Chapter

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

Shilpi Kumari, Moonmoon Hiloidhari, Satya Narayan Naik and Raj Pal Dahiya

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$_2$e, 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$_2$e 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
climate impact assessment, different climate metrics are being used to assess the climatic impact of non-CO₂ GHGs in terms of CO₂ equivalent emission [9, 10]. These climate metrics are estimated in tonnes of CO₂e per year by multiplying each non-CO₂ 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-CO₂ 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-CO₂ GHGs with reference to CO₂ [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 CO₂ at a given time period. The GTP is more useful for those GHGs which have lifetime less than CO₂ such as short-lived GHG: CH₄ [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 CH₄ emission is global in nature, not only restricted to India. Thus, the present chapter is focused on livestock-mediated CH₄ 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 CH₄ 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.
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.
Climate metric GTP (CH₄) for two different time horizons, i.e., 20 and 100 years, is estimated as GTP₂₀ and GTP₁₀₀ as shown in Eq. (2) in Table 2. These two different assessments are highly significant for the GHGs, which have a shorter lifetime than CO₂ 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 (ΔTₜ) is estimated by multiplication of annual CH₄ emission and AGTP [22]. Annual ΔT is used for evaluation of the direct temperature effects contributed by an annual rate of CH₄ emission over time from livestock as shown in Eq. (4) in Table 2.

### 2.4 GIS map generation

After the estimation of CH₄ emission and climate metric assessment from livestock CH₄ 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 CH₄ 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 CH₄ 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.
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

| 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.
districts (emission >50% of total CH4 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 CH4 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 CH4 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 CH4 emission

The estimated CH4 emission data is used to calculate GTP at 20 and 100 year time horizon as GTP20 and GTP100. GTP due to livestock CH4 emission at 20 year time horizon is 1030 Tg CO2e (GTP20) while for 100 year time horizon 62 Tg CO2e
Among the livestock categories, cattle and buffalo are the major sources of CH₄ emission and hence for GTP. The GTP of cattle and buffalo together is worked out to more than 953.9 Tg CO₂e (GTP₂₀) and 56.9 Tg CO₂e (GTP₁₀₀), 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, GTP₂₀ and GTP₁₀₀ vary between 0.01–184 Tg CO₂e (GTP₂₀) and 0.007–18.0 Tg CO₂e (GTP₁₀₀), respectively, with the lowest in Mizoram and highest in Uttar Pradesh (Table 5 and Figure 5b and d). At district level, GTP₂₀ and GTP₁₀₀ vary between 0.009–7.5 Tg CO₂e (GTP₂₀) and 3.75 × 10⁻⁶–0.3 Tg CO₂e (GTP₁₀₀) (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-CO₂ 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-CO₂ GHG gas [15, 16, 26]. In the study, it is observed that climate change impact of CH₄ in GTP₁₀₀ timeframe is smaller as compared to GTP₂₀, indicating that as the time horizon becomes longer, short-lived non-CO₂ GHG gases have less impact on GTP [10, 12]. This also suggests immediate requirements of mitigation measures for CH₄.

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 CH₄ 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 CH₄ emission in Uttar Pradesh, with the lowest response resulting from CH₄ emission in Mizoram. CH₄ emission from livestock from different states can contribute to the surface temperature response (ΔT₂₀), ranging between 8.5 × 10⁻³ and 1.25 × 10⁻¹ mK in 20 year time horizon. While in 100 year time horizon, ΔT₁₀₀ 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 CH₄ emission at district level is also evaluated here. At 20 year time

Figure 4.
Livestock category-wise GTP estimate for CH₄ emission at different time horizons (a) GTP₂₀ and (b) GTP₁₀₀.
horizon, the $\Delta T_{20}$ varies from $1.53 \times 10^{-7}$ to 0.005 mK due to Indian livestock sector. However, at 100 year time horizon, the $\Delta T_{100}$ varies from $7.66 \times 10^{-9}$ 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 ($\Delta T$) is shown in Figure 6.

It is estimated that the surface temperature will keep rising till 2021 reaching the peak temperature rise ($\Delta T$) 0.937 mK and would start decreasing thereafter. After few years of span beyond the year 2084, the surface temperature response would
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 5.
GTP estimate of CH$_4$ emission in India: GTP$_{20}$ of CH$_4$ in Tg CO$_2$e at (a) district and (b) state level; GTP$_{100}$ of CH$_4$ in Tg CO$_2$e at (c) district and (d) state level.
3.2.3 Comparison between GTP and GWP

Here, CH₄ emission values are used to compare its GTP results with GWP values using GWP of CH₄, i.e., 34 [11]. The different values of GTP and GWP are given in Table 6. It is found that the results from GTP₂₀ (1030 Tg CO₂e) to GTP₁₀₀ (62 Tg CO₂e) drop off quickly compared to GWP₂₀ (1292 Tg CO₂e) and GWP₁₀₀ (430 Tg CO₂e). Both the climate metrics, GWP and GTP, are worked out in “CO₂ 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, GWP₁₀₀ is higher than that of GTP₁₀₀ due to the integrative nature of the GWP [11]. Also in the case of GTP₂₀ and GTP₁₀₀, the GTP₂₀ is 17 times higher than that of GTP₁₀₀, while GWP₂₀ is only 3 times higher than that of GWP₁₀₀. 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 CO₂, and it is equal to the ratio of AGTP of reference gas and AGTP of CO₂. 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 CO₂, 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 |
|-------------------|----------------------|-------------------|
|                   | GTP₂₀ | GTP₁₀₀ | GWP₂₀ | GWP₁₀₀ | GTP₂₀ | GTP₁₀₀ | GWP₂₀ | GWP₁₀₀ |
| 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 GTP₂₀, GTP₁₀₀, GWP₂₀, and GWP₁₀₀ of estimated CH₄ 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 CO₂ [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 CH₄ emission estimation depends mainly on two factors, i.e., livestock population and CH₄-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 CH₄ 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

| Country level | CH₄ (Tg year⁻¹) | GWP (Tg CO₂e) | GTP₂₀ (Tg CO₂e) | GTP₁₀₀ (Tg CO₂e) | ΔT₂₀ (mK) | ΔT₁₀₀ (mK) |
|---------------|----------------|---------------|-----------------|------------------|-----------|-----------|
| 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     |

| State level   | CH₄ (Tg year⁻¹) | GWP (Tg CO₂e) | GTP₂₀ (Tg CO₂e) | GTP₁₀₀ (Tg CO₂e) | ΔT₂₀ (mK) | ΔT₁₀₀ (mK) |
|---------------|----------------|---------------|-----------------|------------------|-----------|-----------|
| Minimum       | 0.00           | 0.00          | 0.00            | 0.00             | 0.00      | 0.0000    |
| 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 CH₄ 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$_2$e and 62 Tg GTP$_{100}$ CO$_2$e, 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 ($\Delta T$) to vary from $8.49 \times 10^{-3}$ to $1.25 \times 10^{-1}$ mK in 20 year time horizon and from $4.23 \times 10^{-5}$ to $6.25 \times 10^{-2}$ mK in 100 year time horizon. On the other hand, at district level, the $\Delta T$ varies from $1.53 \times 10^{-7}$ to $0.005$ mK in 20 years and from $7.66 \times 10^{-9}$ 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 $4.6 \times 10^{-14}$ and $2.3 \times 10^{-15}$ 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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References

[1] Casey JW, Holden NM. The relationship between greenhouse gas emissions and the intensity of milk production in Ireland. Journal of Environmental Quality. 2005;34(2):429-436. DOI: 10.2134/jeq2005.0429

[2] Garnett T. Livestock-related greenhouse gas emissions: Impacts and options for policy makers. Environmental Science & Policy. 2009;12(4):491-503. DOI: 10.1016/j.envsci.2009.01.006

[3] Kumari S, Dahiya RP, Kumari N, Sharawat I. Estimation of methane emission from livestock through enteric fermentation using system dynamic model in India. International Journal of Environmental Research and Development. 2014;4:347-352

[4] Gerber PJ, Steinfeld H, Henderson B, Mottet A, Opio C, Dijkman J, et al. Tackling Climate Change through Livestock: A Global Assessment of Emissions and Mitigation Opportunities. Food and Agriculture Organization of the United Nations (FAO). Rome; 2013

[5] Kumari S, Dahiya RP, Naik SN, Hiloidhari M, Thakur IS, Sharawat I, et al. Projection of methane emissions from livestock through enteric fermentation: A case study from India. Environmental Development. 2016;20:31-44. DOI: 10.1016/j.envdev.2016.08.001

[6] IPCC. Climate Change: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the IPCC. Cambridge and New York: Cambridge University Press; 2013

[7] Steinfeld H, Gerber P. Livestock production and the global environment: Consume less or produce better? Proceedings of the National Academy of Sciences. 2010;107(43):18237-18238. DOI: 10.1073/pnas.1012541107

[8] Kipling RP, Bannink A, Bellocchi G, Dalgaard T, Fox NJ, Hutchings NJ, et al. Modeling European ruminant production systems: Facing the challenges of climate change. Agricultural Systems. 2016;147:24-37. DOI: 10.1016/j.agsy.2016.05.007

[9] Fuglestvedt JS, Berntsen TK, Godal O, Sausen R, Shine KP, Skodvin T. Metrics of climate change: Assessing radiative forcing and emission indices. Climatic Change. 2003;58(3):267-331

[10] Huntingford C, Lowe JA, Howarth N, Bowerman NH, Gohar LK, Otto A, et al. The implications of carbon dioxide and methane exchange for the heavy mitigation RCP2.6 scenario under two metrics. Environmental Science & Policy. 2015;51:77-87. DOI: 10.1016/j.envsci.2015.03.013

[11] IPCC (Intergovernmental Panel on Climate Change). Climate change 2014. In: IPCC Fifth Assessment Report. Geneva, Switzerland: IPCC; 2014

[12] Shine KP, Fuglestvedt JS, Hailemariam K, Stuben N. Alternatives to the global warming potential for comparing climate impacts of emissions of greenhouse gases. Climatic Change. 2005;68(3):281-302

[13] Sarofim MC. The GTP of methane: Modeling analysis of temperature impacts of methane and carbon dioxide reductions. Environmental Modeling and Assessment. 2012;17(3):231-239. DOI: 10.1007/s10666-011-9287-x

[14] Shine KP, Fuglestvedt JS, Hailemariam K, Stuben N. Alternatives to the global warming potential for comparing climate impacts of emissions of greenhouse gases. Climatic Change. 2005;68(3):281-302

[15] Shine KP, Berntsen TK, Fuglestvedt JS, Skeie RB, Stuben N. Comparing the
climate effect of emissions of short-and long-lived climate agents. Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences. 2007;365(1856): 1903-1914. DOI: 10.1098/rsta.2007.2050

[16] Peters GP, Aamaas B, Berntsen T, Fuglestvedt JS. The integrated global temperature change potential (iGTP) and relationships between emission metrics. Environmental Research Letters. 2011;6(4):044021. DOI: 10.1088/1748-9326/6/4/044021

[17] Persson UM, Johansson DJ, Cederberg C, Hedenus F, Bryngelsson D. Climate metrics and the carbon footprint of livestock products: Where’s the beef? Environmental Research Letters. 2015;10(3):034005

[18] Government of India. 19th Livestock Census 2014. New Delhi: Ministry of Agriculture, Govt. of India, Department of Animal Husbandry, Dairying and Fisheries; 2014

[19] BAHS. Ministry of Agriculture and Farmers Welfare Department of Animal Husbandry, Dairying and Fisheries. India. 2012

[20] IPCC. In: Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, editors. IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. Japan: IGES; 2006

[21] Farquharson D, Jaramillo P, Schivley G, Klima K, Carlson D, Samaras C. Beyond global warming potential: A comparative application of climate impact metrics for the life cycle assessment of coal and natural gas based electricity. Journal of Industrial Ecology. 2017;21(4): 857-873. DOI: 10.1111/jiec.12475

[22] Giuntoli J, Agostini A, Caserini S, Lugato E, Baxter D, Marelli L. Climate change impacts of power generation from residual biomass. Biomass and Bioenergy. 2016;89:146-158. DOI: 10.1016/j.biombioe.2016.02.024

[23] Manning M, Reisinger A, Bodeker G. Global Warming Potentials and Alternate Metrics. New Zealand Climate Change Research Centre; 2009

[24] Boucher O, Friedlingstein P, Collins B, Shine KP. The indirect global warming potential and global temperature change potential due to methane oxidation. Environmental Research Letters. 2009;21(4):4, 044007. DOI: 10.1088/1748-9326/4/4/044007

[25] Joos F, Roth R, Fuglestvedt JS, Peters GP, Enting IG, Bloh WV, et al. Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: A multi-model analysis. Atmospheric Chemistry and Physics. 2013;13(5):2793-2825. DOI: 10.5194/acp-13-2793-2013

[26] Kumari S, Hiloidhari M, Kumari N, Naik SN, Dahiya RP. Climate change impact of livestock CH4 emission in India: Global temperature change potential (GTP) and surface temperature response. Ecotoxicology and Environmental Safety. 2018;147:516-522. DOI: 10.1016/j.ecoenv.2017.09.003

[27] Fagodiya RK, Pathak H, Kumar A, Bhatia A, Jain N. Global temperature change potential of nitrogen use in agriculture: A 50-year assessment. Scientific Reports. 2017;7:44928. DOI: 10.1038/srep44928

[28] Shine KP. The global warming potential—The need for an interdisciplinary retrial. Climatic Change. 2009;96(4):467-472. DOI: 10.1007/s10584-009-9647-6

[29] BAHS 2014. Ministry of Agriculture and Farmers Welfare Department of Animal Husbandry, Dairying and Fisheries. India

[30] Patra AK. Prediction of enteric methane emission from buffaloes using statistical models. Agriculture, Ecosystems & Environment. 2014;195: 139-148. DOI: 10.1016/j.agee.2014.06.006