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Chapter

Methane Emission Assessment from Indian Livestock and Its Role in Climate Change Using Climate Metrics

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Abstract

Indian livestock farming is one of the significant anthropogenic sources of methane (CH_4) in the world. Here, CH_4 emission from Indian livestock and climate change impact in terms of two climate metrics, global surface temperature change potential (GTP) and absolute GTP (AGTP), to assess the surface temperature changes for 20 and 100 year time frame have been studied. CH_4 emission from Indian livestock was 15.3 Tg in 2012. GTP_{20} and GTP_{100} for livestock-related CH_4 emission in India in 2012 were 1030 and 62 Tg CO_2e, respectively. The study also illustrates that CH_4 emissions can cause a surface temperature increase of up to 0.7–0.036 mK over the 20 and 100 year time periods, respectively. Thus, the negative climate change impact is global in nature, not only restricted to India. GTP and AGTP can be used in climate change impact study and as a more policy relevant tool.

Keywords: CH_4 emission, climate change, global temperature change potential (GTP), absolute GTP (AGTP)

1. Introduction

With the growing awareness toward the detrimental impacts of climate change, identifying and controlling of potential sources of greenhouse gas (GHG) emission have become a universal priority. Livestock farming is one of the most prominent anthropogenic sources of GHGs [1–3]. The total global GHG emission from livestock is 7.1 gigatonnes CO_2e year^{-1}, which accounts for 14.5% of all anthropogenic emissions [4, 5]. India, China, Brazil, and the USA are major regional contributors of GHG emission from livestock [6]. The growing economy and increasing demand for livestock products such as meat and dairy products increase challenges on livestock production and thus risk for climate change [7]. Therefore, it is very important in the coming future to reduce GHG emissions from livestock and promote sustainable livestock farming [8].

For sustainable livestock farming, climate change impact assessment of GHG emission and effective climate mitigation policies development are needed. For

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climate impact assessment, different climate metrics are being used to assess the climatic impact of non-CO_2 GHGs in terms of CO_2 equivalent emission [9, 10]. These climate metrics are estimated in tonnes of CO_2e per year by multiplying each non-CO_2 GHG emission with their absolute value [11]. Different climate metrics are available with different time horizons such as 20, 50, and 100 years, and it can be used for different non-CO_2 GHGs [6]. The assessment may be applied instantaneously or may be integrated over a specified period of time [6]. In IPCC first assessment report, global warming potential (GWP) is proposed as a method for comparing the potential climate impact of different non-CO_2 GHGs with reference to CO_2 [12]. But later on, the use of GWP in climate impact assessment has not been encouraged by many scientists as GWP does not explain the magnitude of climate change, i.e., impact on temperature rise [12, 13]. Thus, [14] proposed the global surface temperature change potential (GTP) as an alternative metric to GWP to assess climate change impact of GHG emission on climate change to assess its potential impact on surface temperature rise.

The GTP is the ratio of the change in the global mean surface temperature due to pulse or sustained GHG emission relative to CO_2 at a given time period. The GTP is more useful for those GHGs which have lifetime less than CO_2 such as short-lived GHG: CH_4 [15–17]. In comparison with GWP, the GTP gives climate impact in terms of change in temperature, and so it is a more policy-relevant tool for climate change impact mitigation [13, 15].

The negative climate change impact due to CH_4 emission is global in nature, not only restricted to India. Thus, the present chapter is focused on livestock-mediated CH_4 emission estimation in India and also to assess its role in climate change impact in terms of global surface temperature change potential (GTP) and absolute global surface temperature change potential (AGTP) for potential rise in surface temperature to identify the role of Indian livestock in climate change impact. This study focuses to evaluate the impact of livestock-mediated CH_4 emission on surface temperature change. Thus, the study helps researchers and scientists to predict climate change impact evaluation in terms of potential rise in global surface temperature using climate metrics due to any anthropogenic emission sources in future.

2. Methodology

The methodology is divided into three sections as presented in flow chart (**Figure 1**).

2.1 Livestock database collection

The livestock population database is taken from the Department of Animal Husbandry and Statistics, India, for the year 2012 [18]. The livestock census covers all the states (28) and 7 union territories (UTs) as well as all the districts (649) of India [19]. Once, the database is collected, it is sorted and categorized into four categories: cattle, buffalo, goat, and sheep. The cattle group is further categorized into two categories: dairy and nondairy cattle. Other livestock categories including population of pigs, horses, mules, and ponies are comparatively small (less than 5% of total livestock population) and therefore not included in the research work here.

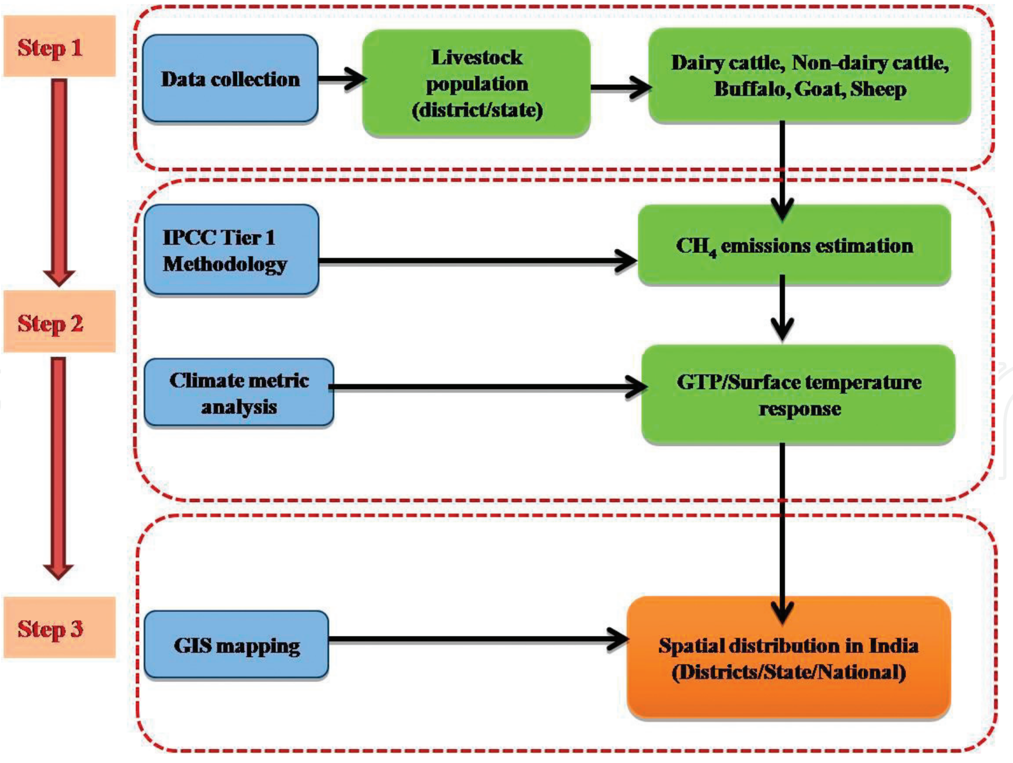

Figure 1.
Flow chart of methodology for estimation of CH_4 and climate metrics assessment. And results are represented in GIS mapping at district, state, and national level.

2.2 Estimation of CH_4 emission

Here, in IPCC guidelines, Tier 1 methodology is used for CH_4 emission estimation [20]. In IPCC Tier 1 methodology, country-wise livestock category-wise specific emission factors are available for enteric fermentation and manure management as shown in **Table 1**. The equation followed in CH_4 emission estimation is shown in **Table 2** as Eq. (1).

2.3 Other climatic metric assessments

The second objective of the present work of the book chapter is climate metric assessment of livestock-related CH_4 emission. Two climate metrics, viz., global surface temperature change potential (GTP) and absolute global surface temperature change potential (AGTP) and surface temperature response were applied for the CH_4 emission estimation from livestock at district, state, and national level.

Category		Enteric fermentation	Manure management
Cattle	Dairy cattle	58	5
	Non-dairy	27	2
Buffalo		55	4
Sheep		5	2
Goat		5	0.22

*IPCC 2006 guidelines.

Table 1.
Specific CH_4 emission factor (kg CH_4 head^{-1} year^{-1}) of different livestock categories.*

Equations with their description
$E_d = \sum_{i=1}^{z} (p_i) \times EF_i$ (1) where, E_d is the CH_4 emission from enteric fermentation and manure management for the *i*th category of livestock (e.g., dairy cattle) in kg $year^{-1}$; p_i is the district wise population of *i*th category of livestock in million; and EF_i is the specific emission factor for *i*th category of livestock in kg CH_4 $head^{-1}$ $year^{-1}$
$GTP_{dt} = E_d \times GTP_t$ (2) GTP_{dt} is **GTP** of livestock-related CH_4 emission for *d*th district at time "**t**" (20 or 100 years), kg CO_2e; E_d is derived from Eq. 1; GTP_t is **GTP** at "**t**" time scale, which is equivalent to 67 for 20 year (GTP_{20}) and 4 for 100 year time horizon (GTP_{100}) [11]
$AGTP_{(CH_4)_t} = A_{CH_4} \times \sum_{j=1}^{2} \left[\left(\frac{\alpha \times c_j}{\alpha - d_j} \right) \times \left(e^{-t/\alpha} - e^{-t/d_j} \right) \right]$ (3) $AGTP_{(CH_4)_t}$ is the absolute global temperature potential of CH_4, K kg^{-1}, and t is 20 or 100 year time horizon; A_{CH_4} is radiative forcing of CH_4, 2.1×10^{-13} W $(kg\ m^2)^{-1}$; α is perturbation life or e-folding time of CH_4, 12 years; c_j is climate sensitive parameters and d_j response times [11]. c_1 and c_2 are 0.631 and 0.429, respectively; d_1 and d_2 are 8.4 and 409.5, respectively; $e^{-t/\alpha}$ is known as an impulse radiative flux (IRF), i.e., changes in instantaneous radiative flux due to pulse emission of GHGs
$\Delta T_t = E_d \times AGTP_{(CH_4)_t}$ (4) An annual CH_4 emission (kg) is multiplied by the **AGTP** values to arrive at the potential of temperature change (ΔT) in a given year (annual AGTP). In the equation, ΔT_t is temperature change response, K; E_d is CH_4 emission attributed by livestock, kg $year^{-1}$

Table 2.
Mathematical expression for CH_4 estimation and climate metric assessment used in methodology.

Climate metric GTP (CH_4) for two different time horizons, i.e., 20 and 100 years, is estimated as GTP_{20} and GTP_{100} as shown in Eq. (2) in **Table 2**. These two different assessments are highly significant for the GHGs, which have a shorter lifetime than CO_2 and more impact in a shorter time period than longer time horizon.

The AGTP estimates the temperature change (in Kelvin, K) at a time (t) associated with GHG emission as shown in Eq. (3) in **Table 2** [11, 12, 21]. The instantaneous surface temperature response (ΔT) is estimated by multiplication of annual CH_4 emission and AGTP [22]. Annual ΔT is used for evaluation of the direct temperature effects contributed by an annual rate of CH_4 emission over time from livestock as shown in Eq. (4) in **Table 2**.

2.4 GIS map generation

After the estimation of CH_4 emission and climate metric assessment from livestock CH_4 emission, GIS software, i.e., ArcGIS software, is applied to generation of spatial map for India up to state and district level. The GIS provides better understanding of results in the form of computerized spatial map. For GIS mapping, standard images have been collected from the National Remote Sensing Centre (NRSC), Government of India, for different districts and states of India. Once these standard images of the district level map and state level map of India have been collected, GIS mapping has been prepared. However, district level map could not be prepared for Jammu and Kashmir and represented at state level map, as their standard images up to district level are not available.

3. Results and discussion

The estimation of CH_4 emission from four different livestock categories, cattle, buffalo, goat, and sheep, in India are evaluated at districts, state, and national level using Eq. (1) mentioned in **Table 2**. In addition to CH_4 emission estimation, climate metrics, viz., global surface temperature change potential and absolute global surface temperature change potential and surface temperature response, are also estimated here (Eqs. (2)–(4), **Table 2**) to understand the climate change impact due to livestock-related CH_4 emission. The results are discussed below.

3.1 CH_4 emission

Using specific emission factors and IPCC Tier 1 methodology, the CH_4 emission in India was estimated to be 15.3 Tg CH_4 in 2012. CH_4 emission related to enteric fermentation is 92% of total CH_4 emission (14.20 Tg CH_4) and the rest 8% (1.16 Tg CH_4) of total CH_4 emission from manure management, respectively. Among the livestock groups, the highest CH_4 emission is contributed by the cattle group which is nearly 51% of total livestock CH_4 emission, and the lowest CH_4 emission is contributed by sheep (as shown in **Table 3**).

Among the 29 states, the top three most emitting states are Uttar Pradesh (2.89 Tg CH_4), followed by Rajasthan (1.52 Tg CH_4) and Madhya Pradesh (1.30 Tg CH_4), and the lowest is in Mizoram (0.018 Tg CH_4). The spatial representation of CH_4 emission at state level is represented through **Figure 2**. From the spatial diagram of livestock CH_4 emission, it is observed that the major emitting states are distributed across the western and the Indo-Gangetic plains of India. CH_4 emission contributions from all the eight northeastern states are only 3.88% of total national emission. The low CH_4 emission is due to less livestock population in comparison with the other states. Details of results of different category-wise livestock estimated CH_4 emission from each state also shown in **Table 4**.

Livestock categories	Enteric fermentation	Manure management	Total
Cattle	7.25	0.59	7.84
Buffalo	5.97	0.43	0.64
Sheep	0.68	0.03	0.71
Goat	0.3	0.13	0.43

Table 3.
National level CH_4 (Tg $year^{-1}$) emission from different categories of livestock.

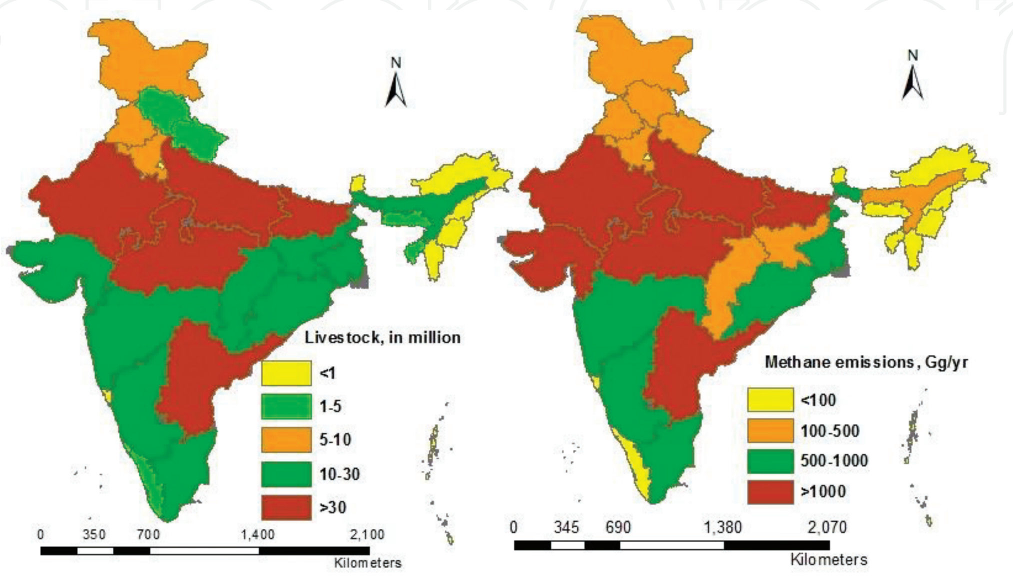

Figure 2.
Spatial distribution of CH_4 emission from livestock in India at state level.

State	Cattle	Buffalo	Sheep	Goat	Total
Andhra Pradesh	383	627	185	47	1242
Arunachal Pradesh	17	0	0	2	19
Assam	403	26	4	32	465
Bihar	508	446	2	63	1019
Chhattisgarh	373	82	1	17	473
Goa	2	0	0	0	2
Gujarat	417	613	12	26	1068
Haryana	78	359	3	2	442
Himachal Pradesh	93	42	6	6	147
Jammu and Kashmir	120	44	24	11	199
Jharkhand	328	70	4	34	436
Karnataka	410	205	67	25	707
Kerala	60	6	0	7	73
Madhya Pradesh	783	483	2	42	1310
Maharashtra	622	330	0	44	996
Manipur	10	4	0	0	14
Meghalaya	35	1	0	2	38
Mizoram	1	0	0	0	1
Nagaland	9	0	0	1	10
Orissa	442	43	0	34	519
Punjab	112	304	1	2	419
Rajasthan	586	766	64	113	1529
Sikkim	6	0	0	1	7
Tamil Nadu	392	46	34	43	515
Tripura	37	1	0	3	41
Uttar Pradesh	848	1807	9	81	2745
Uttarakhand	84	58	3	7	152
West Bengal	662	35	8	60	765
UTs	10	11	0	0	21

Table 4.
State-wise livestock category-wise CH_4 emission, Gg year^{-1} in the year 2012.

As there are significant variations in terms of livestock populations up to district level, CH_4 emission pattern also shows wide variations in India as shown in **Figure 3**. Banas Kantha, Gujarat (112 Gg CH_4); Paschim Medinipur, West Bengal (103 Gg CH_4); and Jaipur, Rajasthan (102 Gg CH_4) are top three districts in terms of livestock-related CH_4 emission. Furthermore, out of the total 15.3 Tg CH_4 emission in India, about 50% of the emission is contributed by 153 districts alone out of total 649 total districts. Within 153 districts, of the 4 livestock groups, maximum CH_4 emission (more than 50%) is contributed by buffalo in 84 districts followed by cattle (55 districts). Thus, this detailed GIS-based representation of the spatial distribution of CH_4 emission from livestock reveals that the highest emitting

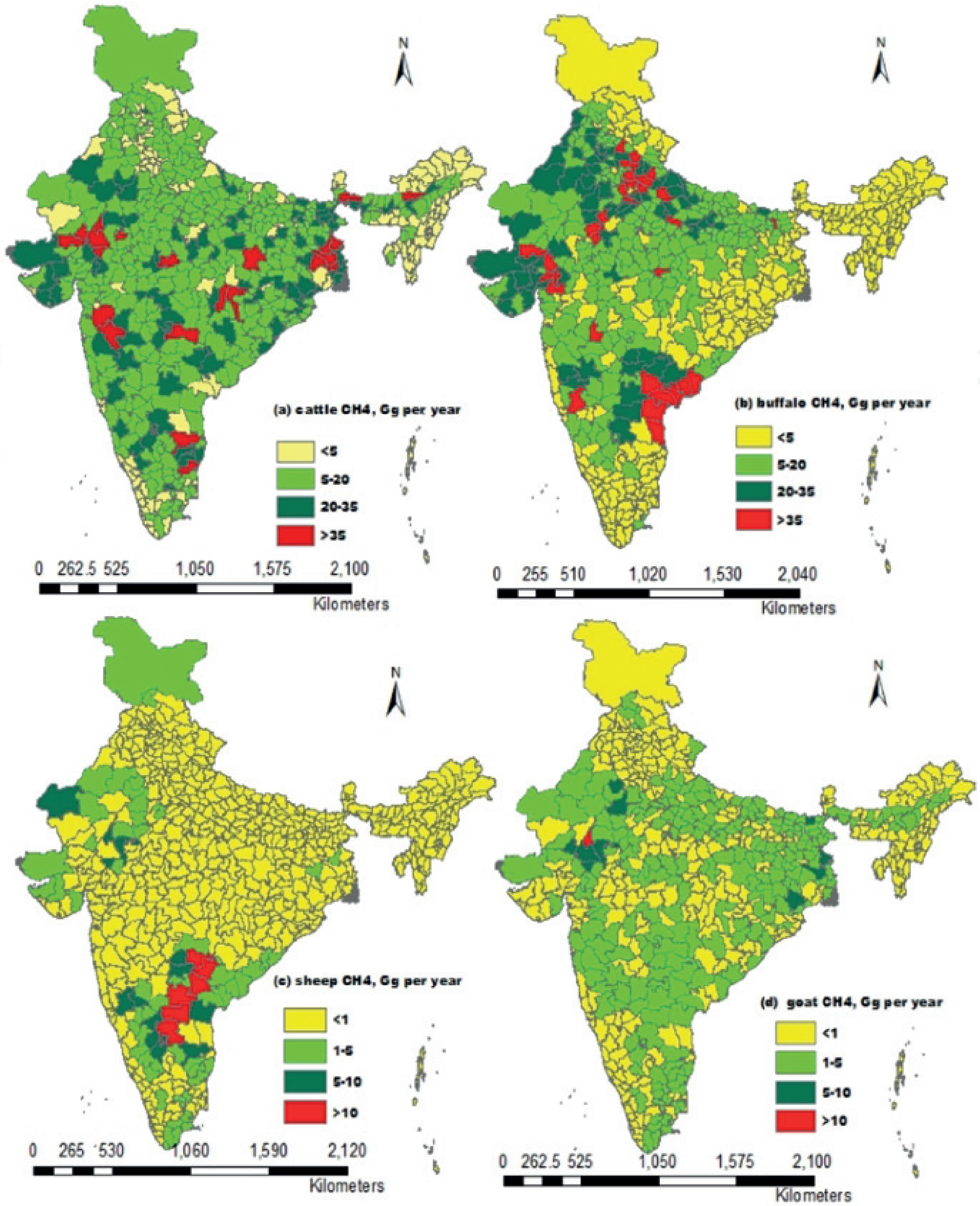

Figure 3.
CH_4 emission (Gg $year^{-1}$) from different categories of livestock at district levels in India, (a) emission from cattle, (b) emission from buffalo, (c) emission from sheep, and (d) emission from goat.

districts (emission >50% of total CH_4 emission) are located in the states of Uttar Pradesh, Gujarat, West Bengal, Rajasthan, Andhra Pradesh, and Maharashtra.

3.2 Climate metric assessment

The above estimation of livestock CH_4 emission is estimated further used to estimate its role in climate change using climate metrics in terms of GTP and AGTP. These are further elaborated to estimate surface temperature response (ΔT) from CH_4 emission due to Indian livestock. The results obtained from using Eqs. (2)–(4) (see **Table 2**) indicate significant contribution to GHG effect in global warming.

3.2.1 GTP of CH_4 emission

The estimated CH_4 emission data is used to calculate GTP at 20 and 100 year time horizon as GTP_{20} and GTP_{100}. GTP due to livestock CH_4 emission at 20 year time horizon is 1030 Tg CO_2e (GTP_{20}) while for 100 year time horizon 62 Tg CO_2e

(GTP_{100}). Among the livestock categories, cattle and buffalo are the major sources of CH_4 emission and hence for GTP. The GTP of cattle and buffalo together is worked out to more than 953.9 Tg CO_2e (GTP_{20}) and 56.9 Tg CO_2e (GTP_{100}), respectively, as given in **Figure 4**. The results also indicate that enteric fermentation is the major contributor (more than 90%) to GTP.

Similarly, at state level, GTP_{20} and GTP_{100} vary between 0.01–184 Tg CO_2e (GTP_{20}) and 0.007–18.0 Tg CO_2e (GTP_{100}), respectively, with the lowest in Mizoram and highest in Uttar Pradesh (**Table 5** and **Figure 5b** and **d**). At district level, GTP_{20} and GTP_{100} vary between 0.009–7.5 Tg CO_2e (GTP_{20}) and 3.75×10^{-6}–0.3 Tg CO_2e (GTP_{100}) (**Figure 5a** and **c**).

The GTP is a common unit of climate impact assessment per unit of GHG emissions. The results and findings of the climate metrics allow policymakers to develop GHG emission mitigation policies for different anthropogenic GHG emission sectors and for other non-CO_2 GHG gases [23]. The different time horizon for GTP measurement (e.g., 20 and 100 years) allows comparisons of the global warming impacts of a gas over a period of time [24, 25]. The larger the value of GTP, the higher will be the potential for temperature change by a given non-CO_2 GHG gas [15, 16, 26]. In the study, it is observed that climate change impact of CH_4 in GTP_{100} timeframe is smaller as compared to GTP_{20}, indicating that as the time horizon becomes longer, short-lived non-CO_2 GHG gases have less impact on GTP [10, 12]. This also suggests immediate requirements of mitigation measures for CH_4.

3.2.2 AGTP and surface temperature response (ΔT)

Similarly, climatic metric AGTP is also estimated, and it is worked out 4.56×10^{-14} and 2.28×10^{-15} K kg^{-1}, for 20 and 100 year time frames, respectively. The AGTP can be used to explore more about climate change impact assessment than GWP [27]. The AGTP value is further used to estimate surface temperature response (ΔT). The surface temperature response (ΔT) of CH_4 emission from the country for 20 year time frame is 0.70 mK (milli-Kelvin), and 100 year time frame is 0.036 mK.

At the state level, the highest global surface temperature response is observed resulting from CH_4 emission in Uttar Pradesh, with the lowest response resulting from CH_4 emission in Mizoram. CH_4 emission from livestock from different states can contribute to the surface temperature response (ΔT_{20}), ranging between 8.5×10^{-5} and 1.25×10^{-1} mK in 20 year time horizon. While in 100 year time horizon, ΔT_{100} varies from 4.23×10^{-5} to 6.50×10^{-3} mK for different states.

Potential rise in surface temperature due to Indian livestock sector that results from the annual CH_4 emission at district level is also evaluated here. At 20 year time

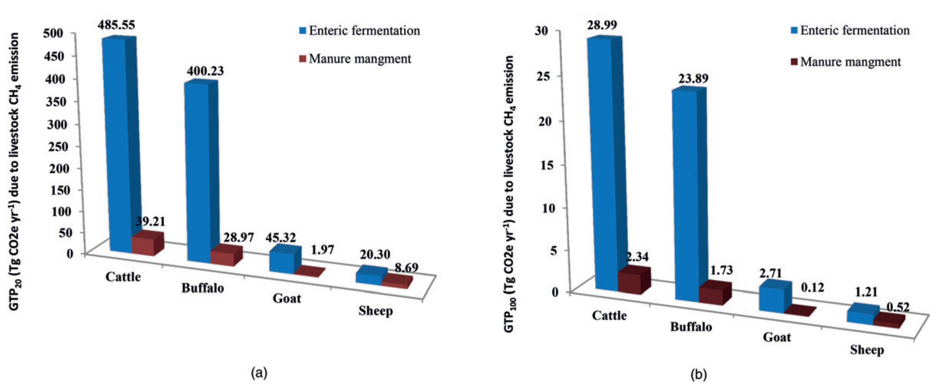

Figure 4.
Livestock category-wise GTP estimate for CH_4 emission at different time horizons (a) GTP_{20} and (b) GTP_{100}.

State	GTP_{20}	GTP_{100}
Andhra Pradesh	80.03	4.78
Arunachal Pradesh	1.29	0.08
Assam	31.09	1.86
Bihar	68.31	4.08
Chhattisgarh	31.65	1.89
Goa	0.17	0.01
Gujarat	71.30	4.26
Haryana	29.54	1.76
Himachal Pradesh	9.71	0.58
Jammu and Kashmir	12.86	0.77
Jharkhand	29.15	1.74
Karnataka	46.18	2.76
Kerala	4.87	0.29
Madhya Pradesh	87.75	5.24
Maharashtra	66.75	3.98
Manipur	0.98	0.06
Meghalaya	2.64	0.16
Mizoram	0.12	0.01
Nagaland	0.64	0.04
Odisha	34.75	2.07
Punjab	28.09	1.68
Rajasthan	101.29	6.05
Sikkim	0.44	0.03
Tamil Nadu	33.83	2.02
Tripura	2.72	0.16
Uttar Pradesh	183.79	10.97
Uttarakhand	10.12	0.60
West Bengal	51.12	3.05
UTs	1.54	0.09

Table 5.
State-wise GTP_{20} and GTP_{100} of CH_4 emission.

horizon, the ΔT_{20} varies from 1.53×10^{-7} to 0.005 mK due to Indian livestock sector. However, at 100 year time horizon, the ΔT_{100} varies from 7.66×10^{-9} to 0.0002 mK.

In addition to the above, the AGTP is also used to estimate the year-by-year response from a single year's CH_4 emission from livestock. The continuous analysis of AGTP is used to calculate the climate change impact on surface temperature using the annual AGTP calculation. The surface temperature change by the year (ΔT) is shown in **Figure 6**.

It is estimated that the surface temperature will keep rising till 2021 reaching the peak temperature rise (ΔT) 0.937 mK and would start decreasing thereafter. After few years of span beyond the year 2084, the surface temperature response would

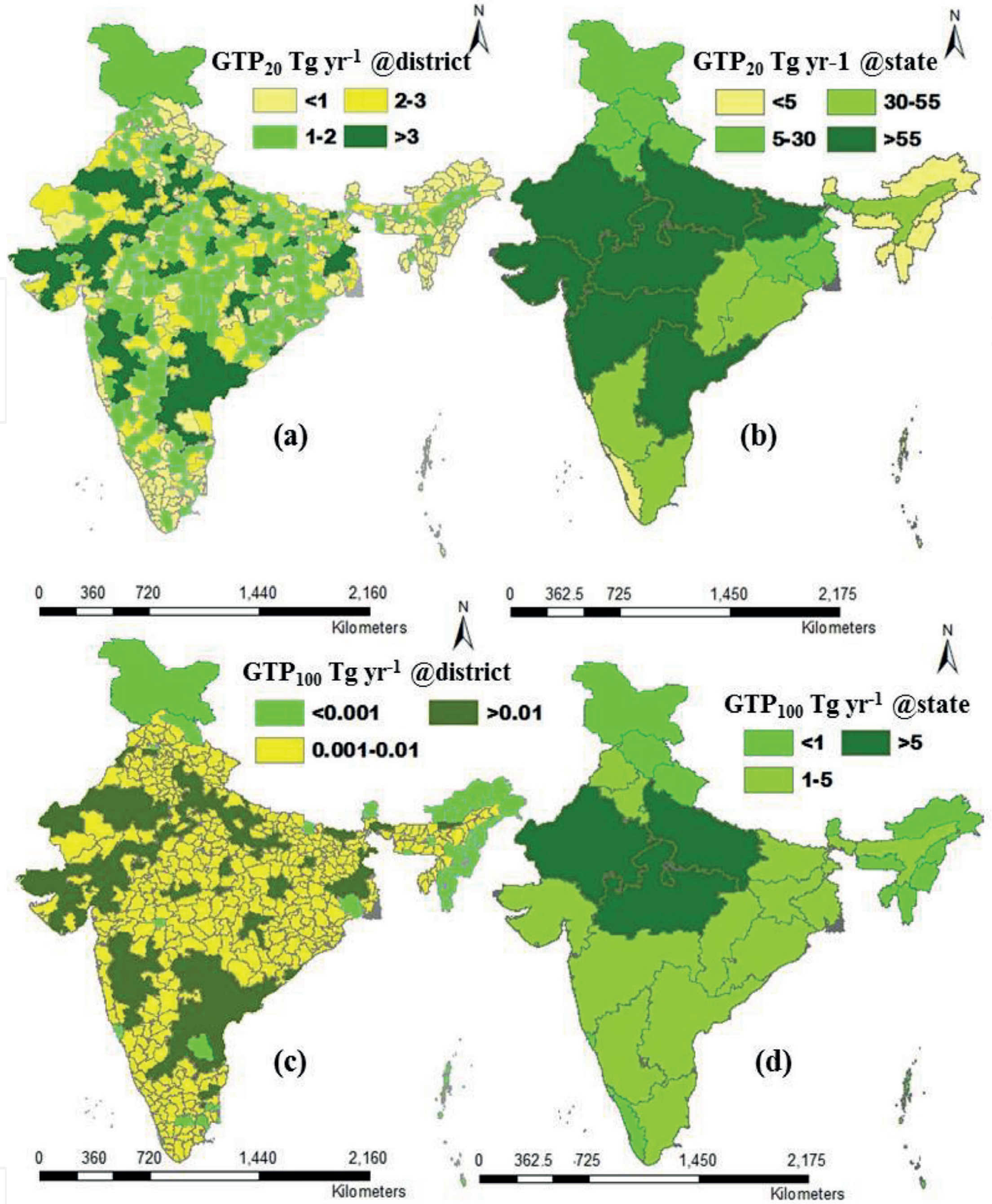

Figure 5.
GTP estimate of CH_4 emission in India: GTP_{20} of CH_4 in Tg CO_2e at (a) district and (b) state level; GTP_{100} of CH_4 in Tg CO_2e at (c) district and (d) state level.

asymptotically attain steady state. The continuous AGTP calculation is useful for policy makers when comparing multiple greenhouse gases. Due to high radiative forcing, CH_4 can cause large impacts on climate change on short time scales, but due to its short lifetime, that impact decreases more quickly than for longer-lived GHG gases. Although the potential rise in surface temperature due to different livestock size in states and districts is global in nature, their contribution from livestock is significantly variable with respect to different livestock sizes. Hence, estimating contribution from each state and each district will be useful for policy makers to develop decentralized mitigation policy. Thus, the surface temperature response gives significant information that CH_4 emission from livestock sector, even at small scale, can lead to significant climate change impact.

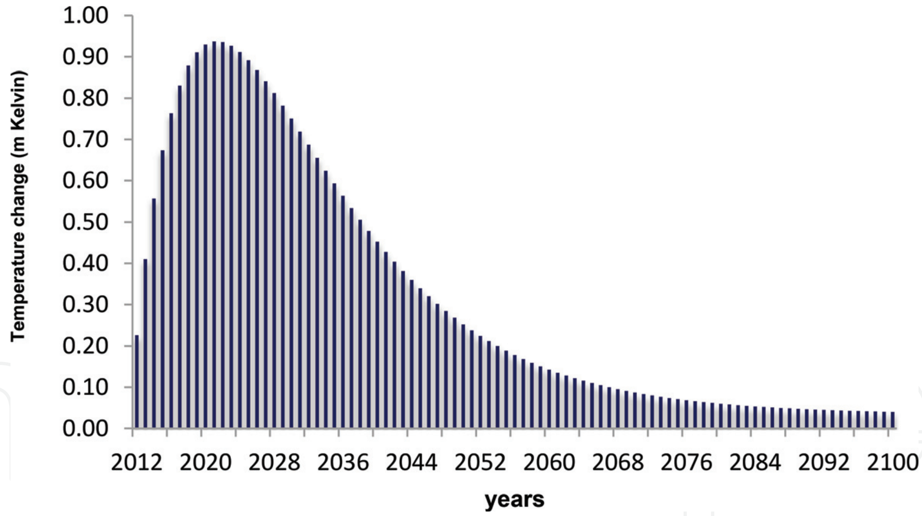

Figure 6.
Year-by-year surface temperature response (ΔT) due to constant rate of CH_4 emission, Tg year^{-1}.

3.2.3 Comparison between GTP and GWP

Here, CH_4 emission values are used to compare its GTP results with GWP values using GWP of CH_4, i.e., 34 [11]. The different values of GTP and GWP are given in **Table 6**. It is found that the results from GTP_{20} (1030 Tg CO_2e) to GTP_{100} (62 Tg CO_2e) drop off quickly compared to GWP_{20} (1292 Tg CO_2e) and GWP_{100} (430 Tg CO_2e). Both the climate metrics, GWP and GTP, are worked out in "CO_2 equivalents" but fundamentally different by construction, and therefore different numerical values can be expected [11]. If we look at the findings of GWP and GTP over the same period of time, GWP_{100} is higher than that of GTP_{100} due to the integrative nature of the GWP [11]. Also in the case of GTP_{20} and GTP_{100}, the GTP_{20} is 17 times higher than that of GTP_{100}, while GWP_{20} is only 3 times higher than that of GWP_{100}. The GTP calculation is based on assumptions about the climate sensitivity and heat uptake by the ocean and significantly varies with the change in these assumptions [11]. GTP is a metric which is used with reference to CO_2, and it is equal to the ratio of AGTP of reference gas and AGTP of CO_2. AGTP is the absolute GTP that gives temperature change per unit of GHG emission. As already discussed, GTP is an endpoint metric therefore for short GHG having half-life less than CO_2; its climate metric, taken for large time horizon, is less than that of climate metric calculated for short time horizon [11]. The differences in GTP and GWP could be due to the fact that the GTP accounts the atmospheric adjustment time scale of the

Category	Enteric fermentation				Manure management			
	GTP_{20}	GTP_{100}	GWP_{20}	GWP_{100}	GTP_{20}	GTP_{100}	GWP_{20}	GWP_{100}
Cattle	485.55	28.99	608.75	202.92	39.21	2.34	49.16	16.39
Buffalo	400.23	23.89	501.78	167.26	28.97	1.73	36.32	12.11
Goat	45.32	2.71	56.82	18.94	1.97	0.12	2.47	0.82
Sheep	20.30	1.21	25.45	8.48	8.69	0.52	10.90	3.63
Total	951.40	56.80	1192.80	397.60	78.84	4.71	98.85	32.95

Table 6.
Comparison between GTP_{20}, GTP_{100}, GWP_{20}, and GWP_{100} of estimated CH_4 emission from livestock.

component and the response time scale of the climate system, which is not considered in the GWP. Climatic impact assessment has been facing difficulties when comparing the effect of short- and long-lived GHGs. The GWP and GTP of long-lived gases are the same [10]. However, for short-lived GHGs, the GWP does not account the radiative forcing for a short period.

Therefore, the GTP has been proposed for the comparison of the impact of GHG emissions on temperature changes at a specific time in future rather than the radiative forcing over a period of time [23]. Hence, we can say that the GTP compares temperatures at the end of a given time period due to GHG emissions. In comparison to GWP, GTP extends the information from radiative forcing to rise in the surface temperature relative to that of CO_2 [11]. The GTP further extends the cause-effect chain by adding the temperature impact assessment in comparison with GWP and hence more relevant by comparing temperature changes [28]. The GTP is a function of time and used for analyzing the economic benefits from emission reduction. Therefore, it is useful to develop cost-effective policy for mitigation policies targeting temperature reduction.

Overall the results estimated here are compiled in **Table 7** in which the minimum, the maximum, and average are given.

3.3 Uncertainty analysis

The CH_4 emission estimation depends mainly on two factors, i.e., livestock population and CH_4-specific emission factors of different types of livestock categories. Both the factor could be a source of uncertainty. For the livestock population database, we rely on livestock census taken from the reports published by the Government of India [29], and emission factors are collected from the IPCC report [20]. During livestock census, the database collection based on only 5% of the total livestock population is used for sampling purposes during the census, which is then aggregated into 100% data. This creates uncertainty in the methodology. Also, in IPCC guidelines 2006, three types of estimation methodology are proposed, i.e., basic method IPCC Tier 1, intermediate method IPCC Tier 2, and complex method IPCC Tier 3. As the method becomes advance, uncertainty related to methodology decreases. As found by Patra [30], Tier 1 method overestimates the CH_4 emission by 15% compared to Tier 2 estimate. But, IPCC Tier 1 is readily available which covers for national or international level in combination with default emission

	CH_4 (Tg year^{-1})	GWP (Tg CO_2e)	GTP_{20} (Tg CO_2e)	GTP_{100} (Tg CO_2e)	ΔT_{20} (mK)	ΔT_{100} (mK)
Country level	15.3	523	1030	61.51	0.70	0.036
State level						
Minimum	0.12	4.06	0.01	0.00	0.00	0.00
Maximum	2.74	93.35	183.79	10.97	0.13	0.006
Average	0.43	14.93	29.22	1.74	0.02	0.001
District level						
Minimum	0.00	0.00	0.00	0.00	0.00	0.000
Maximum	0.11	3.82	7.53	0.45	0.002	0.003
Average	0.02	0.81	1.59	0.10	0.0005	0.0006

Table 7.
Results of CH_4 emission and other climate metrics at national, state, and district levels.

factors. Therefore, it is feasible for all countries. But, country-specific or even smaller region-specific emission factors would bring more precise information. However, such issues could not be considered in the present work and would require further investigation.

4. Conclusions

The findings of the study are CH_4 emission, high GTP and surface temperature response at district level, state level, and national level in India. The total CH_4 emission in India is 15.3 Tg in 2012, with the highest almost 92% of the emission occurring via enteric fermentation. The GTP due to CH_4 emission at 20 and 100 year time horizon in India is 1030 Tg GTP_{20} CO_2e and 62 Tg GTP_{100} CO_2e, respectively. The livestock emission in India has the potential to cause the surface temperature rise up to 0.69 mK and 0.036 mK over 20 and 100 year time period, respectively. At a state level, the emission can cause the surface temperature response (ΔT) to vary from 8.49×10^{-5} to 1.25×10^{-1} mK in 20 year time horizon and from 4.23×10^{-5} to 6.25×10^{-2} mK in 100 year time horizon. On the other hand, at district level, the ΔT varies from 1.53×10^{-7} to 0.005 mK in 20 years and from 7.66×10^{-9} to 0.0002 mK in 100 years' time frame. The GTP values of CH_4 for 20 and 100 years are 67 and 4, respectively. The AGTP values for the same time horizons are 4.6×10^{-14} and 2.3×10^{-15} K kg^{-1}. GTP is a metric, which is used in comparing multiple gases with reference to CO_2, whereas AGTP is the absolute GTP giving temperature change per unit of GHG emission. Temperature indices like GTP and AGTP both give the surface temperature change and response using pulse emission. GTP of any greenhouse gas is equal to the ratio of AGTP of the given gas and AGTP of CO_2. The AGTP measures the temperature change over the period of time after the GHG emission. It depends upon some factors such as climate sensitivity and ocean uptake of heat by the ocean. All of these factors response vary with the time horizon and may substantially modify climate metrics GTP and AGTP.

So, it follows a decreasing trend with an increase over the period of time from 20 to 100 years. GTP and AGTP follow the same pattern and also decrease with the year. These temperature indices GTP and AGTP both can be used to study the impact on surface temperature due to GHG emission with time. This finding helps to study the climate change impact on surface temperature from CH_4 emission, which can cause climate damage over a short period of time, even emitted in small quantity.

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