2) in two sites during the three seasons.

The grassland showed annual methane consumption rates of –11.02 kg ha^{-1} yr^{-1} (Fig. 1). This value is higher than-1.75 to -3.06 kg ha^{-1} yr^{-1} measured in temperate native grassland[9]. Significant negative correlation was observed between soil organic matter Vs methane fluxes (r = -0.40, $p<0.05$, n =36) (Fig. 2a) while significant positive correlation was observed between NH_4^+N, NO_3^-N Vs methane fluxes (r =0.35, $p<0.05$, n =36; r= 0.47, $P<0.05$, n=36) (Fig. 2 b,c). Soil moisture showed significant positive correlation with methane fluxes (r=0.41, $p<0.05$, n=36). Annual methane release from the legume (Soyabean and Chickpea) sown agricultural field was found to be 5.09 kg ha^{-1} yr $^{-1}$(Fig1). Methane flux showed significant negative correlation with soil organic matter content (r = -0.51, $p<0.05$, n =18) (Fig. 3a). Significant positive correlation was observed between NH_4^+N, NO_3^-N Vs methane fluxes (r=0.51, $p<0.05$, n =18; r=0.49, $P<0.05$ n=18) (Figs. 3 b,c).Methane fluxes in grassland ranged from -4.70 to 7.30 mg m^{-2} d^{-1}. The results indicate that methane consumption in soils were maximum in the winter season and minimum in the summer season while methane emission was seen during the rainy season. The grassland belongs to productive vertisol soils with clayey nature. The dominance clay mineral in most of vertisols appears to be Montmorillonite, and clay content recorded was 40 - 42%[1]. This clayey soil is sticky when wet and very hard when dry.

The soil contains small cracks (of 1 meter depth) at the end of summer and just in the beginning of wet seasons when the soil temperature remained high (30.5-36.5^{0}C) resulting into high infiltration rates which decreases drastically with wetting. The soil pores spaces in grassland being replaced by rain water during rainy season on account of days continuously receiving rains (62 and 79 days within two years) and idealistic for an anaerobic conditions. Soil water content increased to 30.62 at the site during rainy season as compared to lower values received earlier in the summer seasons. Organic matter received on the grassland in the form of litter during earlier season started decomposing during the rainy season. Thus the high soil moisture content and decomposing soluble organic matter, decrease the oxygen concentration in soil atmosphere. Rainfall also stimulates heterotrophic activity in soils, decreasing the soil oxygen concentration, which is an important regulator of trace- gas (methane) flux. A decrease in soil oxygen concentration, results in anaerobic conditions in grassland. The methane producing bacteria easily becomes active in anoxic environment[10] hence attributing to significant methane emission from soils during the rainy season, as compared to negative fluxes during the summer and winter seasons. Methane consumption was maximum in winter season, because under oxic condition, an adequate level of soil moisture and an optimum temperature is needed for the optimal functioning of methanotrophs. Such conditions were frequently present in the winter season at the selected site, causing maximum methane consumption. In contrast, summers are relatively hot in a tropical country like India and soil become very dry soil water content becomes low due to high soil temperature, conditions less favourable for the optimum functioning of methanotrophic bacteria. As soil becomes very dry, consumption rates decreases as direct effects of moisture stress pull down biological demand[8]. The water potential of microbial

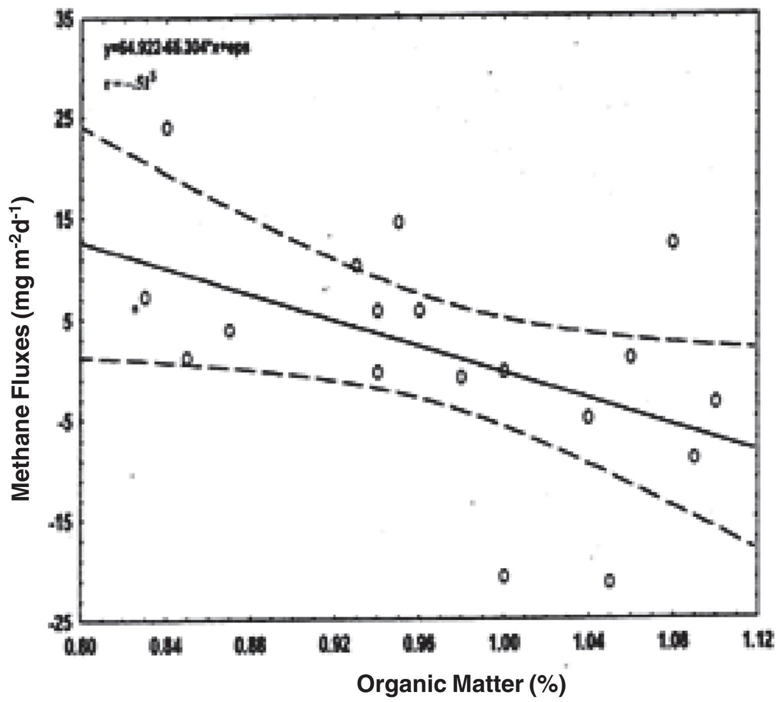

Fig 3(a): Relationship between CH_4 flux and soil organic matter.

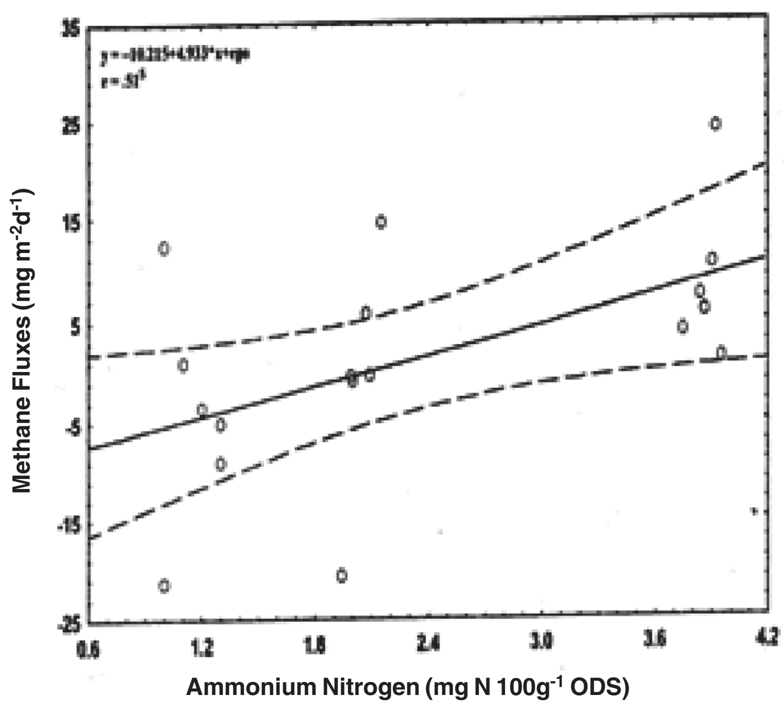

Fig 3(b): Relationship between CH_4 flux and Ammonium Nitrogen. Dotted curves show the 95% confidence interval for the regression in Agricultural field.

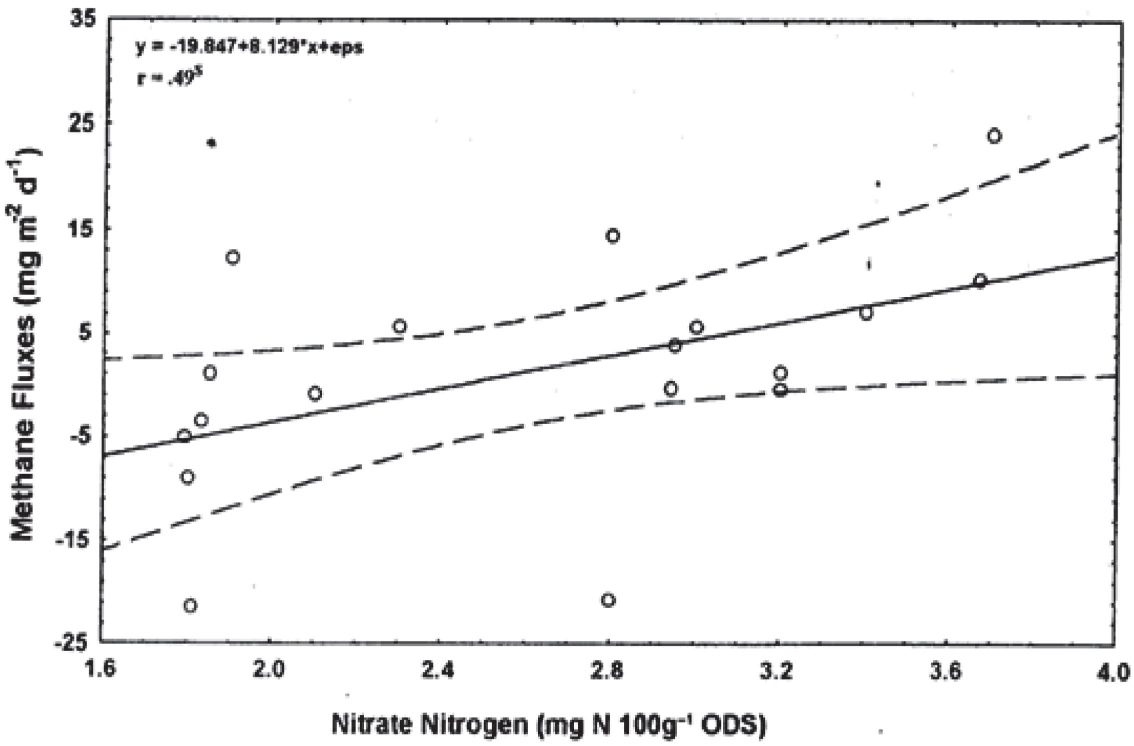

Fig 3(c): Relationship between CH_4 flux and Nitrate Nitrogen. Dotted curves show the 95% confidence interval for the regression in Agricultural field.

cell is more or less at equilibrium with its microclimate in the soil. Decreased water potential of soil decreases the availability of water for microbes in soils, and therefore the microbial activity is affected due to change in soil water content. Some lowest amount of soil water is essential to maintain the physiological cell functions of the bacteria whose cells have water contents between 233-566% H_2O per cellular dry weight[14]. Hence, lower rates of methane consumption were observed during the summer season. Methane fluxes in Soybean and Chickpea agro ecosystem ranged from - 0.32 to 8.75 mg m^{-2} day^{-1}. Results indicated that agro ecosystem under study showed higher methane consumption during the summer and lowest during the winter season. In contrast methane emission was observed during the rainy season. During the summer, the study site was kept without crop cover (fallow field). Field was ploughed every year to kill vegetation, to bury crop residues, to loosen the soil for preparation of a seed bed for next crop and to increase absorption of air and water. The increased oxygen supply after postharvest hastens the liberation of available nutrients. Soil becomes oxic and conditions favorable for methane consuming bacteria. Hence higher rates of methane consumption were observed during the summer .During Soybean cropping (rainy season) pores space being replaced by rain water during the rainy season on account of days continuously rains (62 day). Soil becomes saturated to field capacity and soil moisture becomes (30.21%). Anaerobic condition is developed, favourable for the functioning of methane producing bacteria. Little nitrogenous fertilizer (8kg N ha^{-1}) in the form of urea and diammonium phosphate were increased in the field as an initial dose at the time of seed sowing to increase the crop yield and soil fertility. Nitrogen was also added to the field from symbiotic nitrogen fixation. During the chickpea cropping (winter season) field was irrigated whenever required to supplement precipitation. Due to irrigation soil water content increased to 28%. Urea and diammonium phosphate was added at the time of sowing of seeds of Chickpea. Thus high soil water content and fertilization / nitrogen input by symbiosis might have caused methane emission or reduced methane consumption during the rainy and the winter season. The overall results point out that natural system plays an important role in the uptake of methane. The study also revealed that disturbances in the natural system lead to more contribution of this greenhouse gas, e.g. agricultural practices on land clearing of natural communities. Thus it can be concluded that natural systems such as grassland should be maintained because they have the potentiality to absorb methane being acting as sink. The leguminous crop fields the major hotspot in the present study for methane emission, a thorough study to minimizing strategies are needed.

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