Monazite–Nd is considered as a uniphase multicomponent solid solution containing U, Th, Y and Zr, with Nd-rich LREE dominance with coupled substitutions of U and Th for Ce. Metamorphic origin was assigned to neodymium-rich monazite from the Eastern Ghats. Detailed geochemical and mineralogical studies of these rocks are underway.

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Global methane emission from rice paddies: Excellent methodology but poor extrapolation

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Methane emission from rice paddies would require a source of carbon as a substrate and a reducing soil environment. The maximum methane production from glucose, presuming it as a source of carbon, was estimated on the basis of known micro-biochemical reactions. The total biomass of rice paddies from the various regions was estimated using grain yield and biomass partition coefficient (Harvest Index). The relation of biomass and methane emission was used as reported earlier for estimating methane emission from rice paddies. The maximum global methane emission from rice paddies was estimated 7.08×10^{12} g as against 110×10^{12} g and 60×10^{12} g reported by IPCC in 1990 and 1994, respectively. The need for identifying new sources of methane is emphasized, and the limitations of experimental methodology highlighted.

METHANE has been identified as an important greenhouse gas which can contribute to global warming. It has been estimated that methane accounted for 15% towards the global warming effect from 1800 to 1990. Therefore, efforts have been made to identify sources and sinks of methane to account for its annual increase in the atmosphere.

The estimates of methane release from rice paddies are based essentially on the studies conducted at Davis Campus, University of California, USA, and Vercelli in Italy. These authors have developed excellent techniques of sample collection and measurements but their biological and agricultural aspects have not been well attended to. The extrapolations lack realism, leading to excessive overestimation of methane release from rice paddies. This has possibly diverted attention from the as-yet unidentified source of methane. This commentary examines the limitations in estimates of methane release from rice paddies. However, before a new basis of estimates is presented, the mechanism of methane release from rice paddies is described, followed by a section on extrapolation.

Mechanism of methane release from rice paddies

1. The rice plant does not produce any methane by itself. It only serves as a mechanism of transport of methane dissolved in rhizosphere[1].
2. Methane is produced in a reduced environment by one of the three groups of methanogenic bacteria. The mechanism involves conversion of various organic acids such as acetic acid produced from organic carbon to methane as follows:

$$CH_3COOH \rightarrow CH_4 + CO_2 \qquad (1)$$

$$CO_2 + 4H_2A \rightarrow CH_4 + 2H_2O + 4A \qquad (2)$$

   Therefore, the occurrence of organic carbon is an essential requirement for generating methane.
3. Besides organic carbon in the soil, the rice plant could leach some amount of the organic carbon in the rhizosphere and in the soil. The more the organic carbon content of the soil, the higher will be the potential for methane production.
4. The methanogenic bacteria are active in the pH range of 6 5–8.0. In acidic environment they do not function. In addition, the saline water and hence saline soil impairs methane formation remarkably[2].

Several authors have made the following observations which they found difficult to explain[3-5, 9, 10].

I. The rice plots heavily fertilized (200 kg N ha^{-1}) had more methane emission than non-fertilized plots.
II. There was a diurnal variation in methane emission which increased in the late afternoon reaching a peak between 1800 and 2100 hours but becoming very small by early morning. This observation has to be noted for California, USA, Italy or Germany, where the crop is grown in summer, when the day length is 16 h or more, providing a prolonged photosynthesis duration.

III. There is considerable variation in methane release during the vegetative period (growth period), and the maximum emission is reached during or near the flowering period. After flowering, the emission of methane declines sharply. The peak emission value remains for a period of 10–15 days in the crop duration of 90–100 days. This period accounts for 90% of the total methane release during the whole crop season[3].

IV. Soils having a higher content of organic matter produce more methane and the production is temperature-dependent.

The above observations can be explained as follows:

(i) The increase in methane emission by rice plants in response to heavy fertilization would be a function of increased biomass production. Since methane is produced in rhizosphere from organic carbon released by the rice plant, a higher above-ground biomass would potentially release more organic carbon. Accordingly, a heavily fertilized crop, particularly having a higher organic carbon in soil, would release more methane. A poorly fertilized crop produces a poor above-ground biomass and a poor grain yield, would release lesser amounts of organic carbon in soil, causing lower methane emissions. Therefore, grain yield could form the basis of methane emission potential

(ii) Diurnal variation in methane is expected if methane production is dependent on the release of organic carbon from the current photoassimilates. Therefore, depending upon the day length of 12–18 h, this period would differ at different locations as observed in several studies[3, 6]. Thus, this observation represents the expression of photoassimilation (photosynthesis) capacity.

(iii) The variation in methane release during the vegetative period on an area basis is expected because the biomass increases gradually, reaching the maximum weight by flowering. All published data on methane emission are comparable to growth rate curves. Since the rate of photosynthesis declines after the commencement of grain development, the supply of current assimilates for methane production would decrease. Hence, it is correct to observe that methane emission declines after flowering. The observation that a 2-week peak period accounts for 90% of the total methane emission during the entire growth period would appear physiologically a correct result.

(iv) Dependence of methane emission on organic carbon of the soil and the soil temperature would be expected on the basis of the functioning of methanogenic bacteria.

Thus, the above results are strongly suggestive of methane emission being dependent on the above-ground biomass. The latter could be estimated from the grain yield for different regions of the world. In addition, some of the important features of experimentation, particularly the agricultural aspects, can be summarized as follows:

High organic matter of the soil (2.5%), 7.0 or 7.8 pH, which is optimum for methane production, 200 kg N ha^{-1} or more to a crop of unspecified growth with a common productivity level of 7000 kg ha^{-1} rice paddy grain. Assuming a harvest index of 40%, the biomass productivity would be 17,500 kg ha^{-1}; the photosynthetically active period was 16 h or more per day.

The above features of agricultural aspects of experimentation would lead to maximum production and release of methane, which are not found in rice-growing areas of Asia. Therefore, it is important to describe the conditions of rice-growing areas.

Characteristics of rice-growing areas

The rice-cultivated area and production in Asia is 89.5% and 91.6% of the world area and production, respectively. Almost all this area is monsoonic, 15% of the area being upland. In the rainfed area the standing water creates a reducing environment. The reducing environment, because of standing water, does not exceed for 2–3 weeks of the growing period in rainfed areas. The soil organic carbon is low (0.5% or less) and the pH is often in the acidic range (4.5–6.5). The coastal areas are often served by saline water. The average fertilizer nitrogen application ranges from nil to 60 kg N ha^{-1}. Thus, the biomass and yield achieved are much lower than that obtained in California and Italian experiments.

Biomass–methane relationship

Recently, the relationship between biomass and methane release has been established[10]. In fact, the effects of diurnal variation and those of variation in growth duration are ultimately reflected in the biomass production capacity. This will also be true for the application of fertilizer, which is responsible for increasing the biomass and

Table 1. Methane emission from rice paddies from India

Region	Rice paddy area ($\times 10^{10}$ m^2)	Rice paddy area upland ($\times 10^{10}$ m^2)	Yield (kg ha^{-1})	Estimated biomass (g m^2)	Annual total methane emission ($\times 10^{11}$ g)
Biomass yield					
East	18.4	2.58	1181	354	2.93
North	8.4	0.84	2283	570	2.05
South	7.8	0.78	2265	543	1.90
West	7.3	0.51	2688	420	1.38
Total	**41.9**	**4.71**	–	–	**8.26**

Table 2. Methane emission from rice paddies from Asia

Country	Rice area ($\times 10^{10}$ m^2)	Methane release area ($\times 10^{10}$ m^2)	Yield of paddy (kg ha^{-1})	Estimated biomass ($\times 10^{11}$ g m^2)	Annual total methane release ($\times 10^{11}$ g)
India	41.5	35.0	2590	777	12.2
China	32.4	32.4	5537	1329	19.37
Bangladesh	10.6	9.6	2502	751	3.1
Indonesia	10.3	9.5	4111	987	4.2
Thailand	9.9	8.9	2077	623	2.5
Vietnam	5.8	5.3	3089	927	2.2
Burma	4.8	4.0	2853	856	1.5
Philippines	3.5	3.1	2705	812	1.1
Pakistan	2.1	2.1	2269	681	0.64
Korea	2.1	2.1	6970	1672	1.58
Japan	2.1	2.1	6188	1480	1.39
Malaysia	1.22	1.1	2668	800	0.4
Cambodia	1.8	1.0	1167	300	0.2
Nepal	1.1	1.05	2638	791	0.36
Sri Lanka	0.73	0.67	2670	801	0.24
Laos	0.52	0.21	2369	710	0.07
Others	1.01	1.0	2072	623	0.28
Total	**131.47**	–	–	–	**51.32** or 5.13 $\times 10^{12}$

Table 3. Methane emission from rice paddies from Asia

Region	Area ($\times 10^{10}$ m^2)	Yield (kg ha^{-1})	Biomass for a season (g m^2)	Total annual methane emission ($\times 10^{11}$ g^2)
Africa	5.5	1899	570	1.41
NC America	1.8	5100	1530	1.24
South America	6.9	2507	752	2.33
Asia	131.0	3539	1000	58.95
Europe	0.42	5138	1500	2.83
USSR	0.65	3861	1100	3.22
Oceania	0.11	6917	1729	0.86
Total	**146.38**	–	–	**70.84** or 7.08 $\times 10^{12}$

yield. Therefore, biomass and methane relationship would provide a better method of estimating emissions from around the world.

Biomass–methane relationship methodology

The following methodology for estimating methane emission from India, Asia and the world has been used.

Step 1. The rice paddy grain yield is multiplied by a factor of 3 in low-yield regions and by 2.5 in high-yield regions to obtain the total biomass.

Step 2. Biomass per hectare is converted to biomass/m^2 and is used for determining methane emission per day following Fisher *et al.*[7].

Step 3. According to Holzapfel-Pschorn and Seiler[3], the peak methane released for a 2-week period accounted for 90% of the CH_4 emitted during the entire period of growth. Since the calculated biomass in Step 2 is the maximum potential, it was multiplied by 30 days (instead of 2 weeks) to obtain total emission during the whole growth period.

Step 4. The methane emission obtained from Step 3 was used for calculating methane release from the rice-growing regions.

Step 5. Deductions were done only for upland rice paddy, where methane does not occur because of the oxidizing environment. No deductions have been made for the soil pH reaction.

Thus, the total flux is calculated as follows:

Total methane flux = *Methane emission area* × *duration* of emission (30 days peak emission) × mg methane kg^{-1} biomass × biomass.

For example, the methane emission for eastern India will be

Flux = 18.4 × 10^{10} m^2 (area) × 30 days × 150 methane mg kg^{-1} biomass × 0.354 kg m^2 (estimated biomass m^2)

$$= 18.4 \times 10^{10} \times 4.5 \text{ g} \times 0.354$$

$$= 29.3 \times 10^{10} \text{ g}.$$

The results of these estimates are given in Tables 1–3 for India, Asia and the world, respectively. On the basis of these calculations based on biomass, the potential estimate of methane release from India, Asia and the world is 8.26 × 10^{11} g, 5.13 × 10^{12} g and 7.08 × 10^{12} g, respectively. In Table 1 the emission from India is 8.26×10^{11} g and in Table 2 it is 1.22×10^{12} g. Such a discrepancy arises because of the weightage of average for the whole rice-growing area as against estimation for each region separately. The above calculations have the following important features which make them overestimates rather than underestimates:

1. During the entire period of growth the maximum methane emission for a period of 10–15 days accounts for 90% of the total emission. This 10–15 days period is the period of maximum biomass. The present calculations have considered 30 days emissions with the maximum biomass obtained from grain yield values. This is for a crop of 90 days duration. Thus, these estimates are in fact overestimates.
2. The average yield of a country is not a weighted average based on productivity of the area. For example, eastern India has an average yield of 1171 kg ha^{-1} for a rice area of 18.4 million hectare. North India has an average yield of 2283 kg ha^{-1} yield from an area of 8.4 million hectare. The average of these yield averages is 1722 kg ha^{-1} for the two regions. The emission from 18.3 million hectare will increase by 50% but would be reduced by only 20% for an area of 8.4 million hectare. Thus, the estimates based on larger area are likely to be higher.

Theoretical consideration

Methane production in a reducing environment is accomplished by methanogenic bacteria using a source of carbon. When the rice plant is attributed as the source of methane, we are assuming that all the required carbon source (carbohydrate) would have been supplied by the plant to the rhizosphere. Assuming that this supply is as glucose, the following reactions would occur:

$$C_6H_{12}O_6 \rightarrow 2CH_3COOH + 2CO_2 \tag{1}$$

$$2CH_3COOH \rightarrow 2CH_4 + 2CO_2 \tag{2}$$

$$C_6H_{12}O_6 + 2O_2 \rightarrow 2CH_4 + 4CO_2 + H_2O. \tag{3}$$

Thus, for two molecules of methane to be produced one molecule of glucose would be needed. This means that for 32 g methane to be produced, 180 g glucose would be required. When we consider the reports of 50 g m^2 methane release, it means that 281 g m^2 glucose would have been provided. This amount of glucose would be equal to 225 g m^2 dry matter or 2250 kg ha^{-1} (300 g m^2–400 g m^2) dry matter. In all those regions where biomass production is only 3000–4000 kg ha^{-1} such a conclusion would be theoretically impractical. Normally, in most studies only 10–15% of the total assimilate is assigned to root growth, which would include leaching from roots also. Thus, the estimates of 20 g m^2 methane release or above would be impractical to achieve theoretically.

Conclusions

This study brings out estimates of methane emission based on biomass as an important means of assessing global methane emissions. On this basis it is estimated that the annual global methane emission from rice paddies would be 7.08×10^{12} g as against 110×10^{12} g stated in IPCC report[8]. Therefore, there is a need to make more realistic measurements of methane in situations where rice grows. Extrapolations of results from California and Europe have serious limitations from agricultural viewpoint.

This study emphasizes that it is likely that we are missing an important source of methane for which more efforts are needed.

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A low-cost strategy for *in vitro* propagation of banana

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A simple low-cost method for micropropagation of banana has been standardized. To reduce the cost of production of tissue-cultured bananas, multiplication of shoots was carried out on a medium prepared with tap water and commercial-grade sugar as the carbon source. Shoot tips grown on such a medium showed