GIS-Based Assessment of Methane Emission from Livestock in India

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Abstract
Livestock farming is a major source of livelihood in India, but also a potential source of greenhouse gases (GHGs) emission, particularly CH4. The present research provides a detailed spatial livestock mediated CH4 emission inventory covering all the districts and states of India. Results show livestock CH4 emission in India is 15.3 Tg yr-1 with Banas Kantha (Gujarat) and Uttar Pradesh being the highest emission contributor at district and state level, respectively. Thus, monitoring and understanding spatial livestock distribution and its CH4 emission pattern is essential for policy design to ensure sustainable livestock farming and effective climate mitigation policies.

Keywords: Livestock farming; GIS; CH4 emission; Climate mitigation; India

Introduction
Climate change is altering the world ecosystems and threatening the comfort of current and future generations. To control the temperature, rise below 2° Celsius as envised in the Paris climate deal and avoid risky climate change, halt in global emissions is immediately required. With these growing concerns of the detrimental impacts of climate change, identification and controlling of potential sources of greenhouse gases (GHGs) emissions has become an international priority [1]. Main contributors of anthropogenic GHGs are CO2, CH4 and N2O, where agriculture is a major source of emission for last two GHGs [2,3]. The livestock sector is considered as one of the major anthropogenic sources of GHGs emissions [4,5]. Livestock production and environmental impacts are facing unprecedented challenges due to the growing economy and rapid demand for meat and dairy products [6]. This will be an important issue in coming decades to reduce GHGs emissions from livestock sector and to support economic services in a sustainable way [7]. Within the livestock farming, milk and meat production contribute significant amount of GHGs emissions.

Enteric fermentative digestion by ruminant animals is the world’s largest source of CH4 emissions [8]. The specific digestive system of ruminant animals such as cattle, buffalo, sheep, and goat are associated with high levels of CH4 production [9,10]. It is also estimated that 5.6–7.5 Gt CO2e GHGs yr-1 is emitted annually by livestock sector between 1995 and 2005 where the most important sources of emissions were enteric CH4 (1.6–2.7 GtCO2e yr−1) [11]. Among livestock group, cattle dominate (64–78%) the sector’s emissions [11]. However, livestock contribute significant part of the livelihoods of at least 1.3 billion poor people in rural households [12]. Despite the importance of livestock to the poor and the magnitude of the changes that are likely to be fall on livestock systems, the intersection of climate change and livestock in developing countries is a relatively neglected research area [13]. Environmental legislation and public concerns about the environmental footprint of livestock production operations have increased pressure on producers to adopt measures to reduce atmospheric and environmental pollution [14]. Worldwide initiatives such as the Kyoto Protocol demand that GHGs emissions should be reduced or at least prevented from further increase [15]. Monitoring and understanding the distribution of livestock in relation to production system at various geographical scales is essential for designing intervention to ensure sustainability of livestock production [16].

India, the world’s 2nd most populace country is also the world’s 3rd largest GHGs emitter, contributing ~7% of the global total [17]. To be effective and least cost, climate policy requires the reduction of emissions of all GHGs [18]. It is reported that Indian livestock sector emits significant GHGs, particularly in the form of CH4 [19,20]. In India, enteric CH4 emission is high due to two main reasons: large number of ruminant densities over large area and poor feeding management [21,22]. The Paris climate...
Assessment of GHGs emissions from the livestock sector and identifying the hot-spots of emissions as well as livestock population is pre-requisite for cost-effective emission reduction goals. The hot spot analysis can be helpful to minimize negative environmental impact of livestock production and design and implement more effective policy instruments for livestock farmers at different scales including local policy making. However, no assessment has been conducted in India to assess the geographical distribution of CH$_4$ emission from livestock at small spatial units up to district level. Furthermore, district level partitioning of emissions among the different livestock groups (cattle, buffalo, goat, and sheep) and CH$_4$ fluxes per capita and per geographical unit are also have not been previously studied. Aiming to fulfill this research gap, the present research is conducted in India on GIS platform to (i) assess district and state level CH$_4$ emission from different livestock categories, (ii) per capita and per geographical area wise spatial distribution of livestock and CH$_4$ emission, and (iii) identify livestock-mediated CH$_4$ emission hotspots in India.

**Methodology**

The methodology is divided into three sections as shown in Figure 1. In summary, estimation of CH$_4$ emission from livestock is based on the IPCC Tier 1 guideline [24]. The livestock population and CH$_4$ emission is estimated at district, state and national level. In addition to CH$_4$ emission, CH$_4$ flux per capita and per unit geographical area are also calculated. The findings are then applied in the GIS (Geographical Information System) platform to map spatial distribution of CH$_4$ emission in India.

**Figure 1: Flow chart of the methodology for estimation of spatial distribution of CH4 emissions from livestock in India.**

The first section of the method is comprised of livestock population database collection and associated CH$_4$ emission estimation. Livestock population database are collected from the Department of Animal Husbandry and Statistics, India for year 2012 [25]. The collected livestock database of all the 28 states and 7 UTs covering 649 districts of India is divided into four categories viz. cattle, buffalo, goat and sheep. CH$_4$ emission is estimated from enteric fermentation and manure management practices. The specific CH$_4$ emission factor for each category of livestock as given in IPCC guidelines, 2006 (Table 1) both for enteric fermentation and manure management are used to further calculate livestock category-wise emission. Finally, the district-wise CH$_4$ emission are summed together to estimate state-wise and national-level CH$_4$ emission.

**Table 1: Specific CH4 emissions factor (kg CH4 head-1 yr-1) for different livestock categories.**

| Category | Enteric fermentation | Manure management |
|----------|----------------------|-------------------|
| Cattle   | Dairy cattle         | 58                |
|          | Non-dairy            | 27                |
| Buffalo  |                      | 55                |
| Sheep    |                      | 5                 |
| Goat     |                      | 5                 |

|          |                      | 0.22              |
Per capita and per unit geographical area-based CH₄ emission flux are calculated for each district of India considering district-wise human population and geographical area data available from the Census of India, 2011 [26]. The district wise CH₄ emission fluxes are presented as GgCO₂e CH₄ km⁻² and Gg CO₂e CH₄ capita⁻¹. In third step, ArcGIS software is used to generate the spatial CH₄ emission distribution map in India at district, state and national level. For a spatial map generation, standard images for different districts and states of India have been collected from the National Remote Sensing Centre (NRSC), Government of India. Once the standard images of the district level map and state level map of India have been collected, CH₄ emission is categorized in to different rank to generate CH₄ emission. However, district level map is not available for Jammu and Kashmir. Therefore, it is represented at state level map.

Results

CH₄ emissions from livestock (cattle, buffalo, goat and sheep) are estimated both from enteric fermentation and manure management processes at district, state and national level in India and the results are presented below.

CH₄ Emission at National Level

Overall, livestock CH₄ emission in India are estimated to be 15.3 Tg CH₄ on annual basis considering 2012 livestock population data as baseline. CH₄ emission related to enteric fermentation and manure management are estimated to be 14.20 Tg and 1.16 Tg, respectively. Thus, it is observed that enteric fermentation contributes more than 90% of emissions. Among the livestock groups, in case of enteric fermentation, livestock category-wise emissions are 51% (7.25 Tg yr⁻¹), 42% (5.97 Tg yr⁻¹), 5% (0.68 Tg yr⁻¹) and 2% (0.30 Tg yr⁻¹) due to cattle, buffalo, goat and sheep, respectively. Similarly, in manure management practices, emission contribution of cattle, buffalo, sheep and goat are estimated at 0.59 Tg yr⁻¹ (50%), 0.43 Tg yr⁻¹ (37%), 0.13 Tg yr⁻¹ (11%) and 0.03 Tg yr⁻¹ (2%), respectively (Figure 2).

Figure 2: Category-wise CH₄ emission due to enteric fermentation and manure management (percentage distribution).

CH₄ Emission at State Level

Among the 28 states and 7 Union Territories (UTs), the highest CH₄ emission is observed in Uttar Pradesh (2746 Gg yr⁻¹), followed by Rajasthan (1528 Gg yr⁻¹) and Madhya Pradesh (1310 Gg yr⁻¹). Spatial distribution of livestock and associated CH₄ emission among the states are shown in Figure 3. It is observed from Figure 3 that Uttar Pradesh, Rajasthan, Madhya Pradesh, Gujarat, Andhra Pradesh and Bihar have annual livestock CH₄ emission greater than 1000 Gg. It is also observed that major
emitting states are distributed in the western and Indo-Gangetic plains of India. In contrast, CH$_4$ emission contributions from all the 8 north-eastern states are very less compared to other parts of the country.

**CH$_4$ Emission at District Level**

![Figure 4: Livestock CH$_4$ emissions from different categories of livestock at district levels in India, (a) livestock CH$_4$ emissions from cattle sector from different districts, (b) livestock CH$_4$ emissions from buffalo from different districts, (c) livestock CH$_4$ emissions from sheep from different districts (d) livestock CH$_4$ emissions from goat from different districts.](image)

CH$_4$ emission show significant variations among the districts of India as shown in Figure 4. The top 10 CH$_4$ emitting districts are listed in Table 2 with other relevant information. The top 3 districts in terms of livestock-related CH$_4$ emissions are Banas Kantha, Gujarat (112 Gg), Paschim Medinipur, West Bengal (103 Gg yr$^{-1}$) and Jaipur, Rajasthan (102 Gg yr$^{-1}$). Furthermore, out of the total 15.3Tg livestock CH$_4$ emission in India, about 50% of the emission is contributed by 153 districts alone (out of total 649 districts). Within the 153 districts, out of the four livestock groups, maximum CH$_4$ emission (more than 50%) is contributed by buffalo in 84 districts followed by cattle (55 districts).

**Table 2: Top 10 CH$_4$ emitting districts in India (emission values in Gg yr$^{-1}$).**

| Livestock category | Top 10 CH$_4$ emitting districts | Livestock population | CH$_4$ emissions (Gg yr$^{-1}$) | CH$_4$ emission |
|--------------------|---------------------------------|----------------------|---------------------------------|-----------------|
| Cattle dairy       | Paschim Medinipur, Ahmadi, Barddhaman, Chittoor, Bankura, Jodhpur, Banas Kantha, Purba | 48                   | 305                             | Among the top 10 districts, the highest and lowest emissions of 46Gg and 24Gg from Paschim Medinipur and Raipur, respectively. |
|                    | Medinipur, and Raipur            |                      |                                 |                  |
| Cattle             | Paschim Medinipur, Bankura, Barddhaman, Raipur, Surguja, Durg, Ahmadnagar, Adilabad, Birbhum, and Nashik | 123                  | 250                             | Highest emission is from Paschim Medinipur (46Gg) and the lowest emission is from Nashik (20Gg) an the top 10 districts. |
| non-dairy          |                                  |                      |                                 |                  |
| Buffalo            | Bulandshahr, Banas Kantha, Aligarh, Jaipur, Alwar, Guntur, Prakasam, Agra, Bharatpur, and Belgaum | 10                   | 604                             | Among the top 10 districts, the highest and lowest emission is from Bulandshahr (74Gg) and Belgaum (49Gg) respectively. |
| Sheep              | Anantapur, Mahbubnagar, Nalgonda, Warangal, Karimnagar, Kurnool, Prakasam, Barmer, Y.S.R., and Chittoor | 20                   | 139                             | Among the top 10 districts, the highest and lowest emission is from Anantapur (28Gg) and Chittoor (9Gg) respectively. |
In case of cattle sector, Paschim Medinipur (West Bengal) shows the highest emission (91 Gg yr⁻¹) among the districts in India. Similarly, at district level in buffalo, goat and sheep sectors, the highest CH₄ emission are observed in Bulanshahar, Uttar Pradesh (73 Gg yr⁻¹), Baran, Rajasthan (15 Gg yr⁻¹) and Anantpur, Andhra Pradesh (27 Gg yr⁻¹), respectively. Thus, this detail GIS-based representation of spatial distribution of livestock CH₄ emission reveals that the highest emitting districts (emission > 50% of total CH₄ emission) located in the states of Uttar Pradesh, Gujarat, West Bengal, Rajasthan, Andhra Pradesh, and Maharashtra (Table 2).

Spatial Distribution of Per Thousand and Per Unit Area Livestock CH₄ Emission

![Figure 5: Spatial Livestock distribution and livestock CH₄ emissions intensity from different districts in India; livestock CH₄ emissions intensity per capita in different districts (left), and livestock CH₄ emissions intensity km⁻² of geographical area (right).](image)

Results of district level spatial distribution of livestock and CH₄ emission in terms of per geographical area and per thousand human populations is discussed below. At country average, CH₄ emission per sq km of land area is 6.02 ton km⁻². At district level, the CH₄ emission intensity ranges from the lowest of 1.8 × 10⁻³ ton km⁻² in Dibang Valley district of Arunachal Pradesh to highest of 42.35 ton km⁻² in Gandhinagar district of Gujarat (Figure 4). For nearly 38% of districts (more than 250 districts), the emissions intensity lies in the ranges of 1ton km⁻² to 5 ton/km⁻² as shown in Figure 5. These districts are mainly located in Maharshtra, Madhya Pradesh, Orissa, Kerala, Rajasthan, and Tamilnadu and in some cases in Sikkim, Manipur, Assam. The maximum emission intensity (> 15 ton km⁻²) is observed in 20 districts of India.

At country average, per capita CH₄ emission in India is 12.71 kg capita⁻¹. At district level, the intensity ranges between the lowest value of 2.4 × 10⁻² kg capita⁻¹ in Delhi and highest of 119 kg capita⁻¹ Surajguja district (Gujarat) (Figure 5). Maximum numbers of districts (250 districts) falls in the emission categories of 10-20 kg capita⁻¹ (Figure 5). These districts are in the Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu and some of the districts of Punjab, Rajasthan, Manipur, and Assam. On the other hand, the highest emission of > 20 kg capita⁻¹ is observed for 16 districts.

It is observed that livestock farming is highly dynamic in India. The higher livestock CH₄ emission regions are distributed along the middle gangetic plain, central plateau region, east coastal plains and western dry regions comprising some highly emission intensive districts and states (Uttar Pradesh, Bihar, Madhya Pradesh, Rajasthan, Andhra Pradesh and Tamilnadu). Livestock farming plays an important role in the economy of these states and districts. For example, in Rajasthan, more than 80% rural families linked with livestock farming and livestock farming contribute about 9.16% to the state GDP which is even greater than the national average GDP (~4%). Furthermore, about 35%-50% of the income to small and marginal farmers comes from the dairy and animal husbandry sectors. In Gujarat, about 5.19% state GDP is contributed by livestock. Considering
the immense contribution of livestock farming to the rural economy of India, therefore, future livestock policies should deal CH₄ emission reduction and sustainable livestock farming simultaneously and appropriately.

**Conclusion**

This study identifies that 50% of emission is contributed by 153 districts alone out of 15.3Tg. Major findings are

a. Cattle and buffalo are the major CH₄ emitter (93%) than other livestock groups.
b. The top CH₄ emitting states are Uttar Pradesh, Rajasthan and Madhya Pradesh.
c. The top emitting districts are Banas Kantha, Paschim Medinipur and Jaipur.
d. CH₄ emission intensity is 6.02ton km⁻² and 12.71 kg capita⁻¹.

Thus, livestock CH₄ emission spatial distribution indicate the hotspots region of emission and these findings can be useful to develop districts or state level policy for sustainable livestock farming.

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