Spatial pattern of methane emissions from Indian livestock

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Methane is an important greenhouse gas which significantly contributes to global warming. Livestock is a major anthropogenic source of methane emission from agriculture. India possesses the world's largest livestock population of 485 million, with a high degree of diversity in its composition. Among the livestock categories, cattle dominate with 38.2% followed by goat (25.7%), buffalo (20.2%), sheep (12.7%) and others (3.3%). The detailed state/district-level methane emission inventory by age-groups, indigenous and exotic breeds of different livestock categories was estimated using the country-specific and Indian feed standard-based emission coefficients and recent livestock census 2003. The total methane emission from Indian livestock, which includes enteric fermentation and manure management, was 11.75 Tg for 2003. Enteric fermentation accounts for 10.65 Tg (~91%) compared to 1.09 Tg (~9%) by manure management. Dairy buffalo and indigenous dairy cattle together contribute 60% of the total methane emission. The three high methane emitter states are Uttar Pradesh (14.9%), Rajasthan (9.1%) and Madhya Pradesh (8.5%). The detailed district-level spatial analysis in GIS environment resulted in the identification of clusters of districts with high emissions. Among these, Mednipur District (West Bengal) reported the highest total methane emission of 0.12 Tg. Using the remote sensing-derived livestock available feed/fodder area, the average methane flux from Indian livestock was computed as 74.4 kg/ha.

Keywords: Enteric fermentation, livestock census, manure management, methane emission coefficient.

LIVESTOCK is the most important source of methane emission from the agricultural sector. Livestock contributes about 18% of the global greenhouse gas (GHG) emissions, and as much as 37% of anthropogenic methane, mostly from enteric fermentation by ruminants[1]. Methane emissions from livestock have two components: emission from 'enteric fermentation' and 'manure management'. Ruminant animals, particularly cattle, buffalo, sheep, goat and camel produce significant amounts of methane under anaerobic conditions as part of their normal digestive processes. This microbial fermentation process, referred to as 'enteric fermentation', produces methane as a by-product, which is released mainly through eructation and normal respiration, and a small quantity as flatus. Methane is also produced during anaerobic decomposition of livestock manure by anaerobic and facultative bacteria. Livestock rearing has been an integral part of the agricultural system in India. Currently, India possesses the world's largest livestock population of 485 million, which accounts for 13% of the global livestock population[2]. It has 57% of the world's buffalo and 16% of the cattle population. It ranks first with respect to cattle and buffalo population, second in goat, third in sheep and camel, and seventh in poultry populations in the world[3]. Various attempts have been made earlier to estimate the methane emissions from Indian livestock. A summary of earlier estimates and their approach is presented in Table 1. The current study is aimed at generating the national livestock methane emission inventory using the recent livestock census (2003) and country-specific Indian feed standard-based emission coefficients. The spatial patterns of State/district emissions were derived in GIS environment for detailed analysis. The district-level methane emission flux from livestock was also computed.

A detailed statistical database of age, gender, species-wise population of different livestock categories viz. cattle, buffalo, sheep, goat and others (including horse, pony, mule, donkey, camel, pig) was prepared at the all-India, State/Union Territory, and district levels using the livestock census[2] available on-line. The emission coefficients for methane emissions from enteric fermentation and manure management of different livestock categories were adopted from reported studies[4–6]. These coefficients are country-specific, conform to IPCC good practice guidelines, and have been developed for India's Initial National Communication to the United Nations Framework Convention on Climate Change (IINC–UNFCCC). The statistical approach was used to develop an understanding of the long-term changes in livestock population in India during 1951–2003, and distribution of population under different livestock categories at the all-India, State and district levels for the recent census. A detailed analysis approach was adopted for the estimation of methane emissions from enteric fermentation and manure management. The male and female cattle and buffalo populations were considered under non-dairy and dairy categories respectively.

The district-level emission from enteric fermentation was computed as a product of the livestock population under each category and its emission coefficient. For non-dairy cattle and buffalo, the emission coefficients are based on age group of the livestock, viz. below 1 year, 1–3 years and above 3 years (adult). Emissions from all livestock categories (dairy cattle, non-dairy cattle, dairy buffalo, non-dairy buffalo, sheep, goat, horse, pony, mule, donkey, camel and pig) were aggregated to total emission.

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Table 1. Summary of earlier livestock methane estimates for India

Approach for estimation	Methane emission (Tg)	Estimate year	Reference
Methane emission measurement from cattle and buffalo using facemask technique and regression analysis	–	–	8
Default methane emission factors	10.40	1985	9
Using IPCC (1995) methodology	18.48	1990	10
In vitro dry matter digestibility evaluation of feed resources in different regions	9.02	1992	11
Emission estimates for enteric fermentation only and based on amount and quality of available feed resources	7.26–10.4	1995	12, 13
Country-specific methane emission factors derived from Indian feed standards, IPCC energy equations and dry matter estimation	9.9	1994	5
Dry matter intake approach under different agro-climatic regions	10.07	1994	14
Country-specific Indian feed standard-based methodology as a measure of gross energy intake and derived methane emission factors	9.00	1994	6

$$\mathrm{ME_{ef}} = \sum_{d=1}^{N_d} \left(\sum_{l=1}^{N_l} P_{dl} * E_{dl} + \sum_{l=1}^{N_l} \sum_{a}^{N_a} P_{dla} * E_{dla} \right) * 10^{-9},$$

where $\mathrm{ME_{ef}}$ is the aggregated annual methane emission from enteric fermentation in Tg (Tg = 10^{12} g) at the national level integrated over all the districts and for all livestock categories, P the district-level population (in numbers) of each livestock category (l), d the district, a the age group of livestock, and E is the methane emission coefficient (kg CH_4/animal/yr) for enteric fermentation of each livestock category.

The estimated district-level emissions using IINC–UNFCC coefficients were also cross-compared with district-level estimates made using emission coefficients derived from five other approaches, namely IPCC default tier-I emission factors, National Dairy Research Institute (NDRI), Indian feed standard-based Central Leather Research Institute (CLRI), livestock methane measurements by National Physical Laboratory (NPL), and Asia Least-cost Greenhouse gas Abatement Strategy (ALGAS). Using the IINC and NPL coefficients, district-level methane estimates were made under all three scenarios, viz. maximum, average and minimum for different livestock categories.

The district-level emission from manure management was computed as a product of the livestock population under each category and its emission coefficient. For non-dairy cattle and buffalo, the emission coefficients were based on age group of the livestock, viz. below 1 year, 1–3 years and above 3 years (adult). Emissions from all livestock categories (dairy cattle, non-dairy cattle, dairy buffalo, non-dairy buffalo, sheep, goat, horse, pony, mule, donkey, camel and pig) were aggregated to total emission.

$$\mathrm{ME_{mm}} = \sum_{d=1}^{N_d} \left(\sum_{l=1}^{N_l} P_{dl} * M_{dl} + \sum_{l=1}^{N_l} \sum_{a}^{N_a} P_{dla} * M_{dla} \right) * 10^{-9},$$

where $\mathrm{ME_{mm}}$ is the aggregated annual methane emission from manure management (Tg) at the national level integrated over all the districts and for all livestock categories, P the district-level population (in numbers) of each livestock category (l), d the district, a the age group of the livestock and M the methane emission coefficient (kg CH_4/animal/yr) for manure management of each livestock category.

Methane emissions from enteric fermentation and manure management estimated for different livestock categories of each district were added to arrive at the total methane emission. District-level emissions were aggregated at State/national level to arrive at the total methane emission. For regional methane emissions, district estimates were first aggregated into States and further into northern, eastern, western and southern regions based on the geographical location of the State.

$$\mathrm{LME} = \sum_{d=1}^{N_d} \left\{ \left(\sum_{l=1}^{N_l} P_{dl} * E_{dl} + \sum_{l=1}^{N_l} \sum_{a}^{N_a} P_{dla} * E_{dla} \right) + \left(\sum_{l=1}^{N_l} P_{dl} * M_{dl} + \sum_{l=1}^{N_l} \sum_{a}^{N_a} P_{dla} * M_{dla} \right) \right\} * 10^{-9},$$

where LME is the total livestock-based annual methane emission (Tg) at the national level integrated over all the districts and for all livestock categories, P the district-level population (in numbers) of each livestock category (l), d the district, a is the age-group of livestock and E and M are the methane emission coefficients (kg CH_4/animal/yr) respectively, for enteric fermentation and manure management of each livestock category.

The spatial framework of administrative State and district boundary coverage was created using GIS ARC/INFO ver. 8.3, with Albers Conical Equal Area projection. The State/district estimates of livestock population, methane emission from enteric fermentation, manure management, total emission and other outputs were linked in GIS and logical decisions were used to derive the district and State-level patterns. Qualitative analysis of the total methane emissions among the States/Union Territories classified them into high (above 1.0 Tg), moderate (1.0–0.5 Tg) and low (below 0.5 Tg) categories. Remote sensing-based all-India 1-km land-cover classification map[7] derived using SPOT–VEGETATION (November 1999 to December 2000) and DMSP–OLS data was used to obtain total feed/fodder area available for the livestock. The georeferenced land-cover data with 17 classes were first reprojected to Albers Conical Equal Area and then intersected with district level administrative boundary GIS coverage to derive the potential feed/fodder area (which includes area classified under agriculture and grasslands, including alpine meadow and savannah) available for the livestock in each district. The methane flux (kg/ha) was calculated using total methane emission (enteric fermentation and manure management) and estimated feed/fodder area for each district.

Indian livestock shows a high degree of diversity in its composition. Numerically, cattle dominate with 185.2 million (38.2%), followed by goat 124.3 million (25.7%), buffalo 97.9 million (20.2%), sheep 61.5 million (12.7%) and other livestock 15.7 million (3.3%) according to the recent census 2003. Among the other livestock categories, horse, pony, mule, donkey and camel constitute only 0.15, 0.06, 0.14, and 0.13% respectively. Figure 1 shows the distribution of livestock populations among different categories. Among the cattle, indigenous animals (~87%) dominated over exotic or crossbred species (13%). Dairy buffalo accounts for 80.03 million (82%) and non-dairy buffalo only 17.9 million (18.2%) of the total buffalo population. The cattle and buffalo together constitute 283.4 million or 58.4% of the total livestock population. The long-term analysis of the census data for the period 1951–2003 indicates that the total population has increased by 192.2 million (~65%), with an annual growth rate of 1.26%. Uttar Pradesh, Rajasthan and Andhra Pradesh are the top three States with 58.5, 49.1 and 48.2 million total livestock population, respectively. Among the districts, Mednipur (West Bengal) leads with highest cattle and buffalo population of 3.54 million, followed by Jhalawar (Rajasthan) with 2.7 million.

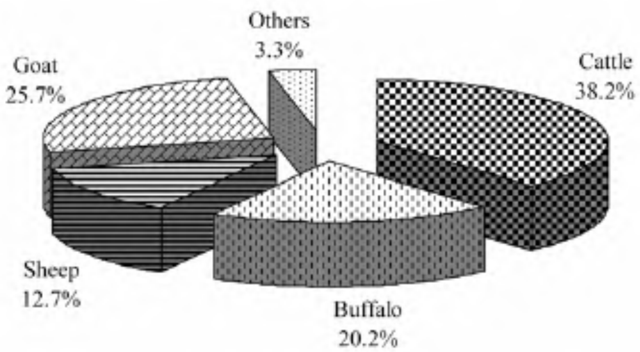

Figure 1. Distribution of Indian livestock populations among different categories (2003).

The estimated methane emission from enteric fermentation of Indian livestock was 10.65 Tg (range 8.1–13.3 Tg). However, NPL-based approach resulted in a total emission of 10.7 Tg (range 9.5–11.8 Tg). Estimates made using other approaches were 12.9 Tg (IPCC default emission factors), 12.3 Tg (NDRI-based emission factors), 8.9 Tg (Indian feed standard-based CLRI approach) and 7.8 Tg (ALGAS). Estimates based on IPCC default and NDRI-based emission factors were 16–22% higher than the estimate based on IINC–UNFCC approach due to higher emission factors for indigenous dairy cattle and buffalo. Amongst the categories, cattle, buffalo, sheep and goat constitute 51%, 42%, 2% and 4.2% respectively, while other livestock contribute only 0.6% to the total emissions from enteric fermentation. Among the cattle, methane emissions from indigenous dairy and non-dairy cattle (2.32 and 2.12 Tg) were higher than exotic dairy and non-dairy cattle (0.85 and 0.11 Tg) due to their higher population and emission coefficients. Young non-dairy cattle and buffalo below 1 year of age produced less methane by enteric fermentation compared to adult animals. Dairy buffalo had higher population as well as emission coefficient compared to non-dairy buffalo, resulting in nine-fold higher methane emission. Detailed estimates of methane emission from enteric fermentation of different livestock categories using different approaches and scenarios are given in Table 2. Methane emission from manure management of all livestock was estimated as 1.09 Tg. Detailed category-wise estimates indicate that other livestock contribute only 0.094 Tg in comparison to 0.99 Tg by cattle and buffalo.

The total estimated methane emission (which includes enteric fermentation and manure management) from Indian livestock was 11.75 Tg for the year 2003. Enteric fermentation constitutes a major part of the total methane emissions accounting for ~91% or 10.65 Tg of the total, while manure management of livestock accounts for only 9% or 1.09 Tg. Cattle and buffalo are the major source of methane emission (10.9 Tg) compared to 0.86 Tg emission from other livestock. Among the livestock categories,

Table 2. Livestock category-wise estimates of methane emission (Tg) from enteric fermentation based on different approaches for 2003

	Approach									
	IINC			NPL						
Livestock category	Minimum	Average	Maximum	Minimum	Average	Maximum	IPCC	NDRI	CLRI	ALGAS
Dairy cattle										
Indigenous	1.91	2.32	2.74	1.99	2.32	2.57	3.82	2.74	1.91	1.91
Exotic	0.75	0.84	0.95	0.77	0.97	1.17	0.91	0.77	0.83	0.63
Non-dairy cattle (indigenous)										
Below 1 yr	0.08	0.09	0.10	0.10	0.12	0.14	0.17	0.08	0.06	0.04
1–3 yrs	0.25	0.27	0.37	0.46	0.37	0.42	0.42	0.27	0.39	0.27
Adults	1.26	1.76	2.09	1.70	2.09	2.25	1.21	1.50	1.31	0.97
Non-dairy cattle (exotic)										
Below 1 yr	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.02	0.02	0.01
1–3 yrs	0.16	0.03	0.04	0.19	0.03	0.04	0.19	0.16	0.21	0.07
Adults	0.07	0.06	0.07	0.08	0.07	0.08	0.06	0.08	0.07	0.07
Dairy buffalo	2.68	4.06	5.45	3.17	3.42	3.66	4.47	5.61	3.09	2.60
Non-dairy buffalo										
Below 1 year	0.04	0.06	0.08	0.07	0.09	0.10	0.17	0.04	0.04	0.05
1–3 yrs	0.06	0.08	0.11	0.10	0.11	0.12	0.21	0.07	0.08	0.08
Adults	0.22	0.29	0.37	0.30	0.33	0.35	0.37	0.35	0.21	0.18
Sheep	0.18	0.23	0.29	0.18	0.23	0.29	0.29	0.23	0.23	0.29
Goat	0.34	0.45	0.58	0.34	0.45	0.57	0.57	0.34	0.34	0.57
Horse and pony	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mule and donkey	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Camel	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Pig	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	8.08	10.65	13.32	9.53	10.7	11.85	12.96	12.33	8.86	7.82

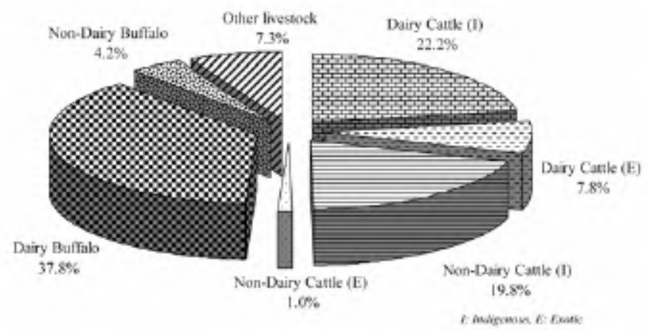

Figure 2. Contribution of different livestock categories to total methane emission (2003).

dairy buffalo contribute maximum emission of 4.4 Tg or ~38%, followed by 2.6 Tg or 22.2% by indigenous dairy cattle. The proportional contribution of dairy buffalo, indigenous dairy cattle, indigenous non-dairy cattle, exotic dairy cattle, minor livestock, non-dairy buffalo and exotic non-dairy cattle was 37.8, 22.2, 19.8, 7.8, 7.3, 4.2 and 1.04% respectively (Figure 2). Detailed population and methane emissions from enteric fermentation and manure management of different livestock categories for the year 2003 are given in Table 3. Uttar Pradesh, Rajasthan and Madhya Pradesh are three high methane emitter States, with a contribution of 1.75 Tg (14.9%), 1.07 Tg (9.1%) and 1.00 Tg (8.5%) respectively. Detailed estimates of State/region-wise livestock population and methane emissions from enteric fermentation and manure management for the year 2003 are given in Table 4. The present estimate for total methane emission of 11.75 Tg (for 2003) is higher in comparison to the earlier estimates (9.9 Tg for 1994 (ref. 5) and 9 Tg for 1997 (ref. 6)). During 1997–2003, the buffalo population had increased by 8.0 million, of which more than 50% increase is attributed to adult dairy buffalo. The methane emission coefficients for dairy buffalo are highest among the livestock categories. Although the cattle population decreased by 13.7 million, the exotic cattle (with higher methane emission coefficient for enteric fermentation) have increased by 4.6 million. Among the other livestock, sheep and goat population has also increased by 3.9 and 1.7 million respectively, during this period. The present inventory was made using country-specific and Indian feed standard-based emission coefficients and the 2003 census.

The spatial analysis in GIS has identified a few districts like Bankura, Burdwan, Mednipur, Murshidabad, North 24-Parganas, South 24-Parganas (West Bengal), Ananthpur, Guntur, Mahboobnagar, Nalgonda, Prakasham, Warangal (Andhra Pradesh), Udaipur, Jaipur (Rajasthan),

Table 3. Category-wise population and methane emission estimates for 2003

Livestock category	Population (millions)	Enteric fermentation emission (Tg)	Manure management emission (Tg)	Total emission (Tg)	Percentage contribution
Dairy cattle					
Indigenous	82.96	2.32	0.289	2.61	22.20
Exotic	19.74	0.84	0.074	0.92	7.83
Sub-total	102.70	3.17	0.363	3.54	30.03
Non-dairy cattle (indigenous)					
Below 1 yr	9.85	0.09	0.012	0.102	0.87
1–3 yrs	12.00	0.27	0.034	0.304	2.59
Adults	55.68	1.76	0.162	1.922	16.36
Sub-total	77.53	2.12	0.208	2.33	19.78
Non-dairy cattle (exotic)					
Below 1 yr	1.90	0.02	0.002	0.022	0.19
1–3 yrs	1.14	0.03	0.003	0.033	0.28
Adults	1.87	0.06	0.004	0.064	0.54
Sub-total	4.91	0.11	0.01	0.12	1.04
Dairy buffalo	80.03	4.06	0.371	4.441	37.78
Non-dairy buffalo					
Below 1 yr	7.37	0.06	0.013	0.073	0.62
1–3 yrs	3.83	0.08	0.014	0.094	0.79
Adults	6.68	0.29	0.028	0.318	2.70
Sub-total	17.88	0.44	0.055	0.490	4.17
Sheep	61.40	0.23	0.010	0.240	2.04
Goat	124.35	0.45	0.020	0.470	3.99
Horse and pony	0.75	0.01	0.001	0.011	0.09
Mule and donkey	0.65	0.02	0.002	0.022	0.19
Camel	0.63	0.03	0.001	0.031	0.26
Pig	13.52	0.01	0.060	0.070	0.59
Sub-total	201.30	0.77	0.094	0.860	7.30
Total	485.00	10.65	1.09	11.75	

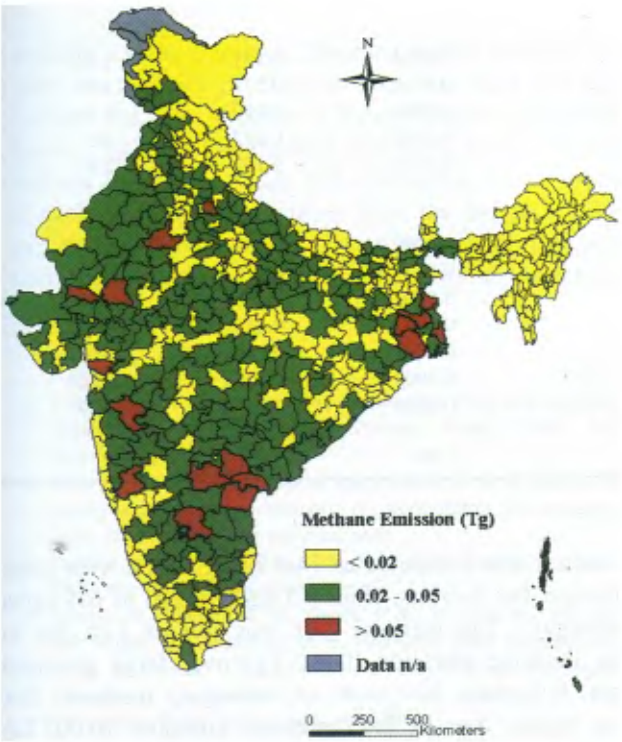

Figure 3. District-level pattern of total methane emission for 2003.

Surat, Banaskantha (Gujarat), Ahmednagar (Maharashtra), Belgaum (Karnataka) and Bulandshar (Uttar Pradesh) with total methane emission above 0.05 Tg. Most of the districts have total methane emission in the range 0.02–0.05 Tg. Almost all districts in the northeastern States, Sikkim, Goa, Himachal Pradesh, Kerala and Uttarakhand lie in the range of very low methane emission (below 0.02 Tg). Detailed district-level analysis indicated high emission in Mednipur (0.12 Tg) and Burdwan (0.067 Tg) districts of West Bengal. District-level spatial pattern of total methane emission (Tg) for the year 2003 is shown in Figure 3. Doda, Budgam, Kupwara and Pulwama districts (Jammu and Kashmir) and Ariyalur District (Tamil Nadu) were not included in this analysis as data were not available. A qualitative spatial comparison of methane emissions from enteric fermentation and manure management, and total methane emission classified all the States and Union Territories into three categories of high, moderate, and low emissions (Figure 4). Uttar Pradesh, Rajasthan and Madhya Pradesh are in the high category with total methane emission above 1.0 Tg, followed by moderate emissions (1.0–0.5 Tg) in Andhra Pradesh, Bihar, Gujarat, Maharashtra, Karnataka, Orissa and West Bengal. Chhattisgarh, Delhi, Haryana, Himachal Pradesh, Goa,

Table 4. State/region-wise detailed estimates of methane emissions (Tg) for 2003

Region/State or Union Territory	Livestock population (millions)	Enteric fermentation emission (Tg)	Manure management emission (Tg)	Total emission (Tg)	Percentage contribution
Northern region					
Delhi	0.37	0.02	0.0006	0.021	0.18
Haryana	8.88	0.33	0.0050	0.330	2.81
Himachal Pradesh	5.12	0.10	0.0359	0.134	1.14
Jammu and Kashmir	9.90	0.15	0.0126	0.163	1.38
Punjab	8.61	0.36	0.0323	0.392	3.34
Uttarakhand	4.94	0.13	0.0126	0.143	1.22
Uttar Pradesh	58.53	1.59	0.1631	1.753	14.92
Sub-total	96.35	2.68	0.2621	2.936	24.99
Eastern region					
Arunachal Pradesh	1.26	0.01	0.0025	0.012	0.10
Assam	13.83	0.27	0.0791	0.349	2.97
Bihar	27.16	0.58	0.0253	0.605	5.15
Jharkhand	15.83	0.30	0.0349	0.335	2.85
Manipur	0.97	0.02	0.0034	0.023	0.19
Meghalaya	1.55	0.02	0.0044	0.024	0.20
Mizoram	0.28	0.00	0.0011	0.001	0.01
Nagaland	1.35	0.02	0.0047	0.025	0.21
Orissa	23.39	0.49	0.0523	0.542	4.61
Sikkim	0.34	0.01	0.0007	0.011	0.09
Tripura	1.46	0.02	0.0034	0.023	0.19
West Bengal	41.62	0.66	0.0730	0.733	6.24
Sub-total	129.03	2.41	0.2848	2.695	22.81
Western region					
Chhattisgarh	13.49	0.03	0.0532	0.083	0.71
Goa	0.21	0.00	0.0005	0.0005	0.00
Gujarat	21.65	0.58	0.0183	0.598	5.08
Madhya Pradesh	35.62	0.91	0.0936	1.004	8.53
Maharashtra	36.76	0.83	0.0814	0.911	7.74
Rajasthan	49.14	0.98	0.0911	1.071	9.10
Sub-total	156.88	3.63	0.3381	3.968	33.78
Southern region					
Andhra Pradesh	48.19	0.88	0.0806	0.961	8.18
Karnataka	25.62	0.52	0.0510	0.571	4.86
Kerala	3.48	0.09	0.0086	0.099	0.84
Tamil Nadu	24.94	0.43	0.0417	0.472	4.01
Sub-total	102.24	1.92	0.1819	2.102	17.89
Union Territory					
Andaman and Nicobar Islands	0.19	0.00	0.0005	0.0005	0.00
Chandigarh	0.031	0.00	0.0100	0.010	0.08
Dadra Nagar Haveli	0.078	0.00	0.0003	0.0003	0.00
Daman and Diu	0.01	0.00	0.0181	0.0181	0.15
Lakshdweep	0.052	0.00	0.0002	0.0002	0.002
Puducherry	0.13	0.00	0.0003	0.0003	0.002
Sub-total	0.50	0.01	0.0294	0.0394	0.34
All-India	485.00	10.65	1.09	11.75	100

Jammu and Kashmir, Jharkhand, Kerala, Punjab, Sikkim, Tamil Nadu, Uttrakhand and the Union Territories, i.e. Andaman and Nicobar Islands, Chandigarh, Dadra and Nagar Haveli, Daman and Diu, Lakshdweep and Puducherry are in the low emissions category (below 0.5 Tg). Using the remote sensing-derived available livestock feed/fodder area, the average methane flux from Indian livestock was computed as 74.4 kg/ha with a wide range amongst the districts, from 0.5 kg/ha (Leh) to 612 kg/ha (Srinagar). The methane flux was low in Leh due to low methane emission (0.003 Tg) over large grassland area (~5 mha). However in Srinagar, methane flux was higher due to low methane emission (0.007 Tg) accompanied with lesser feed/fodder area (0.01 mha)

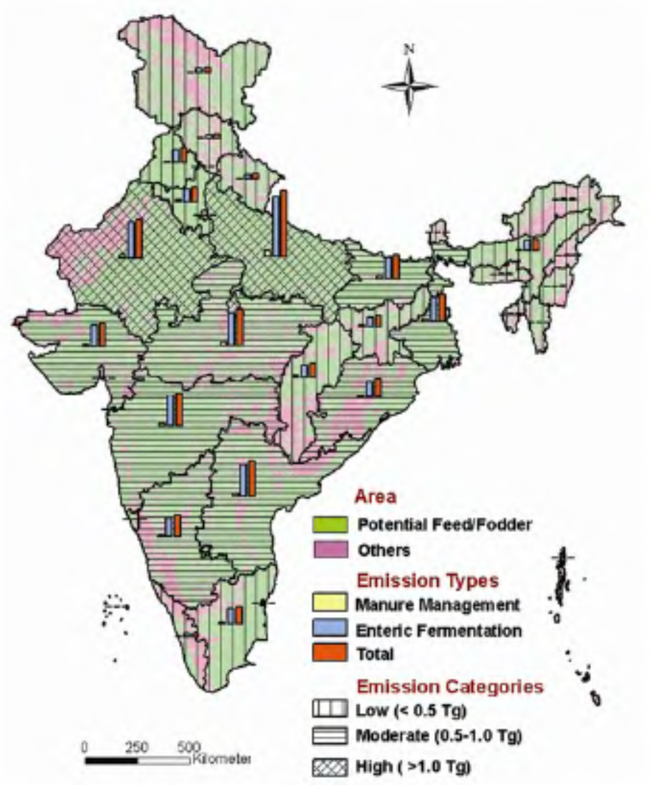

Figure 4. Spatial distribution of methane emission from livestock among States/Union Territories for 2003. (Potential feed/fodder area implies both area under crops and grasslands available for livestock. Other areas include land-cover classes like forest, snow or ice, water bodies, wetlands, bare soil, urban built-up land, etc.)

available for the livestock. Detailed spatial analysis indicated the majority of districts with less than 100 kg/ha methane flux. Few districts in Bihar, Haryana, Karnataka, Kerala, Punjab, Uttar Pradesh and West Bengal reported methane flux in the range 101–250 kg/ha. These outputs of methane emission inventory from the Indian livestock are important inputs for generating spatial integrated multi-source methane emission inventory at the national level.

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ACKNOWLEDGEMENTS. This study was carried out as part of the Environment Impact Assessment of Agriculture project under Earth Observation Applications Mission Programme of DOS–ISRO. We thank Dr R. R. Navalgund, Director, SAC, Ahmedabad for encouragement and the Indiastat team for providing on-line livestock statistics.

Received 27 March 2008; revised accepted 13 January 2009

Molecular diagnosis of transgenic tomato with *osmotin* gene using multiplex polymerase chain reaction

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The requirement for upgradation of analytical methods for the detection of genetically modified (GM) crops is increasing at a fast pace, with a quantum jump in the area of GM crops being grown globally to meet the regulatory and international trade requirements. In the present study, standardization of multiplex polymerase chain reaction (MPCR) for the detection of

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