PARAMETERS CONTROLLING PRODUCTION AND EMISSION OF METHANE FROM PADDY FIELDS

D. C. Parashar , S.C.Garg and A.P.Mitra

National Physical Laboratory, New Delhi-110 012, INDIA

ABSTRACT

Options to mitigate methane emission from paddy fields have been studied by various groups working on methane budget from paddy fields. The need of the day is to work out the feasibility of their implementation. It is clear that methane emission from paddy fields is also dependent on methane production potential of the paddy soil in most of the paddy cultivation regimes except deep water. Production potential in the paddy field depends mainly on the inundation period to bring the redox potential of the soil sufficiently down for its anaerobic behavior . Studies on changes in redox potential with time of inundation have shown large variation depending on the nature of soil in different regions producing rice. It is seen that silty clay loam soils take around 8 to 10 weeks as compared to 3 to 4 weeks in case of sandy clay loam to bring the redox potential to about –150mv or so required to produce methane.

Nature of soil (location of the paddy field) would ,therefore, control the period of inundation for the development of anaerobic behavior . Water management , known to be very effective for mitigation of methane emission (~50 %) with insignificant effect on yield with midseason drainage would also need consideration of nature of soil in the region. Intermittent flooding or multiple drainage may be desirable in certain cases . Major paddy production is from irrigated fields due to high yields and implementation of water management to mitigate methane emission seems quite feasible in irrigated paddy fields due to the associated advantages like economy on water, more effective utilization of fertilizer, reduced salinity of soil etc. The Other mitigation options viz. use of high yielding cultivars, inorganic fertilizers, slurry from biogas plants, lower soil temperature would also reduce methane emission from paddy fields but the implementation of these measures may require considerable financial support in addition to assurance to the farmers by the government at the district level (The district science centers propagate the advancement of science with its benefits to farmers in India)to take care of losses if any on account of implementation of their suggestion. Tendency of the farmers to continue growing the traditional cultivars is an important consideration before recommending new cultivar. Similar situation would arise in other recommendations . Some of these difficulties / bottle necks in the implementation of the options to mitigate methane emission from paddy fields could be discussed in the meeting.

Reduction in methane emission with appropriate water management in irrigated paddy fields may meet a major part of the required methane mitigation from anthropogenic sources and help to stabilize the methane concentration at present level.

1 INTRODUCTION

. Anthropogenic sources in general and paddy cultivation in particular are directly connected with the increase in population. To meet the demands of increasing population, rice production has been increasing and will continue to increase. This increase has been achieved partly by intensifying cropping (two or three crops per year) and partly by cultivating non-traditional land for paddy or by adopting better cultivars and agronomic practices. How the increase in rice production has affected the emission of methane requires an understanding of the various parameters responsible for the emission. Data collected by various authors over the years have led to widely different estimates .India has 28.55% of the Global paddy area under cultivation and includes the wide range of the soil, climate and water management conditions for paddy cultivation. Several scientists have pursued these studies over the years to collect more and more data to achieve more and more reliable estimate. The results obtained in India have shown lower methane emission than the projections by USEPA (Ahuja 1990) and others (Neue & Sass 1998) based on measurement made in Europe and USA. Several campaigns have been carried out in India for the measurement and estimation of methane emission from paddy fields in the last decade or so. These measurements cover most of the major rice growing regions and agroclimatic zones and have validated the initial methane estimates (Parashar et al. 1991) from Indian paddy fields. Measurements of methane concentrations over the last decade has shown a decreasing trend in the rate of increase of methane in the atmosphere and adoption of methane methane mitigation measures in the paddy cultivation may help in bringing the rate of increase to a rather low level. A look at the methane emission studies from paddy fields in India which cover almost all possible parameters which control the emissions have led to the understanding of the possible methods of mitigation of methane emission from paddy fields.

Apart from data generated during the 1991 methane campaign (Parashar et al., 1996), the additional sites of which the data have been included in the present estimates are from Kasindra (Ahmedabad) in Gujarat, Kuttanad in Kerala, and Maruteru in Andhra Pradesh (Parashar et al. 1997). Methane measurement data from stations continued even after the 1991 campaign have also been used as described by Parashar et al. 1997.

The total Indian harvested area available for rice cultivation including multiple cropping is 42.32 Mha. The rice cultivation ecosystems has been classified into two categories, lowland and upland. The upland area is 15% (6.35 Mha) of the total rice area and lowland area has been further categorized into rainfed (including deep water) and irrigated which are 32% (13.54 Mha) and 53% (22.43 Mha) respectively of the total harvested area. Further sub-classification of lowland into rainfed, irrigated and deep water areas have been done, according to the area statistics (Sundaraman 1997, Rice Almanac 1995)

Rainfed lowland including deep water is a substantial portion (32%) of the rice growing areas in India where often, erratic rainfall leads to drought conditions, and incessant rains create flood-prone conditions. Out of the 32% of total area under rainfed category, 16% has been assigned to flood prone which includes 6% (2.54 Mha) of deep-water regime ecosystem and 10% (4.23 Mha) as rainfed flood prone. The rest 16% (6.77 Mha) of the above rainfed lowland area has been categorized as drought prone. The irrigated fields are divided into continuously flooded and intermittently flooded which are 16% (6.77 Mha) and 37% of the total cultivation area respectively. The area under intermittent irrigation has been further sub divided into fields having single aeration and multiple aeration. Multiple aeration occurs due to high water percolation rates of sandy loam soils. These conditions are prevalent in the north and west regions of India. The rice harvested area under intermittent irrigation with single aeration and multiple aeration have been taken as 23% (9.7 Mha) and 14% (5.74 Mha) respectively of the total area (Parashar et al. 1997).

The irrigated fields are defined as the ones which are bunded and require irrigation for maintaining the water at shallow depths. These may either be continuously flooded with water level of 4 to 10 cm or become dry once or many times leading to single or multiple aeration of the paddy fields during the growing season. The irrigated paddy fields may not be shallow flooded with anaerobic soil during crop growth and a sizable part is close to the multiple drainage system with insignificant methane emission. Thus all the estimates of methane emission from different water regimes in India are summerised in Table 1 (Parashar et al. 1997).

Table 1. Seasonal integrated flux for all sub-categories under lowland rice cultivation and annual CH_4 release estimates

		Water regime		Harvested Area (Mha)	Seasonal integrated Flux E_{sif} (g/m^2)	Total emission (Tg/yr)
Upland	None			6.35	-	-
Lowland	Rainfed	Flood prone		4.23	19.0± 6.0	0.80± 0.25
		Drought prone		6.77	6.0± 1.5	0.41± 0.10
	Irrigated	Continuously flooded		6.77	25.1± 8.4	1.70± 0.57
		Intermittently flooded	Single aeration	9.73	6.0± 1.5	0.60± 0.15
			Multiple aeration	5.74	1.36± 0.57	0.08± 0.03
	Deep Water	Water depth >50 cm^2		2.54	19.0± 6.0	0.48± 0.15
Total						4.07± 1.25

Mha-Million hectares, Tg = 10^{12} g

2 MITIGATION OF METHANE EMISSION

Although methane emission measurement studies have shown that the emission is dependent on various parameters like cultivar, organic amendment, fertilizer treatment, nature of soil, soil temperature, yet the water management is the key parameter in controlling the methane emission (Neue & Sass 1998, Parashar et al.1991, Barua et al. 1997, Sass et al. 1992, Neue & Roger 1993). Difference in cultivars can lead to an order of magnitude difference in methane emission (Parashar et al. 1996). Table 2 shows the methane emission associated with different cultivars commonly used in Andhra Pradesh, a major rice growing region of India. It is seen that Annada variety has high yield and comparatively low methane emission and thus its cultivation would be one of the most plausible measures to mitigate methane emission from paddy fields in that region. Organic amendments and different fertilizer treatments (Table 4) are known to affect methane emission on a wide scale (Abrol & Gadgil 1999). Nature of soil (Abrol & Gadgil 1999) and soil temperature (Parashar et al. 1993) may also change the rate of emission significantly but the redox potential controlling the formation of methane strictly depends upon conditions like continuous inundation period during the crop growth. The efforts to increase the production of rice have led to the increase in the area by the use of soil which is not traditional paddy soil. This has resulted in the use of highly permeable coarse textured loam and loamy sand soils subject to availability of irrigation. As such some fields under use for crops like cotton etc. have been deploid for paddy cultivation. Increasing cultivation in the Rabi season with lower soil temperature could be another significant measure in the mitigation of methane emission.

Table 2. Methane emission from different cultivars

Name of Paddy variety	Age of plants from date of transplant (days and stage)	Average height of plants (cm)	No. of panicles inside the collector	Yield ($kgha^{-1}$)	CH_4 efflux ($mgm^{-2}hr^{-1}$)
IET-1444 (Rassi)	75 Just before flowering	61	156	2841	2.54 to 3.6
IET-7614	75 Flowering	56	180	2777	49.0
IET-7564	75 Just ripening	91	209	2236	16.6 to 20.3
IET-7991	75 Ripening	61	165	2120	11.7 to 20.5
IET-7633	75 Just before flowering	51	156	2777	1.3 to 1.48
IR-66	75 Just before flowering	46	168	2983	10.1
Annada	75 Flowering	43	156	4996	6.1
Tella hamsa	75 Just before flowering	51	168		3.4 to 3.9

Table 3. Methane efflux study for Rassi (IET-1444) paddy variety with different fertilizer treatment.

Plot no.	Fertilizer applied (kg/ha)	Mode of application	CH_4 efflux (mg $m^{-2}hr^{-1}$)
1.	NPK (150,90,90)	Urea, DAP*, MOP**	3.2 to 4.0
2.	NPK-Zn (150, 90, 90, 50)	Urea, DAP, MOP, $ZnSO_4$	15.5 to 19.3
3.	NPK-Zn (150, 90, 90, 50) with sulphur	Urea, SSP***, MOP, $ZnSO_4$	1.6 to 2.1
4.	Control (no fertilizer)	--	6.6 to 8.1
5.	Green leaf manure	Equivalent to normal nitrogen dose	80.0

*DAP = Diammonium phosphate
**MOP = Muriate of Potash
***SSP = Single super phosphate [$CaSO_4$, $Ca_3(PO_4)_2$]

Research work carried out during the past fifty years or so (Parihar and Sandhu 1987) to determine the judicious irrigation schedule for different agroclimatic regions of the country has shown that continuous submergence is not essential for increasing the yield/production of rice. Excess of irrigation amounting to misuse of water not only leads to its wastage but also reduces the efficiency of applied fertilizer and other inputs in addition to salinization (Abrol & Gadgil 1999). It is further, seen from these studies that the rice yield is not affected with the disappearance of water on the surface of the soil for four to five days duration where as there is considerable saving on irrigation water (Table 4). Sass, 1995 has shown a reduction by 88% of methane emission with the multiple drainage of the paddy field. Simultaneous measurements of CH_4 and N_2O have been carried out to study the net effect of midseason drainage on total global warming potential of green house gases emitted from paddy fields. Application of nitrogen after the midseason drainage is very effective in reducing N_2O emissions due to aeration in addition to the reducing CH_4 emission (Liping & Erda 2001).

Table 4. Effect of various irrigation practices on yield and irrigation water applied

Treatment	Paddy grain yield (kg/ha)					Irrigation water applied (cm)				
	1974	1975	1976	1977	Mean	1974	1975	1976	1977	Mean
Continuous submergence (farmer's practice)	5830	4543	6670	5018	5515	204	195	170	192	190
1-day drainage	5746	4570	6259	5198	5443	151	138	130	160	145
2-day drainage	-	4903	6522	5168	5531	-	117	121	136	125
3-day drainage	4962	4345	6303	4852	5116	114	92	107	128	113
5-day	4670	4660	6731	4749	5203	96	94	81	112	96

3 THE ROLE OF CLEAN DEVELOPMENT MECHANISM

The role of agriculture sector in climate change emerged strongly in the 1997 Kyoto Protocol to United Nations Framework Convention on Climate Change (UNFCCC). That protocol places special emphasis on the promotion of sustainable forms of agriculture, citing land-use changes, enteric fermentation, manure management, rice cultivation, agricultural soils and biomass burning as sources of greenhouse gases that must be taken into consideration by countries in their reports to the Conference of the UNFCCC Parties.

The "Kyoto Mechanisms" through clean development mechanism (CDM) allow assistance to developing countries in reducing GHG emissions and achieving sustainable development. It, in turn, helps developed parties in achieving compliance with their emission limitations and reduction commitments. The CDM will allow Annex-I parties and Non-annex-I parties to jointly implement projects, which will result in certified emission reductions (CER) to be awarded to Annex-I parties. This mechanism complements the tradable permit approach between Annex-I parties. While details of the implementation of CDM are being debated, its potential as a sustainable development mechanism has to be carefully assessed. Although, no agreement has been reached on the actual mechanisms for getting carbon credits, it is likely that countries will earn carbon credits through more rational fertilizer use, efficient water harvesting, conservation techniques in agricultural practices and better soil protection.. From the developing countries perspective, it is believed that the modifying rice cultivation practices have a low probability of real, measurable and certifiable CDM option. However, this option will assist in sustainable development, and the potential for significant mitigation varies from medium to high.

4 BARRIERS TO MITIGATION

The main obstacles to the accelerated implementation of mitigation options in the agriculture sector are uncertainties regarding costs and benefits, and concern regarding the impact on agricultural yields. Food security is the primary concern of Indian agriculture. The greenhouse gas mitigation options become economically attractive to farmers only if they result in demonstratable productivity gains. In the absence of a financial and institutional support system, may be through district science centers ,farmers will be unwilling to bear the risks of investing in new practices.

5 CONCLUSIONS

The present study indicates that, for reducing methane emission from rice cultivation, the following options are available:

(i) Low-methane rice cultivars wherever study for methane emission potential for regional cultivars is available

(ii) Soil aeration in conjunction with water management (terrace structure would require funding support)

(iii) Use of inorganic fertilizers with biogas slurry to maintain the soil texture.

These options could be implemented if the risk to the farmers is covered through a suitable mechanism like insurance or through participation of Annex-1 countries through CDM. The mitigation options of CH_4 from rice cultivation are a win-win situation, though emissions from rice cultivation are due to inefficient and, sometimes, unsustainable farming, leading to losses to farmers. Therefore, there is room for significant reduction of CH_4 in all the options considered so far. The Kyoto Protocol through CDM allow assistanceto developing countries in reducing GHG emissions and would helpdeveloped parties in achieving compliance with their emission limitations and reduction commitments.Mitigation in this sector will allow sustainable development to thrive.

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