Climate Change Research: Evaluation and Policy Implications
S. Zwerver, R.S.A.R. van Rompaey, M.T.J. Kok and M.M. Berk, (Eds.)

Soil parameters controlling methane emission from rice paddies.

H.A.C. Denier van der Gon and N. van Breemen

Department of Soil Science and Geology, Agricultural University Wageningen, P.O. Box 37, 6700 AA Wageningen, The Netherlands

Abstract

The influence of soil parameters on methane emissions from rice paddies is studied in a collaborative project of Agricultural University Wageningen and the International Rice Research Institute (IRRI). Methane fluxes from wetland rice fields in the Philippines were monitored with a closed chamber technique during two wet seasons (1991 and 1992) and one dry season (1992). Gypsum addition and salinity were found to reduce CH_4 emissions whereas green manuring strongly enhanced the CH_4 fluxes from rice fields. Laboratory experiments with planted pots showed that plant-mediated CH_4 transport is diffusion controlled and that rhizospheric CH_4 oxidation may depend on the plant growth stage.

1. INTRODUCTION

About 20% of the global anthropogenic methane (CH_4) production comes from wetland rice [IPCC, 1992]. However, the uncertainty in the contribution of rice agriculture to the global methane budget is large. To better estimate the total CH_4 source strength of rice and to develop mitigation strategies, factors controlling CH_4 emission from rice must be better understood. In collaboration with the International Rice Research Institute (IRRI) in the Philippines, parameters that influence CH_4 emission from rice fields were screened. Methane fluxes from wetland rice fields with different treatments are monitored with a closed chamber technique as developed by Schütz *et al.* [1989]. This paper gives an overview of the project activities and examples of results.

2. OVERVIEW OF SUBJECTS *(Numbers following a subject refer to Table 1)*

- Effects of sulfate on CH_4 emissions from rice fields [4, 5].
- The impact of salinity on CH_4 emissions from rice fields [6].
- Mechanism of rice plant-mediated CH_4 transport [2].
- Influence of organic amendments on CH_4 emissions from rice fields [1, 7].
- Importance of CH_4 oxidation in the rice rhizosphere [8].
- Influence of soil types on CH_4 emissions [4, 6, 9]
- Assessment of total CH_4 emission from a rice crop cycle [1, 9]

Table 1 Project Publications

[1]	Denier van der Gon, HAC, H-U Neue, RS Lantin, R Wassman, MCR Alberto, JB Aduna and MJP Tan, Controlling factors of methane emissions from rice fields, In: World Inventory of Soil Emission Potentials, Proceedings Internat. Workshop, ISRIC, Wageningen, 1992.
[2]	Denier van der Gon, HAC and N Vanbreemen, Diffusion-controlled transport of methane from soil to atmosphere as mediated by rice plants, *Biogeochemistry 21,* pp. 177-190, 1993.
[3]	Denier van der Gon, HAC, Methane emission from rice agriculture, *Change 15*, pp. 12-14, 1993.
[4]	Denier van der Gon HAC and H-U Neue, Impact of gypsum application on the methane emission from a wetland rice field. *Global Biogeochem. Cycles 8,* pp. 127-134, 1994.
[5]	Denier van der Gon HAC and H-U Neue, CH_4 emission from a wetland rice field - Impact of gypsum application. Climate Change and Rice 14-18 March 1994, Los banos, Philippines. *International Rice Research Notes* (in press), 1994.
[6]	Denier van der Gon HAC and H-U Neue, Methane emission from a wetland rice field as affected by salinity, *Plant and Soil* (in press), 1994.
[7]	Denier van der Gon HAC and H-U Neue, Influence of organic matter incorporation on the methane emission from a wetland rice field, submitted to *Global Biogeochem. Cycles*.
[8]	Denier van der Gon HAC and H-U Neue, Oxidation of methane in the rhizosphere of rice plants (in prep.)
[9]	Denier van der Gon HAC, H-U Neue and N Vanbreemen, Methane emission from wetland rice fields as effected by soil types (in prep.)

3. RESULTS

The project yielded both mechanistic knowledge of the rice-soil-water ecosystem and data to improve CH_4 source strength estimates of rice agriculture.

3.1 Laboratory experiments

A set-up was developed to study plant-mediated CH_4 transport. It was shown, by using binary diffusion coefficients of CH_4 in other gases, that CH_4 transport through rice plants is diffusion-controlled (Table 1; [2]). Furthermore, CH_4 oxidation in the rice rhizosphere was quantified with the use of a specific inhibitor for CH_4 oxidation. The results indicate that the rice growth stage is an important factor determining the rhizospheric CH_4 oxidation (Table 1; [8]).

Rates of CH_4 emissions from intact soil cores were measured during oxic and anoxic incubations using a methodology developed by King *et al.* [1990] (Table 1; [6]). The anoxic CH_4 fluxes from soil cores of a salt-amended plot were 3-4 times lower than from cores of the control plot, whereas the oxic CH_4 fluxes were about equal. The CH_4 production in the salt-amended field was strongly reduced compared to the control field but CH_4 oxidation in the salt-amended plot was even more inhibited than CH_4 production. The net result was about equal oxic CH_4 fluxes from both salt-amended plots and non-amended plots.

3.2 Field experiments

Gypsum is a common amendment on alkaline soils. Adding 6.66 $tons.ha^{-1}$ of gypsum ($CaSO_4$) reduced CH_4 emission by 55-70%, most likely by inhibition of methanogenesis by sulfate-reducing bacteria [Fig. 1]. Amounts of SO_4^{2-} in the soil solution of gypsum-amended plots were sufficient for sulfate-reducing bacteria to outcompete methanogens. CH_4 emissions are much lower from rice fields on high-sulfate containing soils or gypsum-amended soils than from low-sulfate soils. The presence of non-sulfate salt also depressed CH_4 emission, but much less so than gypsum did. The depression of CH_4 emission by (non-sulfate) salinity is also due to inhibition of methanogenesis. However, in saline rice fields CH_4 oxidation was inhibited even more than methanogenesis. Therefore, the reduction in CH_4 emission is not proportional to the reduction in CH_4 production (Table 1; [6]).

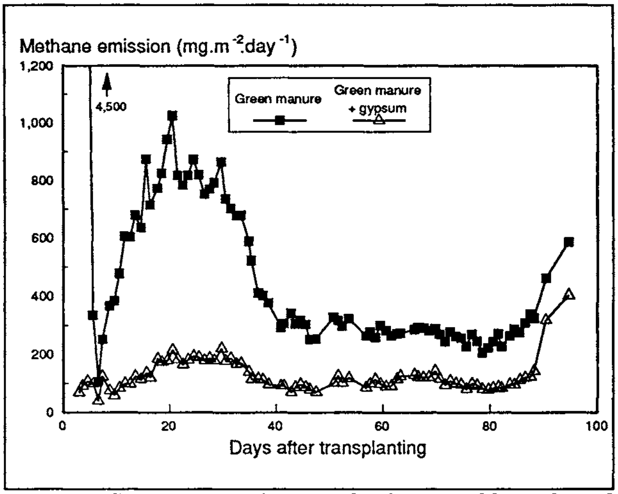

Figure 1. CH_4 emission from wetland rice fields with and without gypsum addition [Denier van der Gon and Neue, 1994].

Fig. 2 illustrates that (1) CH_4 emission is strongly enhanced by organic amendments, (2) organic amendments cause a large release of CH_4 early in the season and, (3) after harvest, when the fields are drained, considerable amounts of soil-entrapped CH_4 are released. In previous studies this flush of CH_4 was not included, which causes an underestimation of total seasonal emission.

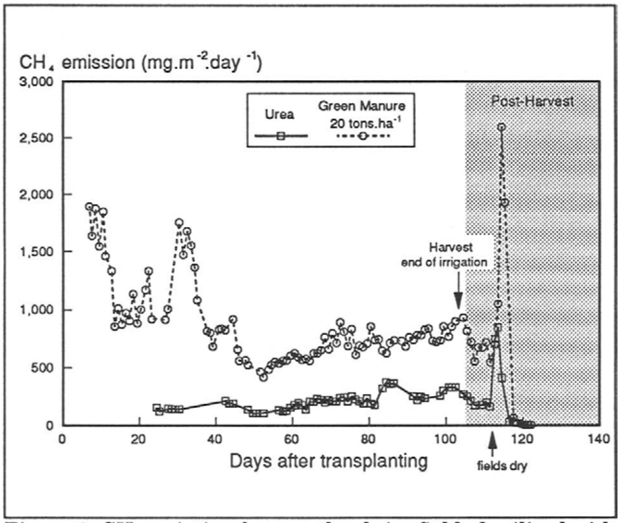

Figure 2. CH_4 emission from wetland rice fields fertilized with urea or green manure.

4. GENERAL DISCUSSION

The laboratory experiments stress the importance of both CH_4 production and CH_4 oxidation when estimating CH_4 emission. They show that the ratio between CH_4 production and CH_4 oxidation is not fixed but may depend on environmental conditions. Furthermore, fluctuations in the methanotrophic activity in the rice rhizosphere may contribute greatly to the observed seasonal fluctuation in CH_4 emissions from rice fields. When looking for mitigation options to reduce CH_4 emission from rice fields, both CH_4 production and CH_4 oxidation have to be taken into account.

Global estimates of methane emission from rice agriculture do not yet take differences in soil types into account. Bachelet and Neue [1993] found that emission estimates were about 25 % smaller if soil differences were considered. So, including soil characteristics could significantly alter the global estimate. Information on CH_4 emission from rice fields on different soil types is scarce. Our results indicate that "soil type" correction factors can be used to estimate CH_4 emissions from flooded rice fields. For example, we showed that CH_4 emissions from wetland rice fields on saline, low-sulfate soils are lower than CH_4 emissions from otherwise comparable non-saline rice fields. On soils naturally high in sulfate or soils amended with large amounts of sulfate-containing substances methane emissions are reduced even more. Fertilization of rice fields with $(NH_4)_2SO_4$ will not depress CH_4 emissions much because the amounts of sulfate added are relatively low.

During pre-flooding and post-harvest considerable amounts of CH_4 can be released from flooded rice fields. In previous monitoring studies these periods were not included, which may cause an underestimation of total seasonal emission by 10-15%. The project improved our knowledge concerning CH_4 emission from rice and revealed errors in the procedures to estimate CH_4 emissions that both justify a reduction and an increase of the estimated CH_4 source strength from rice fields.

5. ACKNOWLEDGMENTS

Without the support and active involvement of H.-U. Neue, R. Wassmann and R.S. Lantin this project would not have been possible. Thanks are due to J.B. Aduna, M.C.R. Alberto and R. Eugenio for help with the experiments. The project was funded by the Dutch National Research Programme on Climate Change and Global Air pollution (*NOP-project* X103-1-B-90-9) and collaborated with the IRRI-EPA project on CH_4 emissions from wetland rice fields.

6. REFERENCES

Bachelet, D. and H.U. Neue, *Chemosphere, 26*, pp. 219-238, 1993.
Denier van der Gon H.A.C. and H.U. Neue, *Global Biogeochem. Cycles 8*, pp. 127-134, 1994.
IPCC Climate Change, Cambridge University Press, Cambridge, 200 p., 1992.
King G.M., P. Roslev and H. Skovgaard, *Appl. Environ. Microbiol. 56*, pp. 2902-2911, 1990.
Schütz, H., A. Holzapfel-Pschorn, R. Conrad, H. Rennenberg and W. Seiler, *J. Geophys. Res., 94*, pp. 16405-16416, 1989.