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Remote Sensing Based Estimates of Methane Emission from Summer Paddy Rice Cultivation in Udham Singh Nagar District in Uttarakhand, India

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Abstract Agricultural activities are associated with the emission of greenhouse gasses, notably methane (CH_4) which is important for anthropogenically influenced climate change. Thus, the feedbacks between the agricultural and climate are important. Methane (CH_4) is the second most important greenhouse gas (GHG). It has a global warming potential that is about 25 times larger than that of carbon dioxide on a time horizon of 100 years, and its emission is regulated by Kyoto protocol in 1990. Almost 40% of global CH_4 emission originates from the agricultural sector, from sources such as wetland rice (*Oryza sativa* L.) fields (i.e., paddy fields) and livestock. Several studies have estimated that the global CH_4 emission from paddy fields accounted for more than 10% of its total anthropogenic emissions. In this study, we have estimated emission of CH_4 from summer paddies and water requirement for summer paddy.

Keywords Summer rice, Methane emission, Climate change.

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Introduction

Intensification of rice cultivation to meet the demand for rice by the increasing human population is imperative, especially in Asia where approximately 90% of the rice is grown and consumed. The concentration of methane (CH_4) has increased since pre-industrial times, and its radiative forcing is second largest after carbon dioxide (CO_2) [1]. However, despite of atmospheric methane, the significance of individual sources of CH_4 remains highly uncertain [2]. Depending on the location, in India rice is grown in two seasons, *kharif* (summer, wet) and *rabi* (winter, dry). Rice is generally transplanted in puddled soils and prefers continued submergence. Long-term cultivation of puddled rice results in the formation of a hard pan with a consequent increase in bulk density and lowering of hydraulic conductivity below the plow layer [3]. Paddy fields have a high capacity for soil carbon sequestration [4—7]. The soil carbon sequestration, i.e., net exchanges of CO_2, could be measured by soil organic carbon (SOC) changes over a sub-decadal or decadal timescale [5, 6].

Continuous flooding helps to ensure sufficient water and weed control. On an average, it takes 1,432 liters of water to produce 1 kg of rice in an irrigated lowland production system. Around 1300—1500 mm is a typical amount of water needed for irrigated rice in Asia.

The conventional method of land preparation for transplanting or sowing not only disturbs the soil environment but also leads to atmospheric pollution. It is estimated that 2.6 kg of carbon dioxide (CO_2) is released to the atmosphere for each liter of diesel fuel consumed [8]. Methane is produced by methanogenesis, the process that occurs when the easily degradable organic matter is devoid of oxygen and other suitable electron acceptors [9]. The C for CH_4 production leading to methanogenesis in the rice ecosystem mainly comes from root exudates and debris of the rice plant growing in the field. Such release of C represents a loss of valuable assimilates that would have otherwise been incorporated into plant tissue or grain [9]. Factors that contribute to an increase in rice production such as the application of organic manures, crop residues, and inorganic fertilizers also increase CH_4 emissions. Substantial production of CH_4 occurs even in non-flooded soils amended with rice straw.

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Materials and Methods

Study area

The study was conducted in Udham Singh Nagar district which lies in the Kumaon division of Uttarakhand. It is located at 28.98´N and 79.40 ´E. It covers an area of 2860 sq km geographical area of which 1490 sq km area belongs to the cultivated land. The major crops of Udham Singh Nagar are sugarcane paddy, wheat, maize and pulses.

Image acquisition

The satellite image is acquired from the website of USGS (http://glovis.usgs.gov/).

Image processing

The image was processed using ENVI 4.7 remote sensing software. The digitization of district boundary was done using QGIS 2.14.2.

The following procedures were followed for estimating methane emission and the water requirement for summer paddy.

*Extraction of files
*Subsetting of the image
*Region of Interest
*Classification
Crop Simulation Model is used for estimating water requirement and methane emission

Calibration and validation of CERES-rice model

CERES-rice model is included in the Decision Support Systems for Agrotechnology Transfer (DSSAT) family of models (Version 4.0), [10]. The CERES-Rice model has been used extensively to assess crop yield under current conditions as well as under climate change over a wide range of environments [11].

Experiment establishment, model calibration
and validation

Experimental records from one year for model parameters calibration and the records of several other years for model validation are considered. The accuracy of the model is checked by calculating the root mean square error (RMSE) between the observed and simulated value :

$$RMSE = \left[\frac{\sum_{i=1}^{n} (simulated_i - observed_i)^2)}{n} \right]^{0.5}$$

where n is the number of comparisons.

Developing a probabilistic assessment
of rice production and water use

First, the historical daily weather data is used to parameterise a weather generator and then to generate 100 years of daily weather data, which represents the baseline climate conditions. A range of climate scenarios and atmospheric CH_4 concentrations are identified for GMT (Global Mean Temperature changes of 1, 2 and 3 ^{0}C respectively, based on GCMs

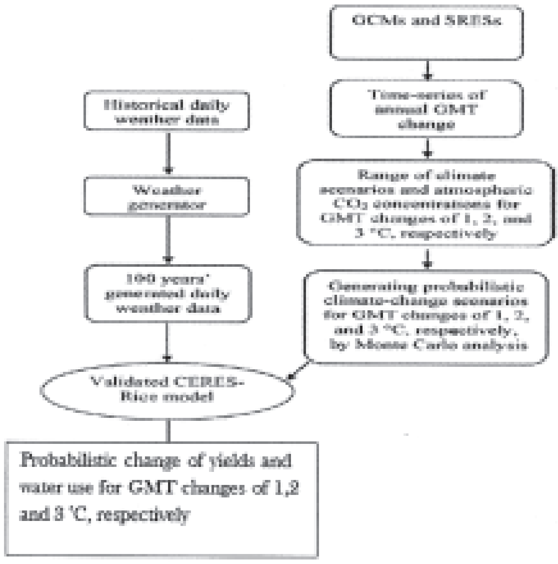

Fig. 1. The general framework of the study.

and SRESs and time series of annual GMT change. Next is used Monte Carlo analysis to develop probabilistic climate-change scenarios for GMT changes of 1, 2 and 3 ^{0}C respectively (Fig. 1.). The validated CERES-Rice model is then run by using both the baseline climate conditions and the most likely climate-change scenarios for GMT changes for 100 years respectively. Finally, the rice yield, evapotranspiration, and irrigation water use between the future climate-change scenarios and the baseline climate conditions was calculated.

Simulation and analysis

For each growing season, the 100 generated years of daily weather data are first input to the CERES-Rice model to simulate rice production and water use under baseline climate conditions. Then, for each of the 100 simulations under baseline climate conditions, the effective most likely scenario classes (up to 100) were used to change climate conditions and to simulate rice production and water use for GMT changes of 1, 2, and 3 ^{0}C respectively, according to the standard routine for climate-change impact studies [12].

Results and Discussion

Area determination

The image of the region obtained is classified using ENVI 4.7 and so the paddy fields are discriminated from other land covers. Quick Stat is then applied to the classified image which estimates the area under paddy cultivation and the area determined is 18,701.730 ha (Fig. 2.).

Methane emission

Rice paddies are a major source of atmospheric CH_4 and there is a need for careful evaluation of the source strength of this ecosystem and of the influence of soil, water and crop management practices on both grain yield and GHG fluxes. The literature suggests that the methane emission from paddy fields of *kharif-rabi* cropping system with continuously flooded water regime is about 135.2 kg per hectare [13]. Accordingly the methane emissions from our region of interest i.e. Udham Singh Nagar district is about 2528473.896 kg.

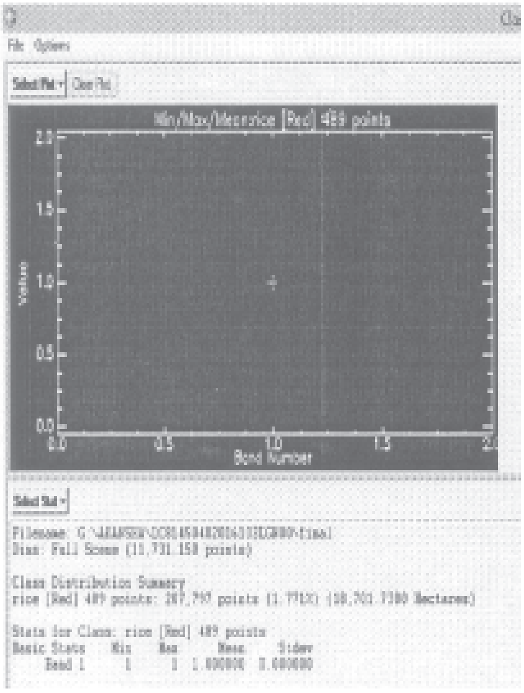

Fig. 2. Quick Stat.

Water requirement

Water demand for rice varies from nursery to the harvesting. Water demand for entire growth period varies from 950 mm to 1050 mm for 3-month duration rice crop and 1120 to 1250 mm for 4-month duration rice crop. The literature suggests that water requirement for lowland or deepwater rice is about 16,500 m^3 per hectare [14]. Therefore, the approximate water requirement for cultivating summer paddy is 308578545 m^3.

Conclusion

The expected doubling of rice production in Asia emphasizes the need for research on improving rice yield with strategies that do not harm the environment. Rice fields represent globally one of the main sources of the greenhouse gas methane (CH_4), but the global source strength of rice cultivation remains uncertain.

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