A Study of the Long-term Trend of Methane Emission over the Indian Region during 1970-2020

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ABSTRACT

Methane, a potent greenhouse gas with a warming effect stronger than CO2, lingers in the atmosphere for 8-11 years, significantly influencing climate change. This study addresses critical data gaps in India's rapidly urbanizing landscape by employing climate change methodologies to estimate national-scale CH4 emissions from landfills. With India generating 90 million tons of solid waste annually, this research contributes to informed sustainable management. Livestock, particularly ruminants, globally emit 65-100 million tons of methane yearly. In India, where agriculture dominates methane emissions, recent reports reveal that 45% of the country's total methane output stems from this sector. Enteric fermentation and manure management processes underscore the complexity of methane emissions in livestock. As methane has been responsible for 30% of the global temperature rise since the Industrial Revolution, urgent reduction measures are imperative for climate and air quality improvement. A comprehensive 52-year analysis, utilizing EDGAR datasets from 1970-2021, reveals diverse country contributions, with China, India, the USA, and Russia leading. Temporal trends indicate a persistent rise, notably in 2021, while spatial distribution identifies concentration peaks in key regions. Agriculture emerges as the primary anthropogenic source, closely followed by the energy sector. Linear trends illuminate disparities in global and Indian methane emissions, providing insights for targeted mitigation. This study, offering evidence of monthly methane emission variations in India over 52 years, also elucidates bio and fossil source dynamics crucial for informed decision-making on global methane emissions. This holistic view enhances our understanding of CH4 emission dynamics, facilitating the formulation of effective strategies for sustainable environmental management.

Keywords: *Methane, Emission, India, EDGAR, and Greenhouse Gas*

1. Introduction

With a global warming potential 28 times higher than CO2 over a century, CH4 is a significant contributor. India, renowned for having one of the world's largest livestock sectors, plays a pivotal role in global methane (CH4) emissions, contributing significantly to the environmental challenge of greenhouse gas emissions (GOI, 2007). With a staggering total of 529 million livestock, predominantly indigenous breeds with limited productivity, India stands out as a major contributor to CH4 emissions (FAO, 2007). The livestock sector in India emits nearly 12 Tg of CH4 annually, with over 90% stemming from enteric fermentation (Chhabra et al., 2013). This emission level surpasses that of the United States, highlighting the substantial impact of India's livestock on the global methane budget (Hristov et al., 2014).

The urgency to address CH4 emissions from India's livestock sector becomes apparent when considering that it accounts for 78% of total CH4 emissions from the agriculture sector and about half of the country's overall CH4 emissions (Swamy and Bhattacharya, 2006). To achieve greenhouse gas emissions reduction goals, understanding the current trends and projecting future emissions is imperative. Despite the availability of baseline emission data, limited studies exist concerning future projections, and India lacks a statewide database for emission forecasts (Chhabra et al., 2013; Singh et al., 2012; Swamy and Bhattacharya, 2006). Recognizing these research gaps, this study aims to project the growth of livestock populations in India.

Livestock farming globally contributes substantially to greenhouse gas emissions, with a total of 7.1 gigatonnes of CO2 equivalents per year, constituting 14.5% of all anthropogenic emissions (Gerber et al., 2013b, Ahmed et al., 2023). Methane (CH4), as the second most abundant greenhouse gas after CO2, contributes nearly 9% to global greenhouse gas emissions, with approximately 35% of anthropogenic CH4 emissions originating from the livestock sector (Ingale et al., 2013). As global demand for livestock products rises, GHG emissions from the sector are projected to increase significantly by 2050 (Kristensen et al., 2011).

Emissions from livestock predominantly occur through enteric fermentation, a process responsible for approximately 37% of anthropogenic CH4 emissions globally (Chhabra et al., 2013; Koneswaran and Nierenberg, 2008). Ruminant animals, particularly cattle, contribute substantially more to GHG emissions than monogastric livestock, and India plays a major role in these global emissions (Ripple et al., 2014; IPCC, 2013). The intricate microbial interactions and waste management practices in livestock, including manure decomposition, add to the complexity of the issue. This introduction sets the stage for a comprehensive exploration of India's livestock-induced methane emissions and the urgent need for strategic interventions to mitigate their environmental impact.

2. Data Source and Methodology

EDGAR, a globally influential database, stands autonomously as a vital resource, meticulously documenting anthropogenic emissions of greenhouse gases and air pollutants. Its distinctiveness lies in providing independent estimates, transcending reliance on reported figures from European Member States or UNFCCC Parties. EDGAR achieves this through international statistics and a steadfast adherence to the IPCC's consistent methodology. The database's reach extends beyond national total emissions, offering detailed gridmaps with a global resolution of 0.1 x 0.1 degrees which is available in the EDGAR web portal (https://edgar.jrc.ec.europa.eu/). This granularity spans from yearly summaries to more intricate monthly and hourly breakdowns, empowering a nuanced comprehension of emissions patterns.

Utilizing the 2006 IPCC Guidelines and the latest country-specific emission factors, this paper undertakes a comprehensive assessment of methane emissions in the world vs India in both the Bio and Fossil sectors. The milestone release, EDGARv7.0, symbolizes a collaborative endeavor between JRC and IEA, focusing on delivering unified estimates of CO2 emissions from fossil fuel combustion. This iteration provides a comprehensive evaluation of emissions for major greenhouse gases—CO2, CH4, N2O, and fluorinated gases—categorized by sector and country. The Emissions Database for Global Atmospheric Research (EDGAR) is more than a repository; it is a pivotal resource offering historical and contemporary anthropogenic emissions globally. The methodology involves uniform emissions calculations per source category, utilizing a generic approach consistently applied across all countries. EDGAR ensures geographical distribution aligned with actual emission sources, fortifying its commitment to providing valuable insights into global emissions patterns.

Highlighting the significance of EDGAR's foundational release, the summary underscores its role in aiding the understanding and management of environmental impacts. Additionally, it introduces the use of Methane emission source abbreviations, such as Bio and Fossil sources, for analysis and comparison with a global resolution of 0.1 x 0.1 degrees data available (2002-2020) on the Copernicus Atmosphere Monitoring Service (CAMS) web portal (https://atmosphere.copernicus.eu/).

3. Results and Discussion

Methane is responsible for around 30% of the rise in global temperatures since the Industrial Revolution, and rapid and sustained reductions in

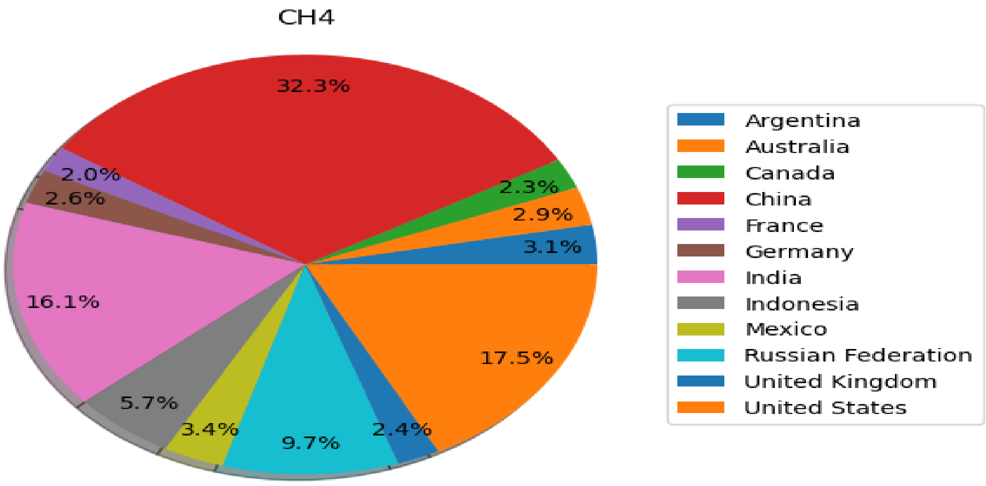

Figure1: Major contribution of various countries producing Mean CH_4 emission for 1970-2021 using Edgar Datasets.

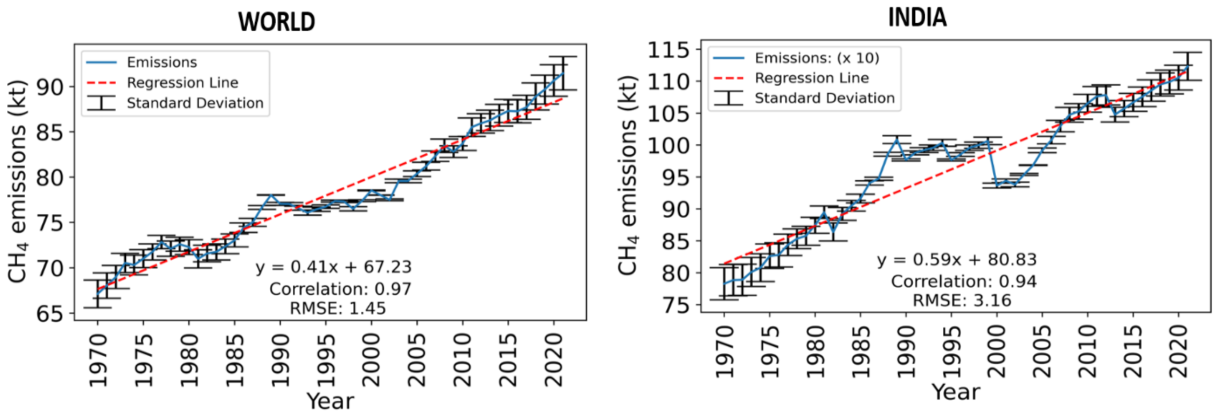

Figure 2: EDGAR Annual Trends of methane emission in World vs India.

methane emissions are key to limiting near-term warming and improving air quality. Two key characteristics determine the impact of different greenhouse gases on the climate: the length of time they remain in the atmosphere and their ability to absorb energy. Methane has a much shorter atmospheric lifetime than carbon dioxide (CO2) – around 12 years compared with centuries – but absorbs much more energy while it exists in the atmosphere. Methane also affects air quality because it can lead to ground-level (tropospheric) ozone, a dangerous air pollutant. Methane leaks can also pose explosion hazards.

The present study suggests the overall comparison of 52-year trends and major contributions over various countries using EDGAR datasets period of 1970-2021. Figure 1 portrays the notable contributions of different countries to the average methane emissions (%) spanning from 1970 to 2021, using EDGAR datasets. The visual representation highlights the diverse roles and contributed nations play in the overall global methane emissions landscape, and variations in contributing countries over the specified timeframe. The current study reveals the highest contribution of methane emission by China (1st 32.3%), India (2nd 16.1%), USA (3rd 17.5%), and Russia (4th 9.7%) are the higher contributor over the major contributions as per our findings using Edgar datasets.

Moreover, the present study provides insights into the temporal and spatial variations in contributing world vs India over the specified timeframe (Figures 2 & 3). Figure 2 illustrates the annual

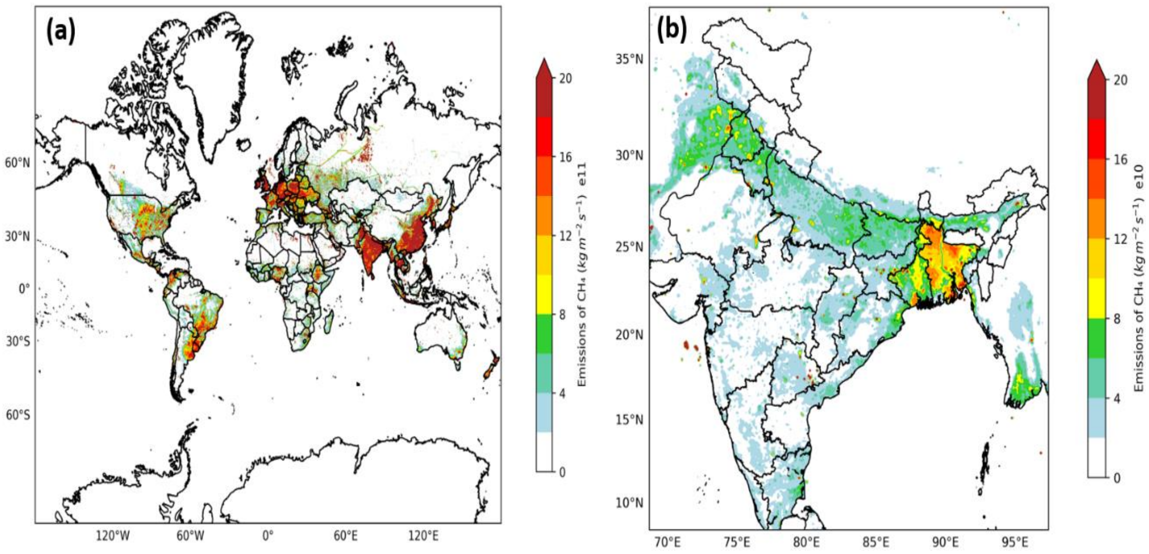

Figure 3: EDGAR Mean Methane emission spatial over world vs India.

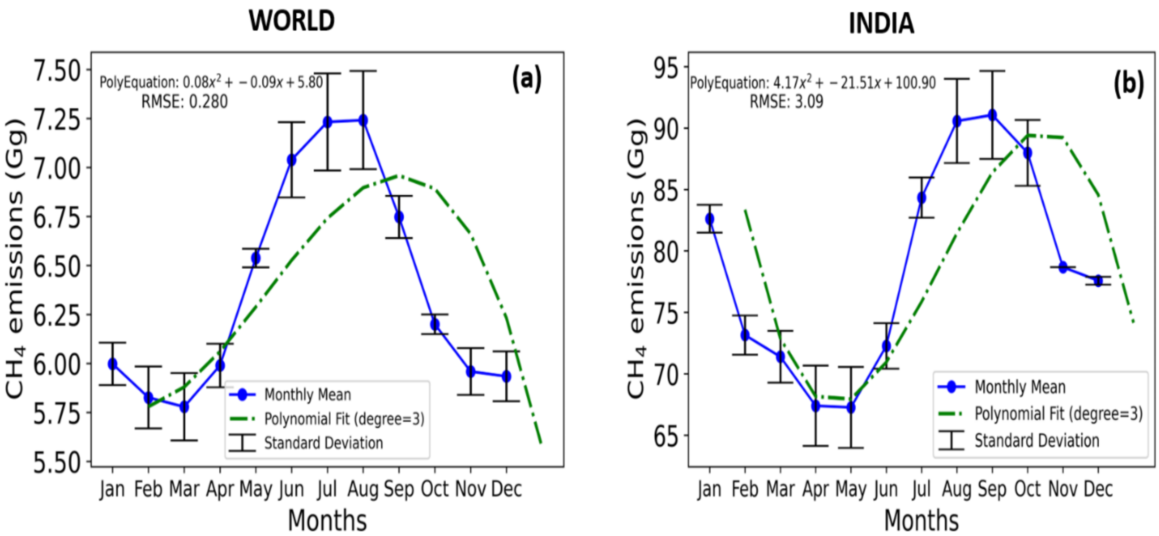

Figure 4: EDGAR Methane emission of monthly variation over World vs India.

trends of methane emissions, drawing a comparative analysis between the global and Indian regions. The visual representation allows for a nuanced examination of how methane emissions have evolved over time on a world scale (Figure 2b) compared to the specific trajectory within the Indian region (figure 2b). The results suggest that increasing trend in both and maximum at 2021 base GDP criteria for the mentioned period. Figure 3 shows the spatial distribution of mean methane emission. The clear evidence of the highest concentration is found over the world and Indian region figures (3a and 3b). Among these top emitters, China, India the United States, Europe, and Russia are the major contributor for the mentioned years. In addition Indian region, the most emissions shows near the Northeastern region (e.g. Westbangal, asam) and Northwestern (e.g. Delhi, Haryana, Punjab) region.

Also, results suggest the monthly variation for India for the same time period (Figure 4). Figures 4a and 4b illustrate the monthly variation in mean methane emissions for the world and India over 52 years. Higher values are predominantly observed in July-August and August-October for the world and India regions, respectively. The current findings also suggest the largest anthropogenic source is

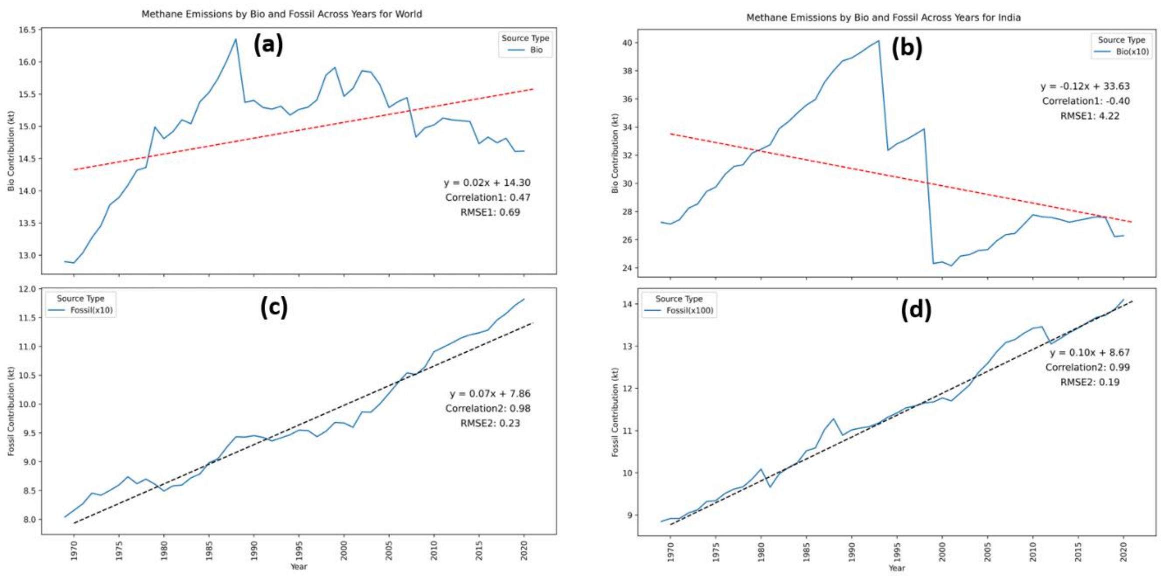

Figure 5: EDGAR Bio and Fossil contribution (kt) of Methane emission over in World vs India for 52years.

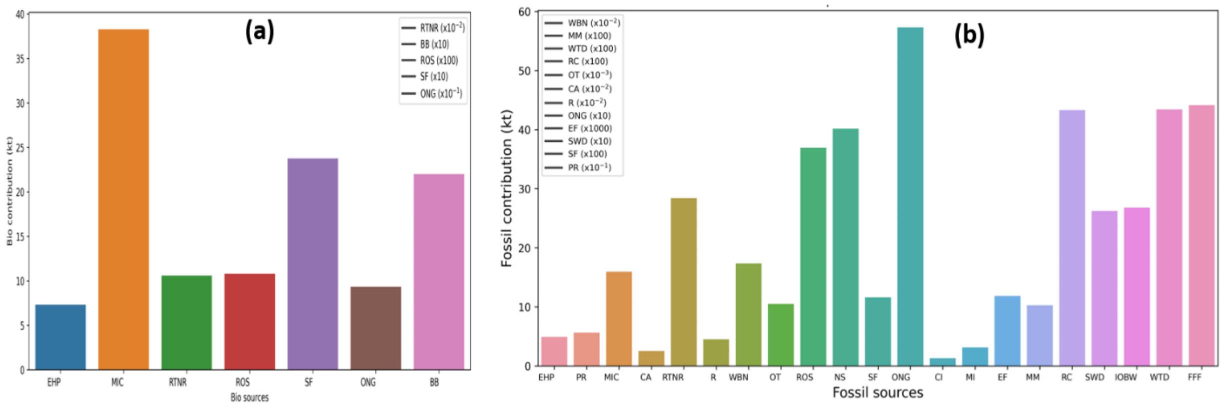

Figure 6: EDGAR Methane emission variation based on the different Bio and fossil sources over India.

agriculture, responsible for around one-quarter of emissions, closely followed by the energy sector, which includes emissions from coal, oil, natural gas, and biofuels (Jha et al 2011; Garg et al 2011; kumari et al 2016). The Edgar Bio and fossil variation of the overall mean methane emission for the world and India for the same time period (Figures 5 & 6).In Figure 5, the EDGAR dataset delineates the linear trends of methane emissions from bio and fossil sources, offering a comprehensive comparison between the global perspective (Figures 5a and 5c) and the specific scenario in India (Figures 5b and 5d). Figures 5c and 5d also suggest a continuously increasing trend, whereas bio sources have shown a decrease in recent decades for both the world and India. The linear trends provide valuable insights into the evolving contributions of these sources over time.

This study utilizing the 2006 IPCC Guidelines provides a comprehensive assessment of methane emissions in India, revealing a notable shift in their proportion within the country's overall greenhouse gas emissions. The agriculture sector, a major contributor to methane emissions, particularly through enteric fermentation, manure use, and rice production, highlights the need for targeted mitigation efforts (Kumari et al 2016; Garg et al 2011). Figure 6 further delves into the details, presenting a bar plot that vividly showcases the variations in bio (Fig 6a) and fossil (Fig 6b) source contributions within India. The abbreviations for

Table 1. Shows the Abbreviation used for the Methane bio and fossil emission sources.

S.No.	Abbreviations	Sources
1.	EHP	Main Activity Electricity and Heat Production
2.	MIC	Manufacturing Industries and Construction
3.	CA	Civil Aviation
4.	RTNR	Road Transportation No Resuspension
5.	WBN	Water-Borne Navigation
6.	OT	Other Transportation
7.	ROS	Residential and Other Sectors
8.	NS	Non-Specified
9.	ONS	Oil and Natural Gas
10.	SWD	Solid Waste Disposal
11.	IOBW	Incineration and Open Burning of Waste
12.	WTD	Wastewater Treatment and Discharge
13.	SF	Solid Fuels
14.	EF	Enteric Fermentation
15.	MM	Manure Management
16.	CI	Chemical Industry
17.	PR	Petroleum Refining - Manufacture of Solid Fuels and Other Energy Industries
18.	BTSW	Biological Treatment of Solid Waste
19.	BB	Emissions from biomass burning
20.	FFF	Fossil fuel fires
21.	MI	Metal Industry
22.	R	Railways
23.	RC	Rice cultivations
24.	GP	Glass Production
25.	OPUC	Other Process Uses of Carbonates
26.	NEP	Non-Energy Products from Fuels and Solvent Use
27.	L	Liming
28.	UA	Urea application
29.	LP	Lime production

bio and fossil sources are presented in the methodology section(Table 1). Bio sources indicate a higher contribution in SF(240 kt; Fig 6a), while fossil sources demonstrate the highest EF (12Mt; Fig 6b).

With urban solid waste emissions on the rise, the paper underscores the importance of adopting geographical and sectoral flexibilities to develop an effective strategy for mitigating methane emissions in India. This visual analysis facilitates a nuanced understanding of methane emissions, enabling the identification of key drivers and the formulation of targeted mitigation strategies. This approach contributes to informed decision-making for sustainable environmental management in India's methane emission landscape.

4. Conclusion and future scope

Methane's substantial role in the global temperature rise highlights its significance in climate change, contributing around 30% since the Industrial Revolution. Its short atmospheric lifetime, coupled with high energy absorption, accentuates its impact. Beyond climate effects, methane adversely influences air quality and poses explosion risks. Urgent, sustained efforts are imperative for near-term warming mitigation and global air quality enhancement. The study utilizes EDGAR datasets, revealing notable contributions from China, India, the USA, and Russia over 52 years (1970-2021), emphasizing the diverse roles nations play in the global methane emissions landscape.

Temporal and spatial variations between global and Indian methane emissions are explored, indicating increasing trends globally and regionally, with concentrations in specific Indian regions. Agriculture emerges as the largest anthropogenic source, responsible for a quarter of emissions, followed by the energy sector. The results highlight significant monthly variations in mean methane emissions, particularly in India, over the examined 52-year period. Figures 4a and 4b underscore that higher emission values occur prominently in July-August and August-October for the world and India regions, respectively. The study provides insights into bio and fossil variations, showcasing continuous global increases and recent decreases in bio sources. Bar plots highlight variations within India, with bio sources contributing more to solid fuels (SF) and fossil sources dominating Enteric Fermentation (EF) for the considering period.

Despite these valuable insights, limitations exist. Discrepancies between data from measurement campaigns and official submissions to the UNFCCC pose challenges. Official inventories, often outdated, lack accuracy, hindering a clear emissions picture. This mismatch persists globally and nationally for all emission sources. The limitations underscore the need for improved data accuracy, updated inventories, and increased reliance on direct measurements. A comprehensive understanding of methane emissions necessitates addressing these limitations to inform effective mitigation strategies.

Addressing the current disparities in data sources and improving the accuracy of official greenhouse gas inventories, especially through incorporating more directly measured data, is crucial for future research. Collaborative efforts are essential to bridge gaps between scientific studies and UN Framework Convention on Climate Change (UNFCCC) submissions at both global and national levels. Prioritizing regular updates to submissions and employing advanced technologies can enhance the precision of emission assessments. Despite current limitations, this study emphasizes the need for collective commitment to refine methodologies, ensuring a more reliable understanding of methane emissions for informed decision-making and sustainable environmental management.

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