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Short communication

Relationship between paddy cultivation and methane emission rate (XCH4) in Haryana

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Climate change, driven by increased greenhouse gas concentrations, poses significant risks to millions of people. Methane, a potent greenhouse gas, significantly impacts Earth's energy balance and plays a major role in climate change. The amount of greenhouse gas emissions from agriculture is significant. The agriculture, forestry and land use sectors contribute between 13% and 21% of global greenhouse gas emissions. Emissions come from direct greenhouse gas emissions (for example from rice production and livestock farming) and from indirect emissions. With regards to direct emissions, nitrous oxide and methane makeup over half of total greenhouse gas emissions from agriculture. Methane is emitted into the atmosphere when organic matter breaks down in flooded rice fields under anaerobic (oxygen-deprived) conditions. The XCH_4 and rice cultivation are positively correlated because locations with significant rice cultivation typically have higher methane emissions. XCH_4 in the atmosphere tend to rise in tandem with the area under rice cultivation, indicating a larger influence of rice agriculture on methane emissions, according to a positive correlation coefficient. In contrast, a negative correlation coefficient would imply an adverse relationship—though this is less typical when it comes to methane emissions and rice farming. Various sources contribute to the buildup of methane in the atmosphere, intensifying its effects (IPCC, 2014; Thakur and Solanki, 2022; Vyas and Jhala, 2023).

Satellite images are a powerful tool for analysing the distribution of various crops and monitoring spatial changes in crop areas. By integrating satellite data into GIS, we can generate different thematic maps for use in land evaluation techniques. Recently, the FAO has been enhancing GIS capabilities in conjunction with its agro-ecological zoning and similar models, applying these technologies to address land-related issues at regional levels (Kumar *et al.,* 2018). Sentinel-5 Precursor (S5p) mission was used that provides low Earth orbit polar satellite system-based information and services on air quality including methane mixing ratio (XCH_4), climate and the ozone layer. The mission of Sentinel 5p is part of the global monitoring of the environment and security (GMES/ COPERNICUS) space component programme. The Sentinel 5p mission is part of the worldwide monitoring of the European programme for the establishment of a European capacity for Earth observation (COPERNICUS). Tropospheric monitoring instrument (TROPOMI) make daily global observations of key atmospheric constituents, including ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide, methane, and formaldehyde as well as cloud and aerosol properties (Lorente *et al.,* 2021; ESA 2024).

The study was carried out to find out rice crop distribution and methane mixing ratio in the rice growing district of Haryana. Ten districts namely Panchkula, Ambala, Fatehabad, Jind, Kaithal, Karnal, Kurukshetra, Panipat, Sonipat, and Yamunanagar situated between $28^0 45'$ to $30^0 35'$ N latitudes and $74^0 25'$ to $77^0 40'$E longitudes, were selected for the study as they contribute (more than 84%) the major rice growing districts in the state (Fig. 1). Landsat 8 images for *kharif* season from, September 4th to 5th, September 28th to 29th, and October 14th to 15^{th} for the year of 2023 were used. These images are available on ESA download portal (www. usgs.gov). Supervised classification techniques were used for the estimation of rice crop area based on Landsat-8 satellite images (Fig. 2). Sentinel 5-p to obtain the methane mixing ratio (XCH4) data is download on global scale. Sentinel 5 Precursor Sensor in TROPOMI were used for analysis. Methane values were extracted from TIFF (raster) files into vector points using GIS software, employing interpolation methods to map the spatial distribution of methane mixing ratios. These values, derived from satellite data,

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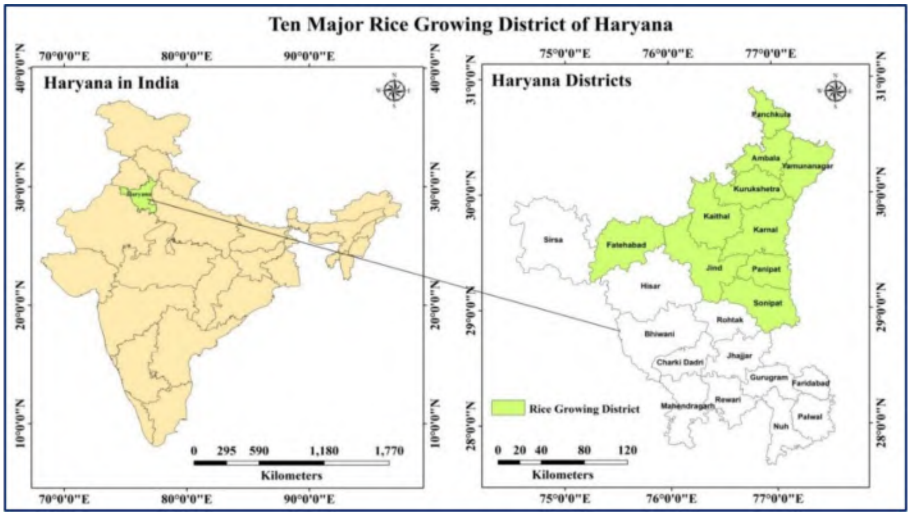

Fig. 1: Location map of study area

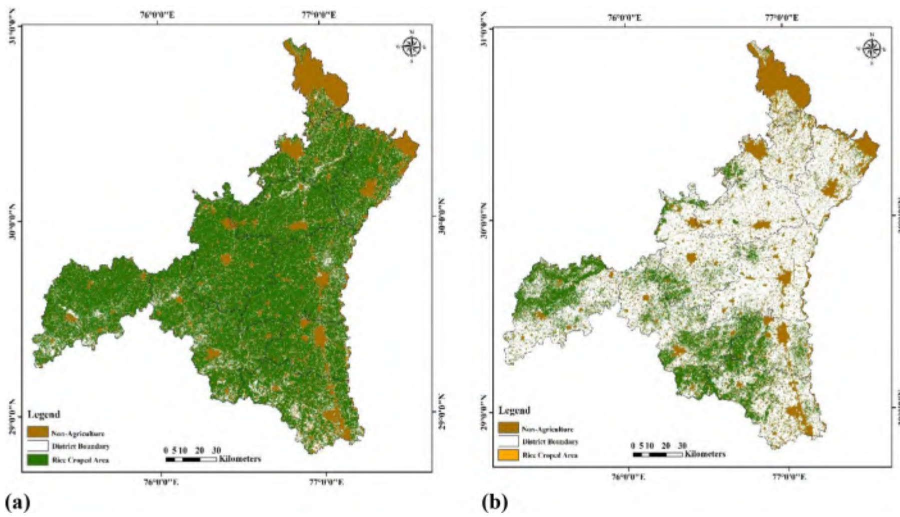

Fig. 2: Rice crop area during (a) September 2023 and (b) October 2023 in the study region

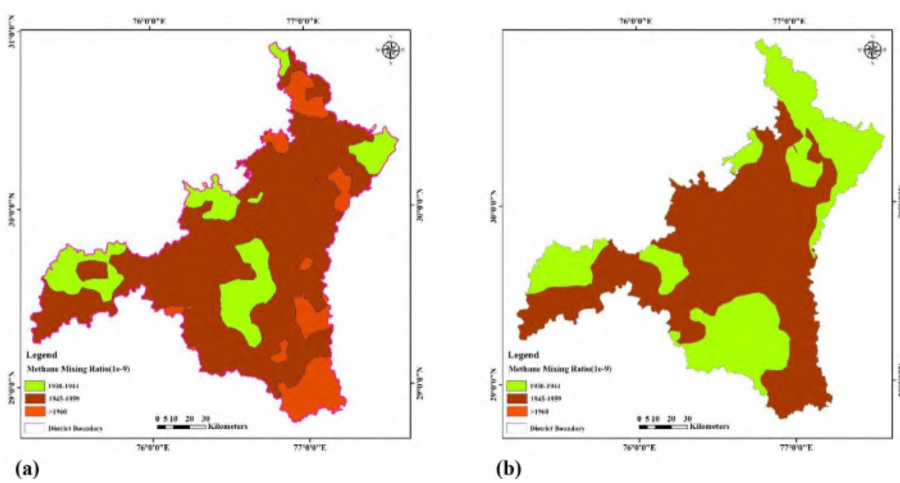

Fig. 3: Spatial distribution of XCH4 during (a) September 2023 (b) October 2023 in the study region

were used to create XCH4 maps (Fig. 3). GIS layers for rice area relate with methane mixing ratio. The spatial distribution of rice crop in Haryana was then examined with methane mixing ratio of XCH_4 value. The methane area estimations were categorized into three classes based on methane mixing ratio of XCH_4 value of 1930-1944 ppb, 1945-1959 ppb, and greater than 1960 ppb. The part per billion (ppb) or (1e9) is the standard measurement unit of a billion (or 1,000,000,000) in scientific and business contexts.

Table 1: XCH_4 and estimated rice crop area during September and October 2023

Month	Rice crop area (ha)	Methane mixing ratio	
		XCH_4 value (ppb)	Area XCH_4 (ha)
September	1,363,092.9	1930-1944	332014.8
		1945-1959	1350827.1
		>1960	246350.7
October	375,985.4	1930-1944	714143.7
		1945-1959	1215049.0
		>1960	0

The rice crop areas and associated methane mixing ratio (XCH_4) for September and October 2023 (Table 1) shows that in September, the rice crop area was 1,363,092.9 ha, with methane mixing ratio values ranging from 1930-1944 XCH4 (332,014.8 ha), 1945-1959 XCH4 (1,350,827.1 ha), and >1960 XCH4 (246,350.7 ha). In October, the rice crop area decreased to 375,985.4 ha, with corresponding methane mixing ratio values of 1930-1944 XCH4 (714,143.7 ha), 1945-1959 XCH4 (1,215,049.0 ha), and >1960 XCH4 (0 ha). This data illustrates the relationship between rice cultivation and methane emissions, highlighting the areas affected by different levels of methane concentrations, where higher rice cultivation is typically associated with higher methane emissions due to the anaerobic conditions in flooded rice paddies. The association that exists between the amount of rice grown and the atmospheric concentration of methane is known as the XCH_4 correlation. This relationship results from the fact that rice paddies that have flooded significantly contribute significantly to methane emissions. Notably, Haryana exhibits the high methane emission during the rice crop season, underscoring rice farming as a significant human-caused source of methane emissions. The study's findings align positively with its objectives, providing valuable insights into methane emission dynamics in rice cultivation.

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***Conflict of interest statement*:** The authors declare that there is no conflict of interest.

***Data availability*:** Data can be provided on reasonable request

***Author Contribution*: K. Ninaniya:** Planning study conception and design, preparing abstract, writeup draft, manuscript preparation, Conceptualization, Methodology, editing **C. Shekhar:** Guidance, planning, composing maps, processing satellite data, interpretation of results, Writing-review and editing; **D. Chahal:** reviewing, data collection; **N. S. Bishnoi:** Analysis tools, introduction.

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