Taylor & Francis
Taylor & Francis Group

Italian Journal of Animal Science

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjas20

Recalculating the global warming impact of italian livestock methane emissions with new metrics

Fabio Correddu, Mondina Francesca Lunesu, Maria Francesca Caratzu & Giuseppe Pulina

To cite this article: Fabio Correddu, Mondina Francesca Lunesu, Maria Francesca Caratzu & Giuseppe Pulina (2023) Recalculating the global warming impact of italian livestock methane emissions with new metrics, Italian Journal of Animal Science, 22:1, 125-135, DOI: 10.1080/1828051X.2023.2167616

To link to this article: https://doi.org/10.1080/1828051X.2023.2167616

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

Published online: 27 Jan 2023.

Submit your article to this journal

Article views: 298

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=tjas20

ITALIAN JOURNAL OF ANIMAL SCIENCE
2023, VOL. 22, NO. 1, 125–135
https://doi.org/10.1080/1828051X.2023.2167616

PAPER

OPEN ACCESS | Check for updates

Recalculating the global warming impact of italian livestock methane emissions with new metrics

Fabio Correddu, Mondina Francesca Lunesu, Maria Francesca Caratzu and Giuseppe Pulina

Dipartimento di Agraria, Università degli studi di Sassari, Sassari, Italy

ABSTRACT

The warming impact of methane (CH_4) emissions calculated using the metrics proposed by the Intergovernmental Panel on Climate Change (IPCC), which measure its global warming potential in 100 years (GWP_{100}) expressed as carbon dioxide equivalents (CO_2e), accounts for the greatest impact in animal production chains. This work uses the new metrics, proposed to consider the difference between short living climate pollutants (SLCP), such as CH_4, and long living climate pollutants (LLCP), such as carbon dioxide (CO_2), which measure the warming equivalent (*we*) effect relative to that of CO_2 in a given time frame (GWP*) and expressed as CO_2we. The GWP* was applied to CH_4 emissions from all Italian livestock supply chains and compared with GWP_{100} for annual and cumulative assessment from 2010 to 2020 of the impact of this gas on climate change. Using official data published by Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) from 1990 to 2020, almost all species, except for buffalo (+272.6% of emissions calculated with the new metrics), revealed lower CH_4 emissions with the greatest re-dimensioning for non-dairy cattle (-53786 kt of CO_2we of calculated with GWP* compared to +66437 kt of CO_2e estimated with the GWP_{100} method). The total cumulative contribution of Italian livestock production to global warming over the past 10 years, including the nitrous oxide (N_2O) emissions, has been greatly negative (-48759 kt of CO_2we) compared to the data calculated using the GWP_{100} method (+206091 kt of CO_2e). In conclusion, the application of GWP* metric to CH_4 emissions of all Italian livestock supply chains allowed to better identify the role of Italian livestock on climate change. Over the 2010–2020 time frame, the Italian animal supply chains reduced the warming impact related to its CH_4 emission, with the ruminants (expect buffaloes) being the major contributor to this positive effect.

HIGHLIGHTS

- The application of GWP* metric reduced the warming impact of CH_4 emissions of Italian dairy cattle, non-dairy cattle, sheep, goats, poultry and rabbits.
- The reduction of CH_4 emission from the major ruminant species is the major contributor to the positive effect on climate change detected over 2010–2020 time frame.
- The application of GWP* metric to CH4 emissions of all Italian livestock supply chains allowed to better identify the role of Italian livestock on climate change.

ARTICLE HISTORY
Received 14 November 2022
Revised 6 January 2023
Accepted 6 January 2023

KEYWORDS
Methane emission; greenhouse gas; global warming potential; new metric; Italian livestock

Introduction

Methane (CH_4) represents the second largest anthropogenic greenhouse-effect gas after carbon dioxide (CO_2) (IPCC 2021). That originated from livestock, either from enteric fermentations or from effluents, contributes about 1/3 of the global methane emissions (Saunois et al. 2020). The comparison among different gases for their warming effect was established by the Intergovernmental Panel for Climate Change (IPCC) in 1990 and updated continuously (IPCC 1990, 2021). The universally used IPCC metrics place 1 kg of CO_2 as the climate-changing unit and compare other gases with this over a given time horizon. The one chosen is 100 years for which all greenhouse gases (GHG) are assigned a global warming potential (GWP) over the horizon of a century (100) and the correspondence is expressed in units of CO_2 equivalents (CO_2e). Briefly, GWP_i considers the ability of each gas (i) to absorb energy (RF) and the length of its atmospheric residency (t) and CO_2 is

CONTACT Mondina Francesca Lunesu mflunesu@uniss.it
This article has been corrected with minor changes. These changes do not impact the academic content of the article.

© 2023 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

the reference gas (r):

$$GWP_i = \frac{\int_0^{TH} RFi(t)dt}{\int_0^{TH} RF_r(t)dt} \quad (1)$$

Although, this metric is widely used, and is the *de facto* standard metric for a range of purposes, it is not suitable for any objective; as reported by the IPCC (1990), there is no universally accepted methodology for combining all the relevant factors into a single metric. In particular, GWP does not allow to highlight the different effects on the warming during the time between Long Living Climate Pollutant (LLCP) and Short Living Climate Pollutant (SLCP). The GWP considers the length of atmospheric residency of each gas, but the different accumulation pattern between LLCP and SLCP is neglected, because it compares the RF accumulated over a time-horizon resulting from a pulse-emission of a specific GHG to a pulse-emission of equal mass of CO_2. This is of crucial importance because the warming effect depends also on the concentration of a GHG in the atmosphere, thus on its accumulation pattern, that is significantly different between LLCP and SLCP: actually, CH_4 has a half-life of 8.6 years, and it is almost completely removed (oxidized and absorbed) after 50 years, while CO_2 resides in the atmosphere for over a century (Saunois et al. 2020). The different accumulation pattern between LLCP and SLCP causes diverse effects on the warming during the time: a) when emissions increase, the warming caused by LLCP (CO_2) increases exponentially, whereas that caused by SLCP increases linearly (CH_4), following the different pattern of gas accumulation in atmosphere; b) under constant emissions, CO_2 causes a linear increase of warming, because it continues to accumulate, whereas that of CH_4 is constant, causing no further warming; c) with decreasing emissions, CO_2 continues to cause increasing warming (reducing the velocity of increase) due to the continue accumulation of the gas, reaching a plateau at zero emissions, whereas the stock of CH_4 starts to decrease when the reduction of emission takes place. A major concern related to calculating the GWP of an SLCP as well as an LLCP is the scenario of decreasing emissions: the temperature continues to rise also in response to decreasing emissions, until they reach and remain at zero emissions; in reality, the temperature begins to decrease at the same time as the former (SLCP) decreases. These differences make difficult to express the SLCP impact on global warming in term of equivalent impact of a LLCP which is the objective of the GWP. On this basis, a group of atmospheric physicists, as part of the Oxford Martin Program on Climate Pollutants project (Shine et al. 2005; Allen et al. 2016, 2018; Cain et al. 2019; Collins et al. 2020), have developed new metrics that account for the different behaviour of different gases (fluxes, emissions, lifetime) to give more reliable values in decreasing or increasing GHG emission scenario, especially for SLCP as CH_4. The IPCC (2021) has also begun to consider these new metrics, and it is expected that the next revisions of global warming potential equivalences among gases will be revised.

Below follows the comparison between the GWP and the new proposed metrics:

$$\mathrm{GWP}(\mathrm{CO_2}e) = \mathrm{E} \times \mathrm{GWP_H}.\ (\mathrm{IPCC\ 1990}) \quad (2)$$

$$\mathrm{GWP}*(\mathrm{CO_2}we) = (\Delta \mathrm{E_{SLCP}}/\Delta \mathrm{t}) \times \mathrm{GWP_H} \times \mathrm{H} \quad (\mathrm{Allen\ et\ al.\ 2018}) \quad (3)$$

$$\mathrm{GWP}*(\mathrm{CO_2}we) = \mathrm{GWP_H} \times [\mathrm{r} \times (\Delta \mathrm{E_{SLCP}}/\Delta \mathrm{t}) \times \mathrm{H} + \mathrm{s} \times \mathrm{E_{SLCP}}]\ (\mathrm{Cain\ et\ al.\ 2019}) \quad (4)$$

where:

- E is the mass emission for a GHG in a given year, H is the forward time horizon and GWP_H is the GWP for a GHG as according to IPCC (1990) over time horizon H;
- ΔE_{SLCP} is the variation of emission rate of a SLCP over the time interval Δt, H is the forward time horizon;
- r and s are the weights of the cumulation (s, stock) and emission rate (r, rate) for a given time H, calculated using a multiple linear regression onto the response to CH_4 emissions in commonly used scenarios, focussing on the time period 1900–2100 ($r = 0.75$, $s = 0.25$).

Compared with the traditional IPCC metric, the new metric rewards those who significantly reduce CH_4 emissions but penalises those who increase emissions much more. However, the GWP* metric does not represent a concession for further CH_4 emissions but more reliably shows the contribution of (declining) CH_4 emissions to a reduction of global warming (Hörtenhuber et al. 2022). Using equations (2 and 4), Figure 1 shows the recalculated data, originally proposed by Cady (2020), displaying the trend of GWP and GWP* of 1 kt of CH_4 expressed respectively in CO_2e and CO_2we as the percentage of CH_4 emission reduction or increase over 20 years.

Smith et al. (2021), considering all the average parameters suggested by Allen et al. (2018) scaled for a time of 20 years, refined the equation (4) into the following equation:

$$GWP * (CO_2we) = GWP_{100} \times \ [4.53 \ \times \ E_{SLCP}(t) - 4.25 \times E_{SLCP}(t-20)] \quad (5)$$

Work is beginning to appear in the literature that uses these new metrics to estimate CH_4 emissions from livestock systems at country level. Liu et al. (2021) recalculated the CH_4 emissions from US cattle industry funding that it has not contributed additional warming since 1986. Place and Mitloehner (2021) analysing the US dairy industry by using the new metrics, forecast that a net zero GHG emission will be reached around 2040. As defined by the IPCC (2021), 'net zero GHG emission is the condition in which metric-weighted anthropogenic GHG emissions are balanced by metric-weighted anthropogenic GHG removals over a specified period'; the quantification of net zero GHG emissions depends on the metric chosen, and it could be different, in term of temperature outcomes, from the quantification of net zero CO_2 (Schleussner et al. 2019). In this contest, the use of new metric to quantify the net zero GHG emission would allow to estimate similar temperature evolution as achieving net zero CO_2 (IPCC 2021). Hörtenhuber et al. (2022), studying the case of CH_4 emissions from Austrian livestock farms, found a large reduction in emissions in dairy cattle and pigs, but not in other species.

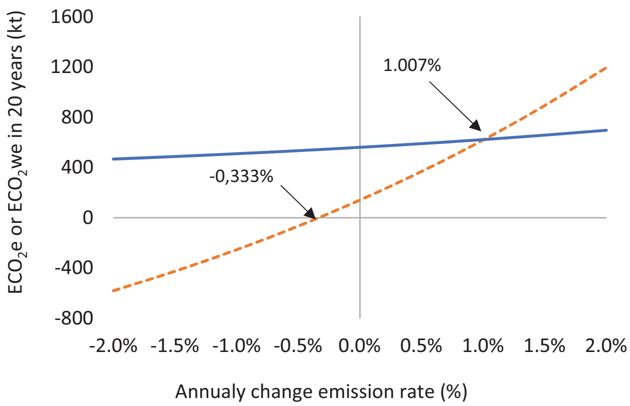

Figure 1. Estimated twenty-year cumulative CO_2 equivalents (ECO_2e) and twenty-year cumulative CO_2 warming equivalents (ECO_2we), calculated applying the global warming potential (GWP) and the global warming potential star (GWP*), respectively, on twenty-year methane emissions. Starting emission was 1 kt of CH_4/year. (Adapted from Cady (2020), with recalculated values).

This paper aimed to apply the new metrics GWP* to CH_4 emissions from the main animal production chains in Italy and to compare them with values obtained using IPCC standards GWP_{100} over the 2010–2020 time frame, alone and including the N_2O direct livestock emissions to obtain an alternative estimation of the cumulative impacts.

Materials and methods

Calculation of methane emission

Data on CH_4 emission for dairy cattle, non-dairy cattle, buffalo, sheep, goat, swine, horses, mule and asses, poultry, and rabbits between 1990 and 2020 (Figure 2) were downloaded from the Italian government agency for environmental monitoring (ISPRA 2022), which produces annual estimates of the environmental impacts of human activities in Italy according to international

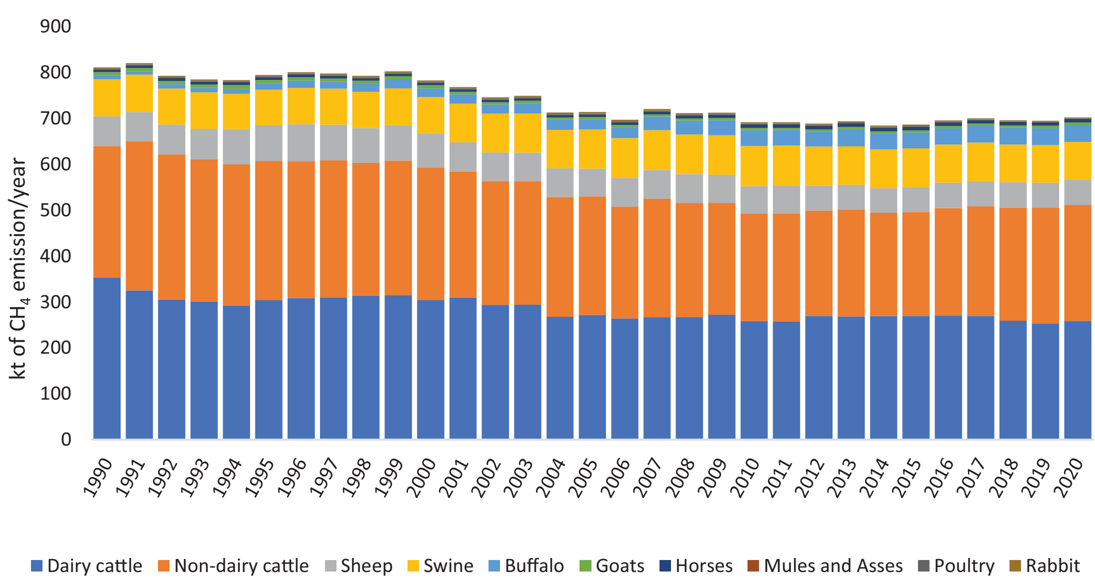

Figure 2. Livestock methane (CH_4) emissions in kilotons (kt) from 1990 to 2020 (Romano et al. 2021) from International Panel on Climate Change (IPCC)'s emission category 'enteric fermentation' and 'manure management systems' (IPCC 2019).

standards. Values of CH_4 emissions were obtained by the sum of the two emission categories indicated by the IPCC (2019): 'enteric fermentation' and 'anaerobic digestion of manure'. The methods used to produce the data are documented in the Italian Greenhouse Gas Inventory 1990–2019 (Romano et al. 2021) and were mainly based on the TIER2 approach.

Calculation of CO_2-equivalent

The CO_2e of annual CH_4 emissions for each species were calculated following the equation (2) of the IPCC (1990), where E is the annual CH_4 emission and GWP_H is the global warming potential of one ponderal unit CH_4 in a time horizon of 100 years corresponding to 28 units of CO_2e (IPCC 2019). The impact values obtained are obviously the same as those calculated by ISPRA for the different species.

Calculation of CO_2-warming equivalent

The CO_2we of annual CH_4 emissions for each species were calculated following the equation (5) of Smith et al. (2021), where $E_{SLCP}(t)$ represents the annual CH_4 emission for a considered year, and $E_{SLCP}(t\text{-}20)$ is the annual CH_4 emission relative to the previous 20 years. Because the available official annual data range from 1990 to 2020, the CO_2we of annual CH_4 emissions were calculated for the decade 2010–2020, a period deemed sufficient for a comparative time series between the two metrics cumulative CH_4 emissions in 11 years (2010–2020) were calculated following the equations (2 and 5).

Results

The CH_4 climate annual impacts of Italian livestock for dairy cattle, non-dairy cattle and buffalo, from 2010 to 2020, calculated by using GWP* showed a value always below zero for the former, but with a trend towards zero in recent years for the second, and values above zero and increasing for buffaloes (Figure 3). Regarding the cumulative climate impact, dairy and non-dairy cattle showed linear increasing when assessed by official IPCC metric (GWP_{100}), whereases it assumed increasingly negative values when assessed using GWP*. Conversely, cumulative impact of buffalo presented increasingly positive values using the two metrics, with the GWP* values having a higher rate of increase than GWP. Sheep and goats showed a trend of GWP* values consistently below zero (except for the first year in sheep and the last year in goats) so that the cumulative values at the end of the period were also strongly negative (Figure 4). For the three largest monogastric species, pigs, horses, and mule-asses, the annual climate-altering values calculated by the two methods were always positive, except for the mules and asses showing negative values for GWP* in the first two years. Cumulative climate impact evidenced higher value calculated by GWP* for swine, an interesting overlap of estimates for horses and the greatest impact for the last category when calculated with GWP*, especially from 2015 (Figure 5). The climate-altering impacts of poultry and rabbits showed, when calculated with the new metric, decreasing annual values moving from positive to negative, with 2014 having values near zero. Cumulative impacts calculated with GWP* (constantly lower than GWP) initially increased, with positive values until 2015, and then started to decrease with increasing negative values (Figure 6). The Figure 7 shows the climate-changing impacts of Italian whole-farming for the years 2010–2020. Values were consistently below zero when calculated with the GWP* metrics, and positive and almost constant when calculated with the GWP. Cumulative impact increased linearly when calculated by GWP, whereases it was increasingly negative when assessed by new metric.

Table 1 shows the quantitative and proportional variation of methane emission from 1991 to 2020, and the cumulative impact calculated with GWP and GWP* of the livestock sector in the 11 years under consideration. Except for buffalo, that increased the methane emissions by the 372% (from 7.8 to 36.9 kt CH_4, from 1991 to 2020, respectively), all ruminant species showed decreased values of their emissions (mean of −18%). Among monogastric animals, poultry and rabbits decreases the CH_4 emissions (mean of −31.7%) whereases, swine, horses, and mules and asses increase their emission by 1.6%, 17.3% and 8.8%, respectively. Overall, the total livestock sector reduced the CH_4 emissions by 14.4%, from 821 to 702 kt CH_4, from 1990 to 2020. In term of cumulative impact, cattle (dairy and non-dairy), sheep, goat, poultry and rabbits evidenced negative values of CO_2we, whereases, buffaloes, horses, and mules and asses had positive values.

Considering the nitrous oxide (N_2O) (direct) emissions over the 11 years as calculated by Romano et al. (2021) for the Italian livestock species, the accumulated climate change value of the GHG emitted, calculated as the sum of these data and those of CH_4 evaluated with the GWP*, is still largely negative and on average equal to −4.43 Mt/year compared with the

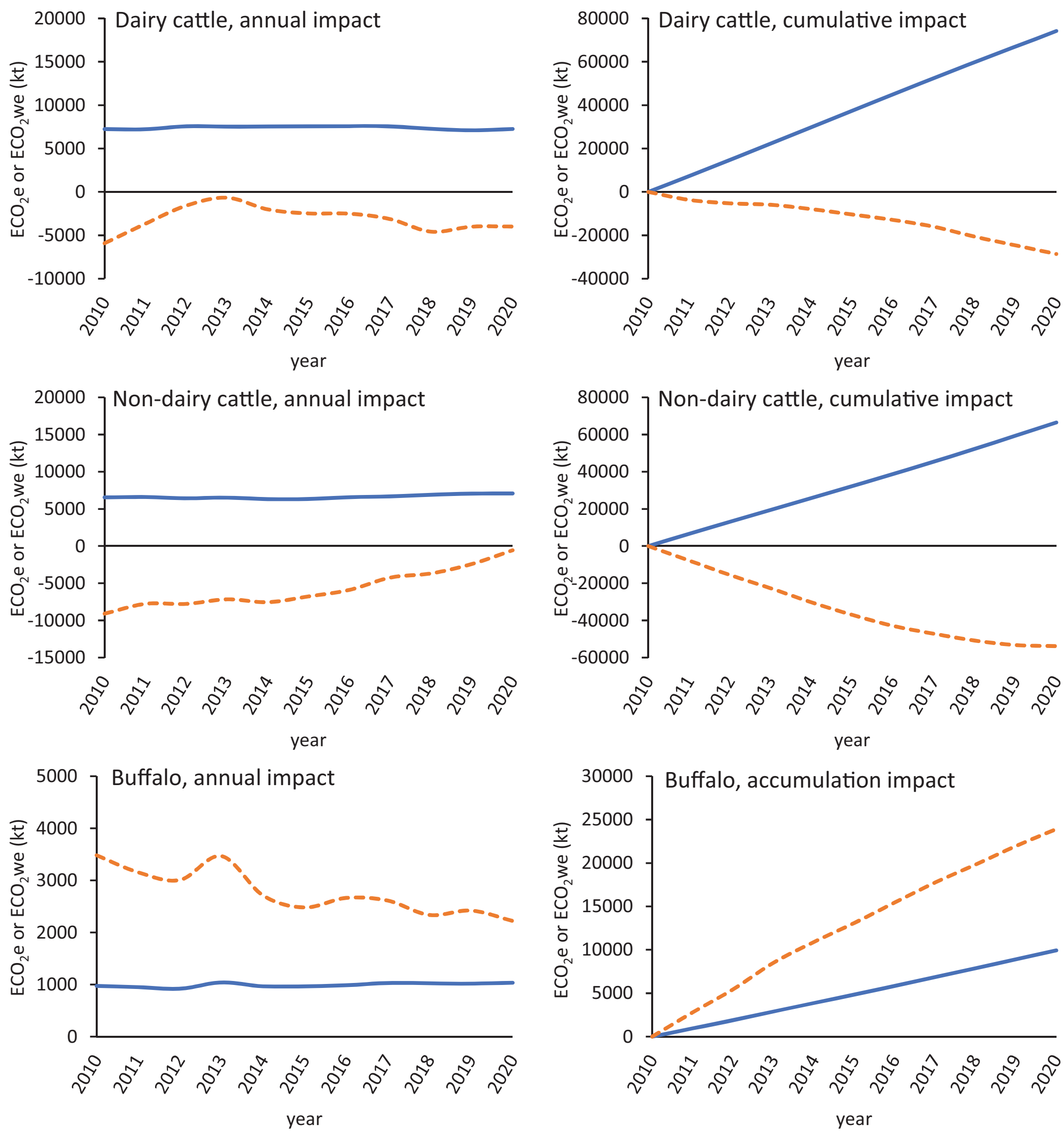

Figure 3. Methane (CH_4) climate impact of Italian livestock for dairy cattle, non-dairy cattle and buffalo, from 2010 to 2020. Annual (left panel) and cumulative (rigth panel) methane emissions estimated as CO_2 equivalents (ECO_2e; blue solid lines) using the global warming potential (GWP), and as CO_2 warming equivalents (ECO_2*we*; orange dotted lines), calculated by global warming potential star (GWP*).

official figure, in which both emissions are calculated with the GWP metrics, which is equal to +18.73 Mt/year (Table 2).

Discussion

In this work, the environmental impact of the CH_4 emissions from the main animal production chains in Italy over the 2010–2020-time frame was assessed using IPCC standards GWP_{100} and the new metric GWP*. The use of the new metric allows to better account for the different physical behaviours of short- and long-lived gases (Forster et al. 2021), that lead to different warming effects. This is of crucial importance for the livestock sector, considering that a large part of the environmental impact is due to the emissions of the SLCP CH_4 (Saunois et al. 2020). It should be stressed that the different metrics (i.e. GWP and GWP*) do not provide the same answer, and the appropriateness of the choice of a specific metric depends on the reasons for which gases are being compared (IPCC 2021). We estimated different pathways of CH_4 emissions for different livestock specie, either looking to the annual emissions and to the cumulative emission framework, for the decade 2010–2020. It should be emphasised that the GWP_{100} is not indicated for use in GHG cumulative frameworks and, in this paper, its comparison with GWP* is only

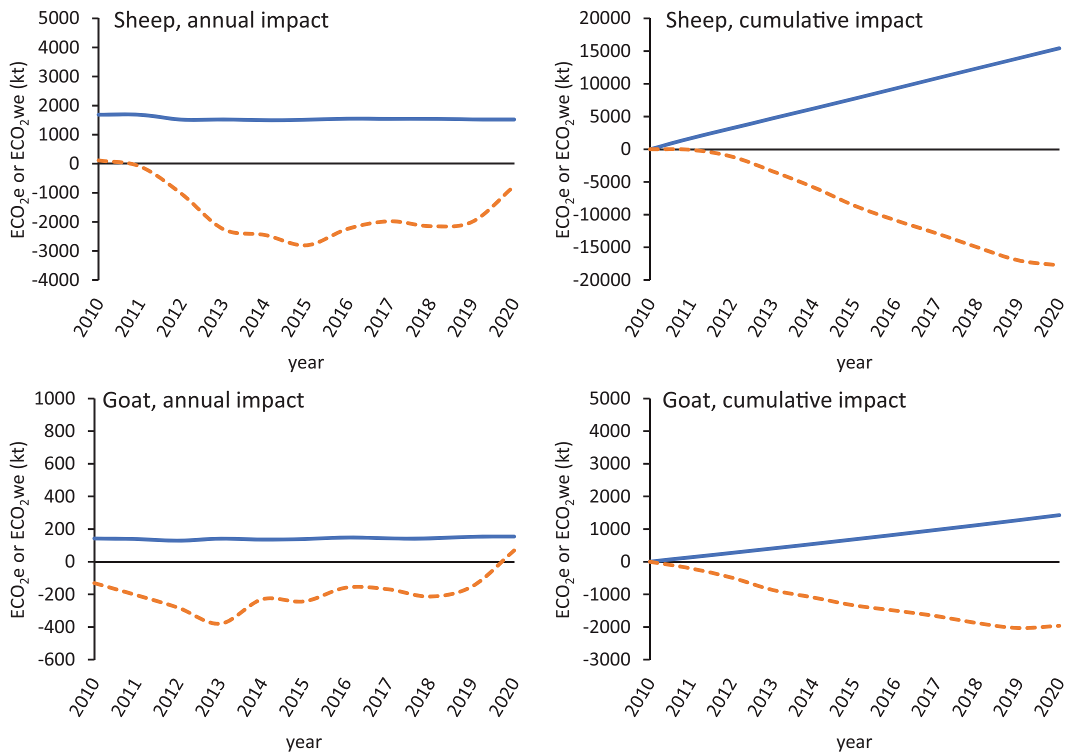

Figure 4. Methane (CH_4) climate impact of Italian livestock for sheep and goat, from 2010 to 2020. Annual (left panel) and cumulative (rigth panel) methane emissions estimated as CO_2 equivalents (ECO_2e; blue solid lines) using the global warming potential (GWP), and as CO_2 warming equivalents (ECO_2we; orange dotted lines), calculated by global warming potential star (GWP*).

intended to highlight wherever the new metrics can be more suitable, and to compare our results with those of recent papers using a similar approach (Del Prado et al. 2021; Liu et al. 2021; Place and Mitloehner 2021). According to the method followed in these last cited works, and to the discussion on the applicability of GWP* of the FAO report (2022), in the present work the CO_2*we* for a time series (a decade) was calculated, in order to consider the dependence of GWP* from the reference baseline year. Indeed, step/pulse metrics like GWP* depend on the emission in the considered year and 20 years ago (reference baseline year); if applied only from the present day relative to 20 years prior, it will only indicate the additional effect of the emissions on the temperature trend at the present day, but it will not reveal the absolute level of warming caused by the methane emissions (FAO 2022).

Climate impact of italian livestock

The trend of climate impact evidenced by the large ruminants of implies that the cumulative impacts calculated with the two metrics, were of opposite sign for the first two categories, while for buffaloes the cumulative impact calculated with GWP* was higher than that calculated with GWP. The results observed for the two cattle categories (dairy and non-dairy) agree with a recent report on the cattle CH_4 climate impact in US (Liu et al. 2021), although the impact is of different magnitude, considering the huge difference in the number of animals.

Regarding the cumulative impact of sheep, the result of the present work agrees with a recent work investigating on the global warming of small ruminant dairy sector in European regions (Del Prado et al. 2021); however, the result for goat were contrasting with our results, being the trend of accumulative impact constantly of positive sign. The authors explain the differences among species with a larger expansion of the goat dairy system compared to sheep ones; on the other hand, in Italy the consistency of both species has decreased in the last decades.

Regarding the three largest monogastric species, pigs, horses, and mule-asses, the absolute values for these classes of livestock are far lower than those for ruminant species, due to both the livestock consistencies discussed below and the lower enteric emissions. In addition to the very limited contribution of poultry and rabbits to the CH_4 emissions of Italian livestock,

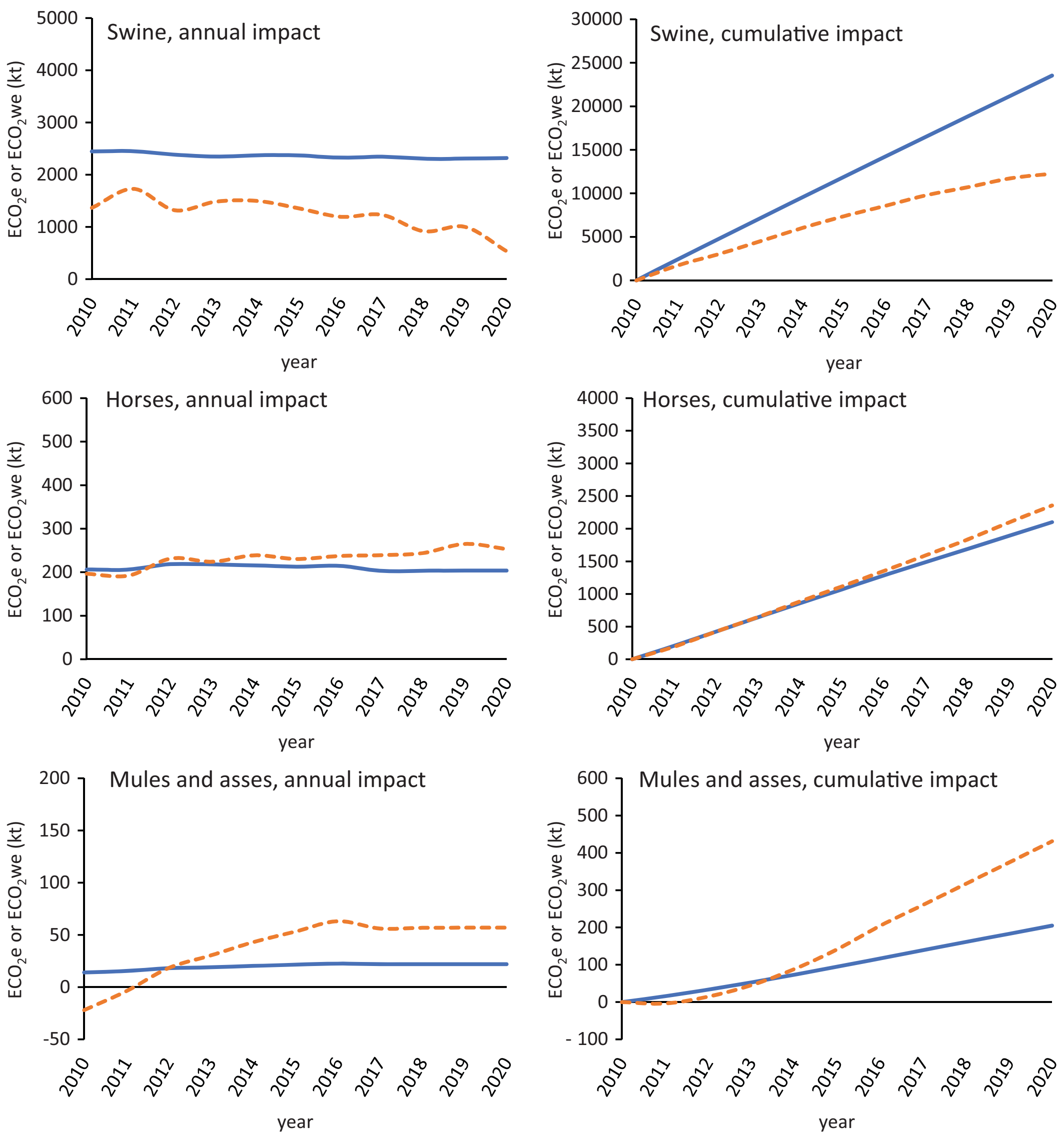

Figure 5. Methane (CH_4) climate impact of Italian livestock for swine, horses, and mules and asses, from 2010 to 2020. Annual (left panel) and cumulative (rigth panel) methane emissions estimated as CO_2 equivalents (ECO_2e; blue solid lines) using the global warming potential (GWP), and as CO_2 warming equivalents (ECO_2we; orange dotted lines), calculated by global warming potential star (GWP*).

the cumulative impact, calculated by GWP*, showed negative contribution of these two categories to the global warming.

The trend of the annual and cumulative impacts of the whole Italian livestock sector was similar to that observed for the dairy and non-dairy cattle, consistently with the huge contribute of these two categories to the total CH4 emission. Obviously, the cumulative results for the 11 years calculated with the two different metrics diverge and show that for the official statistics Italian animal farming has contributed, albeit limitedly compared to other sectors, to global warming, while it has decelerated the phenomenon thanks to the reduction of the heads reared for the species with higher emission of the GHG (Figure 7).

The explanation for the trends found in the calculation of GWP* values can be attributed in large part to the to the variation in the number of the various categories of Italian livestock over the 1991–2020 time frame (Table 3). Dairy cows are constantly decreasing, as well as other cattle, while sheep and pigs have increased at the turn of the millennium and then a numerical fall that influenced the reduction of the impacts calculated with the GWP* metrics; on the contrary, pigs and above all buffaloes showed a numerical increase in the period 2010–2020 compared to the previous twenty years, so their emissions were positive and even higher if calculated with the GWP* metrics than those obtained with GWP.

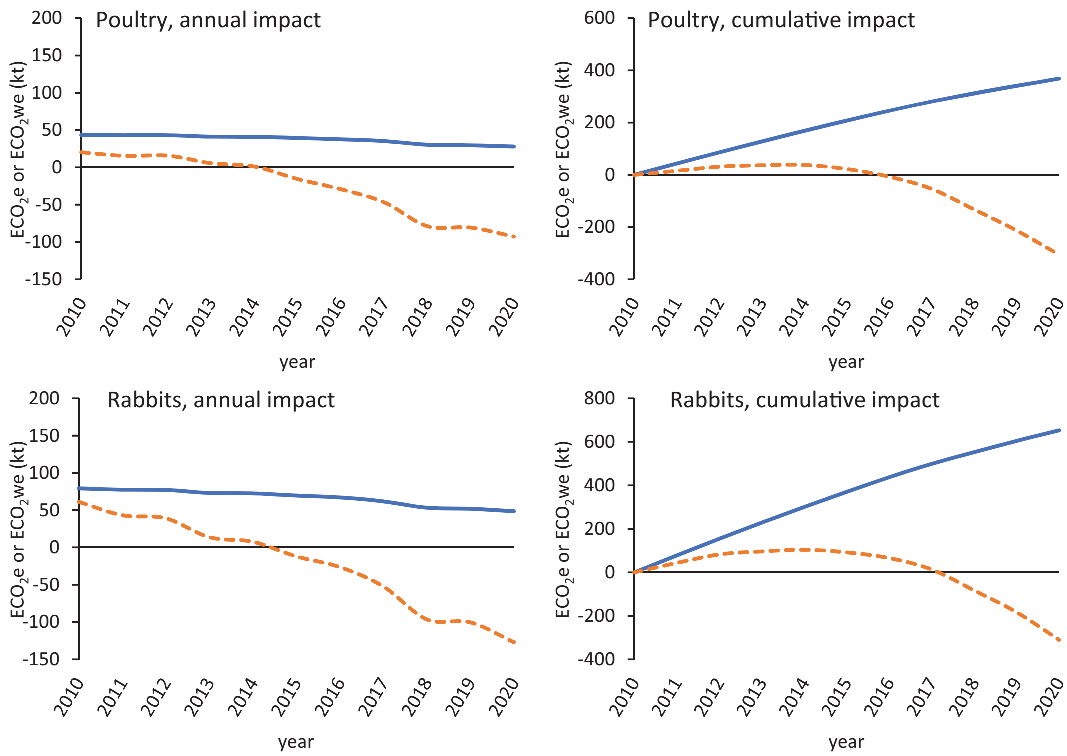

Figure 6. Methane (CH_4) climate impact of Italian livestock for poultry and rabbits, from 2010 to 2020. Annual (left panel) and cumulative (rigth panel) methane emissions estimated as CO_2 equivalents (ECO_2e; blue solid lines) using the global warming potential (GWP), and as CO_2 warming equivalents (ECO_2we; orange dotted lines), calculated by global warming potential star (GWP*).

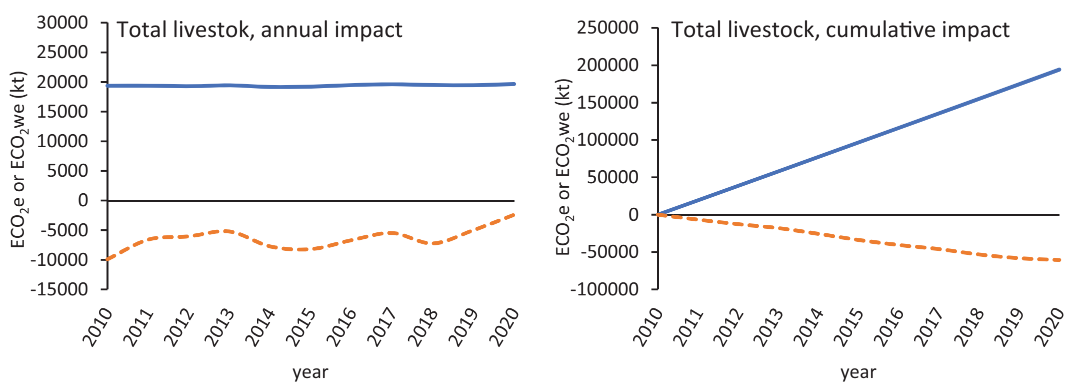

Figure 7. Total methane (CH_4) climate impact of Italian livestock (dairy cattle, non-dairy cattle, buffalo, sheep, goat, swine, horses, mule and asses, poultry, rabbits) from 2010 to 2020. Annual (left panel) and cumulative (rigth panel) methane emissions estimated as CO_2 equivalents (ECO_2e; blue solid lines) using the global warming potential (GWP), and as CO_2 warming equivalents (ECO_2*we*; orange dotted lines), calculated by global warming potential star (GWP*).

Interestingly, a huge variability can be observed in the annual trend of CO_2*we* reported for almost all the species, compared to the trend of CO_2e; this aspect can be explained by the previous mentioned dependence of GWP* on the emissions in the present and 20 years ago. Indeed, when methane emissions show a considerable year to year variability, GWP* results are more variable compared to those of GWP (Meinshausen and Nicholls 2022).

The reduction of climate impact observed using the GWP* only reflects the lowering of number of animals. However, it should be stressed that in general a reduction of GHG emissions is related to the improvement of farm efficiency. For example in Italy, cow's milk production has increased in the last two decades even though the number of animals has decreased (Figure 8) confirming that high-performing herds have a lower emission intensity than low-performing ones

Table 1. Total methane (CH_4) emissions of Italian livestock (dairy cattle, non-dairy cattle, buffalo, sheep, goat, swine, horses, mule and asses, poultry, and rabbits) from 1991 to 2020 (Romano et al. 2021) and methane climate impact from 2010 to 2020 calculated with global warming potential (GWP) and global warming potential star (GWP*) metrics.

Species	CH_4 1991 (kt)	CH_4 2020 (kt)	Total variation (%)	Annual average variation (%)	(SD)[a]	Cumulative GWP 2010–2020 (kt CO_2e)[b]	Cumulative GWP* 2010–2020 (kt CO_2we)[c]
Dairy cattle	325.2	259.1	−20.3	−0.7	3.1	74159	−28610
Non-dairy cattle	325.5	252.8	−22.3	−0.8	2.7	66437	−53786
Buffalo	7.8	36.9	372.2	5.9	10.0	9933	27073
Sheep	63.3	54.4	−14.1	−0.4	4.9	15427	−17763
Goats	6.5	5.5	−15.5	−0.3	7.9	1427	−1962
Swine	81.6	82.9	1.6	0.1	1.8	23530	12266
Horses	6.2	7.3	17.3	0.6	3.7	2100	2356
Mules and Asses	0.7	0.8	8.8	0.7	9.0	205	431
Poultry	1.5	1.0	−32.7	−1.3	4.4	369	−306
Rabbits	2.5	1.7	−30.7	−1.2	4.4	653	−310
Total Livestock	820.9	702.4	−14.4	−0.5	1.7	194240	−60610

[a]SD: standard deviation of Annual average variation; [b]GWP: global warming potential; CO_2e: CO_2 equivalents; [c]GWP*: global warming potential star; CO_2we: CO_2 warming equivalents.

Table 2. Nitrous oxide (N_2O) GWP of Italian livestock (dairy cattle, non-dairy cattle, buffalo, sheep, goat, swine, horses, mule and asses, poultry, and rabbits) from 2010 to 2020 (Romano et al. 2021) and methane (CH_4) + N_2O climate impact from 2010 to 2020 calculated with global warming potential (GWP) and global warming potential star (GWP*) metrics.

Species	N_2O GWP 2010–2020	GWP(N_2O) + GWP(CH_4)	GWP(N_2O) + GWP*(CH_4)
Dairy cattle	3022	77182	−25587
Non-dairy cattle	3639	70076	−50147
Buffalo	505	10438	27578
Sheep	243	15670	−17519
Goats	33	1460	−1929
Swine	2123	25653	14389
Horses	158	2258	2514
Mules and Asses	28	233	459
Poultry	1785	2154	1480
Rabbits	314	966	4
Total Livestock	11851	206091	−48759

Table 3. Time series of Italian livestock from 1991 to 2020 (head × 1000) (Romano et al. 2021).

	(head × 1000)									
Year	Dairy cattle	Non-dairy cattle	Sheep	Swine	Buffalo	Goats	Horses	Mules and Asses	Poultry	Rabbits
1991	2340	5582	8397	8549	83	1261	314	66	173061	15877
1992	2146	5426	8461	8244	103	1355	316	57	172684	16399
1993	2119	5322	8670	8348	101	1409	323	49	173261	16531
1994	2012	5157	9964	8023	108	1658	324	43	178659	16905
1995	2080	5189	10668	8061	148	1373	315	38	184202	17111
1996	2080	5094	10943	8171	172	1419	312	34	183045	17434
1997	2078	5095	10894	8293	161	1351	313	30	186815	17610
1998	2116	5013	10894	8323	186	1331	290	34	198800	17705
1999	2126	5036	11017	8414	200	1397	288	33	196573	18021
2000	2065	4988	11089	8307	192	1375	280	33	176722	17874
2001	2078	4661	8311	8766	194	1025	285	33	195541	18495
2002	1911	4599	8138	9166	185	988	278	29	186367	18853
2003	1913	4591	7951	9157	222	961	283	29	180182	18867
2004	1838	4466	8106	8972	210	978	278	29	178914	19655
2005	1842	4410	7954	9200	205	946	278	30	174667	20504
2006	1821	4296	8227	9281	231	955	287	31	173679	20238
2007	1839	4444	8237	9273	294	920	316	35	179222	20965
2008	1831	4348	8175	9252	307	957	332	36	183588	19515
2009	1878	4224	8013	9157	344	961	344	41	181314	17690
2010	1746	4086	7900	9321	365	983	373	46	175912	17957
2011	1755	4143	7943	9351	354	960	373	51	174787	17549
2012	1857	3886	7016	8662	349	892	396	60	174648	17465
2013	1862	3985	7182	8562	403	976	394	63	176919	16549
2014	1831	3925	7166	8676	369	937	391	67	175564	16436
2015	1826	3955	7149	8675	374	962	385	71	177392	15761
2016	1822	4108	7285	8478	385	1026	388	74	178690	15207
2017	1791	4158	7215	8571	401	992	368	72	178635	14001
2018	1693	4230	7179	8492	401	986	368	72	175022	12090
2019	1643	4332	7001	8510	402	1059	368	72	175520	10874
2020	1638	4355	7034	8543	407	1066	368	72	178907	11010

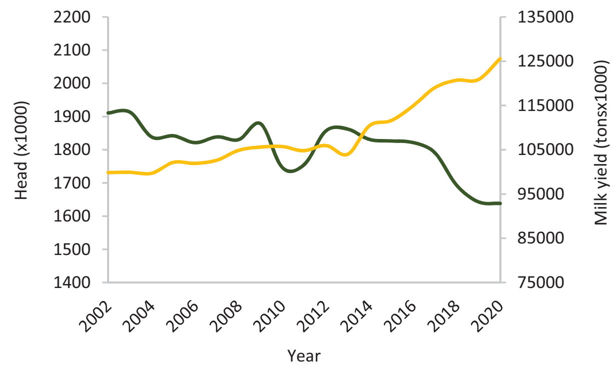

Figure 8. Trend of the dairy cattle consistency (number of head × 1000, dark green line) and cow's milk yield (tons × 1000, yellow line) in Italy from 2002 to 2020. (Romano et al. 2021; ISTAT 2021).

as recently observed by Froldi et al. (2022). Specifically, the CH_4 emission intensity of Italian dairy cattle (kg CH_4/kg of milk), calculated in the present study, decreased from 0.03 to 0.02, corresponding to 0.82 and 0.58 in term of CO_2e, respectively.

Expressed in quantitative terms (Table 1), the cumulative impact of the livestock sector in the 11 years under consideration would have affected more than 194 Mt if calculated using GWP metric, while the value turns out to be almost −60 Mt if calculated using GWP* metric, a big difference. In terms of individual categories, the contribution of the cattle and sheep sector stands out, while the buffalo and pig sectors have accumulated positive impacts removing a share of the virtuous trend of the first two.

Notwithstanding the use of the new metrics is relatively recent, some criticism arose in the scientific debate. Rogelj and Schleussner (2019) warn against the indiscriminate use of these new metrics when applied at the country level. They propose that the GWP* be adjusted for the time series of emissions, so as not to reward countries that have polluted heavily in the past and penalise developing countries that increase them to further their economic growth having low emissions in the past. These authors also warn against the abuse of the negative emissions value that results from applying the new metrics to LLCP reduction cases, which if applied out of scientific context and for policy purposes can be misleading. However, these objections can be applied both among countries and among breeding sectors and can lead to misleading conclusions if the exact purpose for which the measurements were carried out is not specified. The aim of this work was exclusively to provide measurements using the new metrics regardless its application which would require, as observed by Rogelj and Schleussner (2019), the choice of economic contexts and the related parameters that are arbitrary, and which border on speculative reasoning, typical of economic and social sciences.

Conclusions

The application of the GWP* new metrics on the CH_4 emissions of Italian livestock sector compared to the values obtained applying the GWP_{100} standard metric, over 2010–2020 time frame, evidences that the Italian animal supply chains reduced the warming impact of CH_4 emissions.

The result of the work allows to identify differences among species, being ruminants (except buffaloes) major contributors to this positive effect, balancing the increase of the emissions registered by the lowest CH_4 impacting species (buffalo, swine, horses, mules and assess) at national level (18% of total methane emissions).

The entity of the decrease in CH_4 emissions over the 2010–2020 time frame assessed using GWP* was also able to compensate the warming effect of LLCP N_2O of all Italian livestock sector, allowing to better identify its role on climate change.

Acknowledgments

This paper is a follow-up to the communications presented at the conferences Cow is Veg, Rome (Italy), 29 September 2022, and international conference sustainable development and climate change: 30 years after the hc degree in agricultural sciences to Lester Russell Brown, Pisa (Italy), October 19–20, 2022

Ethical approval

All research reported in this research has been conducted in an ethical and responsible manner, and is in full compliance with all relevant codes of experimentation and legislation.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work received financial support from Versoa project (BS Green® Company) and RESTART-UNINUORO Project "Actions for the valorization of agroforestry resources in central Sardinia" Regione Autonoma della Sardegna (fondi FSC 2014–2020).

ORCID

Fabio Correddu http://orcid.org/0000-0002-6098-7519

Mondina Francesca Lunesu http://orcid.org/0000-0002-4260-6364
Maria Francesca Caratzu http://orcid.org/0000-0003-1803-6936
Giuseppe Pulina http://orcid.org/0000-0001-5579-0677

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article.

References

Allen MR, Fuglestvedt JS, Shine KP, Reisinger A, Pierrehumbert RT, Forster PM. 2016. New use of global warming potentials to compare cumulative and short-lived climate pollutants. Nat Clim Change. 6(8):773–776.

Allen MR, Shine KP, Fuglestvedt JS, Millar RJ, Cain M, Frame DJ, Macey AH. 2018. A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. NPJ Clim Atmos Sci. 1(1):1–8.

Cady R. 2020. A literature review of GWP*: a proposed method for estimating Global Warming Potential (GWP*) of short-lived climate pollutants like methane.

Cain M, Lynch J, Allen MR, Fuglestvedt JS, Frame DJ, Macey AH. 2019. Improved calculation of warming-equivalent emissions for short-lived climate pollutants. NPJ Clim Atmos Sci. 2(1):1–7.

Collins WJ, Frame DJ, Fuglestvedt JS, Shine KP. 2020. Stable climate metrics for emissions of short and long-lived species—combining steps and pulses. Environ Res Lett. 15(2): 024018.

Del Prado A, Manzano P, Pardo G. 2021. The role of the European small ruminant dairy sector in stabilising global temperatures: lessons from GWP* warming-equivalent emission metrics. J Dairy Res. 88(1):8–15.

FAO 2022. Methane Emissions in Livestock and Rice Systems – Sources, quantification, mitigation and metrics (Draft for public review). Livestock Environmental Assessment and Performance (LEAP) Partnership. Rome: FAO.

Forster P, Storelvmo T, Armour K, Collins W, Dufresne JL, Frame D, Lunt DJ, Mauritsen T, Palmer MD, Watanabe M, et al. 2021. The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. In: Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthews JBR, Maycock TK, Waterfield T, Yelekçi O, Yu R, Zhou B, editors. Climate Change 2021: the Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, New York, NY: Cambridge University Press. p. 923–1054.

Froldi F, Lamastra L, Trevisan M, Mambretti D, Moschini M. 2022. Environmental impacts of cow's milk in Northern Italy: effects of farming performance. J Clean Prod. 363: 132600.

Hörtenhuber SJ, Seiringer M, Theurl MC, Größbacher V, Piringer G, Kral I, Zollitsch WJ. 2022. Implementing an appropriate metric for the assessment of greenhouse gas emissions from livestock production: a national case study. Animal. 16(10):100638.

IPCC. Intergovernmental Panel on Climate Change 1990. Climate change: the intergovernmental panel on climate change scientific assessment. Cambridge: Cambridge University Press.

IPCC. Intergovernmental Panel on Climate Change 2019. Guidelines for national greenhouse gas inventories - Volume 4: Agriculture, Forestry and Other land Use – Refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. Geneva, Switzerland: IPCC

IPCC. Intergovernmental Panel on Climate Change 2021. Climate Change 2021: The Physical Science Basis. Contribution of working group to the sixth assessment report of the intergovernmental panel on climate change. In: Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthews JBR, Maycock TK, Waterfield T, Yelekçi O, Yu R, Zhou B, editors. Cambridge, New York, NY: Cambridge University Press. p. 2391.

Italian National Institute of Statistics [ISTAT]. 2021. I.Stat - Statistiche ISTAT; [accessed 2022 November]. https://www.istat.it/it/dati-analisi-e-prodotti/statistiche-a-z:-parole-chiave.

Italian National Institute for environmental protection and research- Istituto Superiore per la Protezione e la Ricerca Ambientale [ISPRA]. 2022. [accessed 2022 November]. http://emissioni.sina.isprambiente.it/serie-storiche-emissioni/.

Liu S, Proudman J, Mitloehner FM. 2021. Rethinking methane from animal agriculture. CABI Agric Biosci. 2(1):1–13.

Meinshausen M, Nicholls Z. 2022. GWP* is a model, not a metric. Environ. Res. Lett. 17(4):041002.

Place SE, Mitloehner FM. 2021. Pathway to climate neutrality for U.S. beef and dairy cattle Production. https://clear.ucdavis.edu/sites/g/files/dgvnsk7876/files/inline. files/CLEAR%20Center%20Climate%20Neutrality%20White%20Paper_2.pdf

Rogelj J, Schleussner CF. 2019. Unintentional unfairness when applying new greenhouse gas emissions metrics at country level. Environ Res Lett. 14(11):114039.

Romano D, Arcarese C, Bernetti A, Caputo A, Cordella M, De Lauretis R, Di Cristofaro E, Gagna A, Gonella B, Moricci F, et al. 2021. Italian greenhouse gas inventory 1990–2019. National Inventory Report. ISPRA.

Saunois M, Stavert AR, Poulter B, Bousquet P, Canadell JG, Jackson RB, Raymond PA, Dlugokencky EJ, Houweling S, Patra PK, et al. 2020. The global methane budget 2000–2017. Earth Syst Sci Data. 12(3):1561–1623.

Schleussner CF, Nauels A, Schaeffer M, Hare W, Rogelj J. 2019. Inconsistencies when applying novel metrics for emissions accounting to the Paris agreement. Environ. Res. Lett. 14(12):124055.

Shine KP, Fuglestvedt JS, Hailemariam K, Stuber N. 2005. Alternatives to the global warming potential for comparing climate impacts of emissions of greenhouse gases. Clim Change. 68(3):281–302.

Smith MA, Cain M, Allen MR. 2021. Further improvement of warming-equivalent emissions calculation. NPJ Clim Atmos Sci. 4(1):1–3.