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Remote Sensing based Methane Emission from Rice Fields in Tiruchirapalli District

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Rice cultivation has been recognized as one of the major anthropogenic source for CH_4 emissions. Methane emission from rice fields is a microbial mediated anaerobic activity, mainly favoured by the flooded condition. SAR-based operational mapping of rice crop across a diverse range of environments is possible with the increasing availability of multi-temporal SAR satellite data. Precise estimation of methane emission from rice fields at regional scale depends on accurate assessment of rice area and the corresponding time of flooding in those fields with IPCC emission factor. Start of Season (SoS) map was derived from satellite data showing rice emergence dates in Tiruchirapalli district recording 87 to 121 days of flooding during rice growth period. The rate of methane emission based on IPCC factor ranged from 37.4 to 45.74 kg/ha for a period of 87 to 121 days of flooding. The total methane emission from Tiruchirapalli district was 1.57Gg during Samba season 2015-16.

Key words: Rice, Methane emission, SAR, SoS, IPCC emission factor

Rice cultivation has been recognized as one of the major anthropogenic source for CH_4 emissions. Methane emission from rice fields is a microbial mediated anaerobic activity, mainly favoured by the flooded condition. Methane emissions from paddy fields, which depend on many factors, arises due to the anaerobic decomposition of organic materials in the flooded soil and escapes to the atmosphere mainly by diffusive transport through the paddy plants during the growing season (Nouchi *et al*., 1990). Flooded rice fields are the third largest source of agricultural emissions and contribute about 10-30 per cent of the global methane arising from anaerobic decomposition of organic matter (Wahlen *et al*, 1989).

Remote sensing, with the recent and planned launches of Synthetic Aperture Radar (SAR) sensors coupled with state-of-the-art automated processing, can provide sustainable solutions to this challenge to map and monitor one of the world's most important crops. A rule-based classification approach and parameter selection approach is available for rice mapping in which the rules and parameters are derived from agronomic knowledge of the rice crop and its management. SAR-based operational mapping of rice crop across a diverse range of environments is possible with the increasing availability of multi-temporal SAR satellite data.

The Intergovernmental Panel on Climate Change (IPCC) regularly publishes Guidelines for National Greenhouse Gas Inventories to provide countries with a guideline for determining their emission inventories of greenhouse gases [Intergovernmental Panel on Climate Change (IPCC), 1997, 2000, 2007a]. For CH_4 emission from rice fields, the 1996 IPCC guidelines outline one method that uses annual harvested areas and area-based seasonally integrated emission factors. Therefore, we used the Tier 1 method described in 2006 IPCC guidelines to estimate the methane emissions from rice fields. Tier 1 method which provide a default emission factor for specific sources, conditions, country and regions. Precise estimation of methane emission from rice fields at regional scale depends on accurate assessment of rice area and the corresponding time of flooding in those fields with IPCC Emission factor.

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Material and Methods

The Tiruchirappalli district of Tamil Nadu extends over an area of 4,40,383 hectares. Geographically it lies between 78° 10' to 79° 5' East longitudes and 10°15' to 11°2' North latitudes with an altitude of 90 m.

The Sentinel-1 mission is the European Radar Observatory for the Copernicus joint initiative of the European Commission (EC) and the European Space Agency (ESA). Synthetic Aperture Radar (SAR) has the advantage of operating at wavelengths not impeded by cloud cover or a lack of illumination and can acquire data over a site during day or night time under all weather conditions. Sentinel-1A, with its C-SAR instrument, can offer reliable, repeated wide area monitoring.

First, the SAR time-series data underwent a series of basic processing steps to generate terrain-geocoded $\sigma°$ values suitable for analysis. This multi-temporal stack was analyzed using a rule-based classifier to detect rice areas. The rules for the classifier were based on a small number of parameters that must be selected by the operator or user. Temporal feature descriptors were derived from temporal signatures in the monitored fields and used to guide the user in setting these parameters for each site. It is clear that there must always be a degree of user expertise in the setting of the parameters, relying on expert local knowledge or other sources of information to further guide the parameter values. Finally, the accuracy of the rice area maps was assessed against field data.

IPCC regularly publishes guidelines for national GHGs inventories and CH_4 from rice paddies has been an important component of these guidelines. While there have been many estimates of Global CH_4 emissions from rice fields none of them have been obtained using IPCC guidelines. Therefore, we used the Tier 1 method described in 2006 IPCC guidelines to estimate the methane emissions from rice fields.

The current approach demonstrates the use of secondary data sources available on the methane emission scaling factors, coupled with the information derived on rice cultural types and crop calendar. Methane emission from each type of rice field was firstly calculated by multiplying the emission factor by the corresponding cultivation area and length of cropping period. The values were then extrapolated over each country with respect to the rice area and crop duration for under each cultural type. The rice cultural type wise methane emission value for South Asia was derived by summation of individual emission values for the respective cultural type within each country.

Tier 1 method which provide a default emission factor for specific sources, conditions, country and regions. For rice cultivation in Tamil Nadu they provided the default emission factor is 11g/m^2. Using ArcGis 10.1 generated the model by giving the inputs emission factor, cultivation periods as Start of the Season (SoS), End of the Season (EOS) maps and Harvested area as Rice area map to each and every pixels of rice area maps in different temporal resolution for the purpose of getting minimum and maximum emissions at different duration from Start of the season(SoS).

By using this emission factor in Tier 1 method rice field under specific conditions:

$$CH_4 \text{ rice} = \sum EF.\ T.\ A.\ 10^{-6} \quad (1)$$

Where CH_4 rice = annual CH_4 emission from rice cultivation in a region or country Gg CH_4 a^{-1}

EF = Daily emission factor

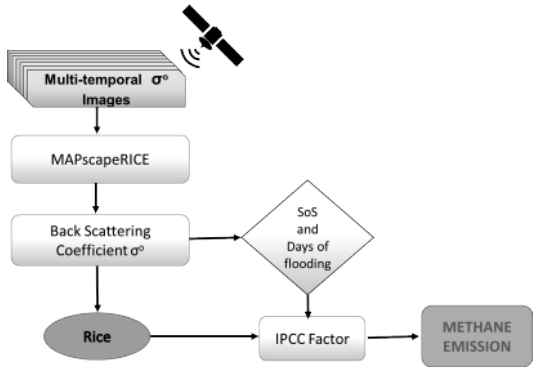
T = Cultivation period

A = Annual Harvested area of rice

Results and Discussion

Rice area map

The Rice area map was derived from multi-temporal C-band SAR imagery from Sentinel 1A for all the 14 blocks of Tiruchirapalli district. Among the 14 blocks of Tiruchirapalli district, Tiruverumbur recorded the maximum rice area of 9321 ha followed by Lalgudi and Pullambadi with an area of 7459 and



4892 ha respectively (Table. 1). The next best blocks in order were Manikandam, Uppiliyapuram, Anthanallur, Manachanallur and Musiri which had rice area of 3936, 3171, 2237, 2061 and 1627 ha respectively. The total classified rice area across the 14 blocks was 36127 ha. The rice area was comparatively less in other blocks. The overall classification accuracy was consistently high (92.0%), with Kappa score of 0.84. There is no relationship between the classification accuracy and either the rice area or the proportion of the footprint classified as rice. Large, homogeneous and landscape-dominating rice areas and small, fragmented, heterogeneous rice areas are all classified equally well.

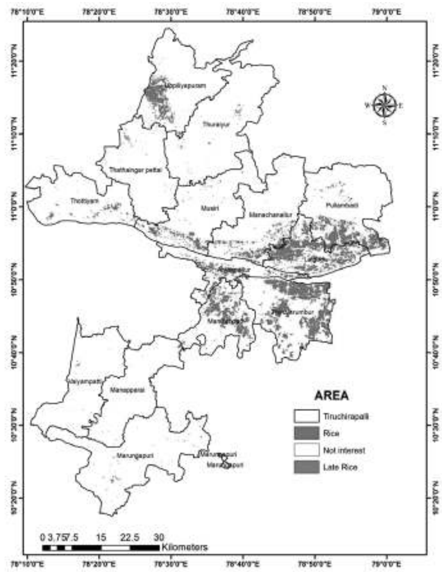


Fig.1. Rice area map of Tiruchirapalli District

Start of the season and days of flooding

Classified image derived from satellite radar data showing rice emergence dates, was generated from the dB stack. Even though there were ten dates of planting, most of fields were planted during 19th and 30th October,2015. In some blocks earlier planting of rice on 1st September, 2015 was observed. Additional information in terms of seasonality of rice i.e. sowing, soaking, ripening, etc. for a given date along with

Peak of Vegetative Stage (PoS) and End of season information is also retrieved from the microwave remote sensing data. There were seven classes observed in Tiruchirapalli district pertaining to Days of flooding ranging from 87 to 121 days. An area of 20,324 ha had 115-121 days of flooding whereas 10161 ha rice area recorded 104 days of flooding. Another 3000 ha rice area was under flooding for less than 95 days.

Table.1.Blockwise methane emission in Tiruchirapalli district based on IPCC method

Block	Rice Area (ha)	Methane Emission (Kg/ha)	Total Methane Emission (Kg)	Total Methane Emission (Gg)
Uppiliyapuram	3171	42.676	135309	0.135
Thuraiyur	222	43.352	9629	0.010
Thathaingarpettai	201	45.064	9067	0.009
Musiri	1627	44.323	72112	0.072
Manachanallur	2061	43.778	90211	0.090
Pullambadi	4892	42.651	208663	0.209
Thottiyam	654	44.201	28927	0.029
Lalgudi	7459	42.818	319385	0.319
Anthanallur	2237	44.823	100251	0.100
Thiruverumbur	9321	43.603	406414	0.406
Manikandam	3936	44.300	174352	0.174
Vaiyampatti	48	45.495	2180	0.002
Manapparai	84	45.090	3806	0.004
Marungapuri	214	44.665	9553	0.010
Tiruchirapalli District	36127	44.060	1569870	1.569

Regional level estimation of methane emission based on IPCC method

Methane emission was worked out based on days of flooding derived from SoS calculated from Sentinel 1A satellite data and integrated to the IPCC factor (Yan *et al*., 2009). The rates of methane emission (kg/ha) and total methane emission (Gg) were estimated and presented in Table 1.

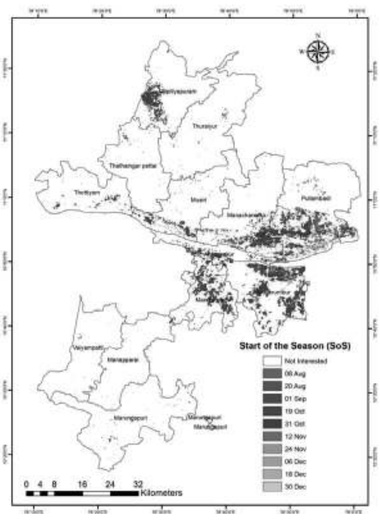


Fig.2. Start of the Season (SoS) map for rice in Tiruchirapalli District

The statistics revealed that the rate of methane emission ranged from 42.65 to 45.50 kg/ha at block level. Among the blocks Vaiyampatti, Manapparai and Thathaingarpettai recorded methane emission rate of more than 45 kg/ha. The major rice growing blocks of Thiruverumbur, Lalgudi, Pullambadi and Manikandam recorded a methane rate of 43.60, 42.82, 42.65 and 44.30 kg/ha, respectively. However, these blocks accounted for less area of rice. Total Methane emission from rice fields of Tiruchirapalli district was estimated to be 1.57 Gg during Samba season 2015-16 (Fig.3.). Considering the contribution from different blocks Thiruverumbur recorded the highest methane emission of 0.46 Gg during the season followed by Lalgudi (0.319 Gg). Pullambadi and Manikandam blocks emitted 0.209 and 0.174 Gg of methane from rice fields during Samba season 2015-2016. Uppiliyapuram and Anthanallur had also contributed a methane emission of 0.135 and 0.10 Gg from Tiruchirapalli district. Other blocks resulted in lesser methane emission (<0.10 Gg).

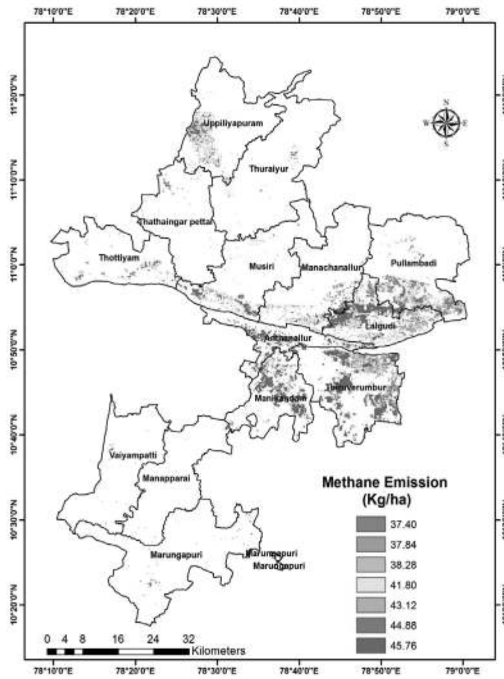


Fig.3. IPCC factor based Methane Emission(kg/ha) from rice fields of Tiruchirapalli District

Conclusion

Spectral dB curve of rice generated using multidate Sentinel 1A SAR data showed a minimum at agronomic flooding and a peak at maximum tillering stage and decreasing thereafter with dB values of −14.4 to −8.41dB with a primary variation of 1.5 to 2.1 dB and a secondary variation of 2.5 to 3.5 dB corresponding to growth at vegetative and maximum tillering stage. Rice area map was generated using a rule based classifier approach with a classification accuracy of 92.0 per cent and Kappa score of 0.84. The total classified rice area in Tiruchirapalli district was 36,127 ha during samba season 2015-16. Among the blocks, Tiruverumbur recorded the highest rice area of 9321 ha followed by Lalgudi and Pullambadi (7459 and 4892 ha respectively). The next best blocks in order were Manikandam, Uppiliyapuram, Anthanallur, Manachanallur and Musiri recording a rice area of 3936, 3171, 2237, 2061 and 1627 ha respectively.

The rate of methane emission based on IPCC factor ranged from 37.4 to 45.74 kg/ha for a period of 87 to 121 days of flooding. The Average rate of methane emission was found to be 43.45 kg/ha. The major rice growing blocks of Thiruverumbur, Lalgudi, Pullambadi and Manikandam recorded a methane rate of 43.60, 42.82, 42.65 and 44.30 kg/ha respectively. Considering the contribution from different blocks Thiruverumbur recorded the highest methane emission of 0.46 Gg during the season followed by Lalgudi (0.319 Gg), Pullambadi (0.209 Gg) and Manikandam (0.174 Gg). The total methane emission from Tiruchirapalli district based on IPCC factor coupled with SAR derived SoS was found to be 1.57Gg during Samba season 2015-16.

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