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Süt Sığırcılığında Gübre Yönetimi ve Enterik Fermantasyondan Kaynaklı Karbon Ayak izi: Burdur, Türkiye Örneği

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ÖZET

Tarım ve hayvancılık, iklim değişikliğinden etkilenen en büyük sektör ağlarından biridir. Küresel ısınma, sera gazlarının (GHG) atmosferde birikmesiyle oluşan ısının Dünya'nın sıcaklığını artırması nedeniyle meydana gelmektedir. Öte yandan karbon ayak izi, canlıların faaliyetlerinden salınan karbondioksit gibi sera gazlarının neden olduğu çevresel zararı ifade eder. Sığırlar, sindirim süreçleri ve gübre yönetimi yoluyla metan (CH_4), azot dioksit (N_2O) ve karbon dioksit (CO_2) gibi sera gazları yayarak küresel ısınmaya katkıda bulunur. Türkiye süt sığırcılığında çok önemli bir konuma sahiptir. Burdur, kültür sığırı popülasyonu ve günlük bin tonun üzerinde çiğ süt üretimi ile önemli bir tarım ve hayvancılık kentidir. Bu çalışmada, Burdur'da gerçekleştirilen süt sığırcılığının karbon ayak izi TÜİK'ten elde edilen verilere dayanarak hesaplanmıştır. Hesaplamada Hükümetlerarası İklim Değişikliği Paneli (IPCC, 2006) rehberinde yer alan Tier 1 yaklaşımı kullanılmıştır.

Anahtar Kelimeler: *Karbon Ayakizi, Gübre Yönetimi, Enterik Fermantasyon*

Carbon Footprint of Manure Management and Enteric Fermentation in Dairy Cattle Farming: The Case of Burdur, Türkiye

ABSTRACT

Agriculture and animal husbandry are one of the largest sector networks affected by climate change. Global warming occurs as a result of the heat generated by the accumulation of greenhouse gases (GHG) in the atmosphere, increasing the temperature of the Earth. On the other hand, carbon footprint refers to the damage caused to the environment by GHGs, such as carbon dioxide released from living beings' activities. Cattle contribute to global warming by emitting GHG such as methane (CH_4), nitrogen dioxide (N_2O) and carbon dioxide (CO_2) through their digestive processes and manure management. Türkiye has a very important position in dairy cattle farming. Burdur is an important agricultural and animal husbandry city with a cultured cattle population and daily raw milk production of over a thousand tons. In this study, the carbon footprint of dairy cattle farming carried out in Burdur was calculated based on data obtained from TÜİK. The Tier 1 approach included in the guide of the Intergovernmental Panel on Climate Change (IPCC, 2006) was used in the calculation.

Keywords: *Carbon Footprint, Manure Management, Enteric Fermentation*

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1. INTRODUCTION

Across the world, factors such as pandemics, droughts, and unemployment are forcing people to migrate, while the rapidly growing population poses a major threat to food security. With the industrial revolution, the rapid spread of factories, demands for more products, and waste problems caused by mass production have led to the depletion of natural resources (Viena et al., 2022).

The rapid increase in population growth and food demand has made it inevitable to make mandatory policies and investments to solve food problems at the international level. Human interventions in nature have consequently led to one of our time's most serious environmental problems, known as the “global climate crisis” (Koyuncu and Akgün, 2018; Ahmet, 2019).

The rapid depletion of natural resources has created serious international food production and distribution challenges. This has necessitated international cooperation and the development of new strategies to ensure food security and transition to sustainable agriculture. Climate change has profoundly affected agriculture, livestock production, and food supply, causing major global environmental and economic crises. It is known that there is a reciprocal relationship between climate change and the livestock sector (Yaylı ve Kılıç, 2020; Erzurum, 2024).

The agricultural sector in Türkiye is important in various aspects, such as providing food production, having a share in exports, providing capital to the food industry, and creating employment. According to TUIK data, there are 17850543 cattle animals in 2021. 2021 The number of dairy cattle enterprises is 1062547. In 2021, milk production from cattle species was 21370116 tons. The provinces with the highest number of milk-giving cows are Konya, Erzurum, and İzmir, and the provinces with the highest milk production are Konya, İzmir, and Erzurum, respectively. The provinces with the highest cow milk yield per animal are Denizli, Tekirdağ, and Burdur (Ulusal Süt Konseyi, 2021).

GHG emissions from milk production mainly consist of CH_4 emissions from the digestion of feed and N_2O emissions from the fertilizer used to grow the feed. It is reported that about 65% of GHG emissions from livestock activities are from cattle. In most developing countries such as Türkiye, 39% of GHG emissions from the livestock sector come from enteric fermentation and 26% from manure management (IPCC, 2006; Herrero et al. 2013). While the livestock sector significantly contributes to climate change with the greenhouse gases it produces, it also directly feels the consequences of climate change. Temperature increases in the atmosphere, sudden weather events, and climate instability can seriously impact livestock activities. The release of greenhouse gases such as CH_4, N_2O, CO_2, and fluorinated gases during farm operations, processing industry, and marketing processes indirectly triggers climate change. However, climate change challenges the sector through greenhouse gases and affects agricultural and animal production. While temperature changes in the atmosphere and sudden weather events directly impact the health, growth, and productivity of animals, they also affect the sector through indirect effects such as reduced water resources, reduced feed quality, and reduced soil fertility. In this case, the livestock sector has become a sector that contributes to climate change and is negatively affected by these changes (Kumaş and Akyüz, 2021).

Climate change adaptation and mitigation efforts in the agricultural sector in Türkiye started in the early 2000s under the leadership of governmental institutions and continue rapidly and effectively today (Arslan et al., 2024). However, it can be said that studies for the livestock sector have not reached a sufficient level (Dellal et al. 2024; Pence et al. 2024).

Carbon footprint is used to monitor the outputs of production and consumption processes. In the context of global warming, the concept of carbon footprint is used to express the environmental impact of activities carried out to meet the needs of living things (Kumaş ve Akyüz, 2021).

Burdur is an important province of our country in dairy cattle breeding, with 98% of its cattle being cultivated breeds and producing over a thousand tons of raw milk daily (Ulusal Süt Konseyi, 2021).

In this study, the carbon footprint of dairy farming in Burdur was calculated based on the data obtained from TUIK. The Tier 1 approach in the guidelines of the Intergovernmental Panel on Climate Change (IPCC, 2006) was used in the calculation.

2. LITERATURE REVIEW

The studies on the topic in the last five years were presented chronologically.

Frank et al. modeled energy and GHG flows in dairy farming and aimed to develop GHG mitigation strategies. They calculated an average emission of 995 g CO_2 equivalent (CO_{2e}) per liter for organic farms in Germany and 1.048 g CO2e per liter for conventional farms. Organic farms have increased carbon storage in the soil, while conventional farms have higher GHG emissions due to high energy consumption and land use change (Frank et al. 2019).

Wattiaux et al. studied the biophysical drivers of the major GHG emission sources on farms: enteric CH_4, and N_2O from manure, N_2O from cropland, and CO_2 emissions. The impact of selected management practices on emission reductions was investigated. In addition, findings from life cycle assessments of dairy production systems in the US Midwest are summarized (Wattiaux et al. 2019).

Ibidhi and Calsamiglia estimated the GHG emissions and carbon footprint of twelve dairy farms in Spain. CH_4 emissions were the largest contributor to total GHG emissions, with an average carbon footprint of 0.84 kg CO_{2e} per 1 kg of milk. Management changes were more effective in reducing the carbon footprint than dietary changes by up to 27.5% (Ibidhi and Calsamiglia, 2020).

Thakuri et al. first estimated enteric CH_4 emission factors for local and improved cattle breeds in Nepal using IPCC Tier 2 methodology. Local cattle's annual CH_4 emission factor was calculated as 33 kg and 46 kg for improved cattle. Using country-specific emission factors can improve the accuracy of national GHG inventories, reduce uncertainties, and contribute to combating climate change (Thakuri et al. 2020).

Tongwane and Moeletsi investigated the causes of CH_4 and N_2O emissions from cattle in nine national regions of South Africa. In 2019, cattle in South Africa produced 35.37 million tons of CO_{2e} emissions, 64.54% of which were from CH_4. The Eastern Cape has the highest emissions, with commercial beef and traditional livestock farming responsible for the majority of total emissions (Tongwane and Moeletsi, 2021).

According to Sahu and Agarwal, the dairy sector is a major source of anthropogenic greenhouse gas emissions measured by carbon footprint. In studies using various international standards and methodologies, enteric CH_4 stood out as the main source of emissions, followed by manure management and fertilizer production. To reduce emissions, balanced feed rations, the reduction of nitrogen-based fertilizers, and the use of alternative energy sources such as biogas are recommended (Sahu and Agarwal, 2021).

Gross et al. argued that converting milk production to organic farming can reduce the carbon footprint by eliminating synthetic manures and production based on on-farm nutrient cycling. A study in Germany found that in the first year of the transition to organic milk production, the carbon footprint per energy-adjusted milk decreased by 9% (Gross et al. 2022).

The study in the Mekelle dairy district in Ethiopia investigated the carbon footprint of urban and semi-urban dairy farms in milk production. The average carbon footprint of urban farms was calculated as 3.2 kg CO_2e/kg and 2.2 kg CO_{2e}/kg for semi-urban farms. It was emphasized that climate-friendly milk production methods should be adopted to reduce greenhouse gas emissions in milk production (Balcha et al. 2022).

Kumar et al. aimed to estimate the carbon footprint for cattle milk produced in Hisar district, Haryana, India. A carbon footprint of 2.13 kg CO_{2e} per cow's milk was calculated using life cycle assessment based on the latest methodologies of IPCC. Enteric fermentation was identified as the largest source of GHG emissions at 35.5%, followed by manure and land management (Kumar et al. 2023).

Salsabil et al. aimed to determine CH_4 and N_2O gas emissions from ruminant livestock in Jember. According to IPCC 2006 methodology, CH_4 emissions from enteric fermentation were determined as 103.321 tons CO_{2e} per year, while CH_4 emissions from manure management were determined as 4.510 tons CO_{2e} per year. Indirect N_2O emissions from manure management were higher than direct N_2O emissions with 0.0763 tons CO_{2e} (Salsabil et al. 2023).

Wang et al. conducted a study to assess carbon emissions in a large-scale dairy farm in northeast China and examined various mitigation scenarios for a zero-carbon target. According to the results, enteric fermentation contributes 38.2%, and manure management contributes 29.4% of carbon emissions in dairy farms. The integrated insemination system reduced the carbon footprint by 10.6% compared to the non-integrated system, and emission reductions of up to 61% were achieved in various scenarios (Wang et al. 2024).

Dağlıooğlu et al. analyzed Izmir's GHG emissions from livestock production according to IPCC 2019 guidelines. The total carbon footprint was calculated as 2826.5 thousand tons CO_{2e}, of which 53% comes from enteric fermentation, 39% from CH_4 from manure management and 8% from N_2O. It was emphasized that the carbon footprint could be reduced by 30% with sustainable manure management methods such as biogas production from manure (Dağlıoğlu et al. 2024).

3. MATERIALS AND METHOD

Burdur is located in the Western Mediterranean region. With its ecological structure, animal production is carried out economically all year round. Two-thirds of its population is active in agriculture and animal husbandry. With 40% of its economy based on milk production, Burdur has an important share in this field with 99% of its cattle, 99% of which are cultivated cattle, and daily raw milk production of over a thousand tons (www.burdur.tarimorman.gov.tr). Burdur, which is known as the capital of the Teke Region, has started a major transformation in the livestock sector, which started with small family farming, has reached 4860 cattle enterprises and approximately 192 thousand cattle by 2023, and has started a major transformation with its modern and technological farms (www.data.tuik.gov.tr).

Tier methods (Tier 1, Tier 2, Tier 3) determined by IPCC are used for carbon footprint calculations. In this study, the Tier 1 approach is preferred. The Tier 1 approach is a simpler and more predictive model. The emission factors in the IPCC guidelines are organized according to animal species and climate zones (temperature conditions). Equation 1-2 was used to calculate the carbon footprint (IPCC, 2006).

The number of animals in the TUIK Dairy cattle category in Burdur province between 2019-2023 is given in Table 1 (www.data.tuik.gov.tr).

Table 1. Number of animals

	Altınyayla	***Ağlasun***	***Bucak***	***Gölhisar***	***Karamanlı***	***Kemer***	***Merkez***	***Tefenni***	***Yeşilova***	***Çavdır***	***Çeltikçi***
2019	1674	4545	20240	11607	9556	5626	52387	6445	13945	9020	4840
2020	1512	3460	22369	10124	8850	5551	52408	7197	13536	9905	4661
2021	1437	3324	22467	9878	7301	5978	46659	6466	13897	8343	4843
2022	1244	2779	20389	10226	7299	5939	43735	6511	16117	7602	4595
2023	1265	2774	21710	10441	8415	5632	45794	6759	14349	7788	4869

$$CH_{4_{ent}} = Ef_t x\ N_t x\ 10^{-6} \quad (1)$$

$$CH_{4_{man}} = \sum_t Ef_t x\ N_t x\ 10^{-6} \quad (2)$$

$CH_{4_{man}}$: methane emissions from manure (Gg CH_4 year^{-1})
$CH_{4_{ent}}$: methane emission from enteric fermentation (10^3 tons CH^4 year^{-1})
Ef_t : Emission factor (kg CH_4 head^{-1} year^{-1})
N_t: total number of animals
t: refers to the animal species.

The value of Ef_t from manure is based on Table 10.14 of the IPCC 2006 guidelines. Türkiye is considered as a developing country (IPCC, 2006). The average air temperature of Burdur for many years (1932-2023) was assumed to be 13.3°C (www.mgm.gov.tr). The emission factor 2 kg CH_4 head^{-1} corresponding to 13.3°C for dairy cattle in Table 10.14 of the IPCC 2006 guidelines was used to calculate methane emissions from manure. Table 10.11 of the IPCC 2006 guidelines was used for Ef_t from enteric fermentation. Since Türkiye is located in Eastern Europe, 99 was accepted for dairy cattle (IPCC, 2006). In converting CH_4 emission to CO_{2e}, the multiplication coefficient was taken as 25 (Erzurum, 2024).

4. RESEARCH AND RESULTS

This study determined the methane emissions from dairy cattle and its CO_{2e} for Burdur districts covering 2019-2023. The amount of CH_4 emissions from manure and enteric fermentation are given in Table 2 and Table 3, respectively. In 2019-2023, the highest CH_4 emission from manure was in the central district and the lowest in the Altınyayla district. It was observed that CH_4 emissions decreased in Altınyayla, Ağlasun, Gölhisar, Karamanlı, Merkez, and Çavdır districts and increased in other districts. In the five years used in the study, the highest amount of CH_4 emission in 2020 occurred in the central district with 0.104816 Gg in 2020, while the lowest amount of CH_4 emission in 2022 occurred in Altınyayla district with 0.022488 Gg. When the total amount of emissions by years is analyzed, it is 0.27977 Gg in 2019 and 0.259592 Gg in 2023. The percentage distribution of the total amount of CH_4 emissions from manure between 2019 and 2023 by districts is given in Figure 1. The total amount of emissions between 2019-2023 is given in Figure 2.

Table 2. CH_4 emissions from manure ($GgCH_4$/year)

Year	Altınyayla	Ağlasun	Bucak	Gölhisar	Karamanlı	Kemer	Center	Tefenni	Yeşilova	Çavdır	Çeltikçi
2019	0.00334	0.00909	0.04048	0.02321	0.01911	0.01125	0.10477	0.01289	0.02789	0.01804	0.00968
2020	0.00302	0.00692	0.04473	0.02024	0.01770	0.01110	0.10481	0.01439	0.02707	0.01981	0.00932
2021	0.00287	0.00664	0.04493	0.01975	0.01460	0.01195	0.09331	0.01293	0.02779	0.01668	0.00968
2022	0.00248	0.00555	0.04077	0.02045	0.01459	0.01187	0.08747	0.01302	0.03223	0.01520	0.00919
2023	0.00253	0.00554	0.04342	0.02088	0.01683	0.01126	0.09158	0.01351	0.02869	0.01557	0.00973

Table 3. CH_4 emissions from enteric fermentation (tons CH_4 $year^{-1}$)

Year	Altınyayla	Ağlasun	Bucak	Gölhisar	Karamanlı	Kemer	Center	Tefenni	Yeşilova	Çavdır	Çeltikçi
2019	165.726	449.955	2003.76	1149.093	946.044	556.974	5186.313	638.055	1380.555	892.98	479.160
2020	149.688	342.54	2214.531	1002.276	876.15	549.549	5188.392	712.503	1340.064	980.595	461.439
2021	142.263	329.076	2224.233	977.922	722.799	591.822	4619.241	640.134	1375.803	825.957	479.457
2022	123.156	275.121	2018.511	1012.374	722.601	587.961	4329.765	644.589	1595.583	752.598	454.905
2023	125.235	274.626	2149.29	1033.659	833.085	557.568	4533.606	669.141	1420.551	771.012	482.031

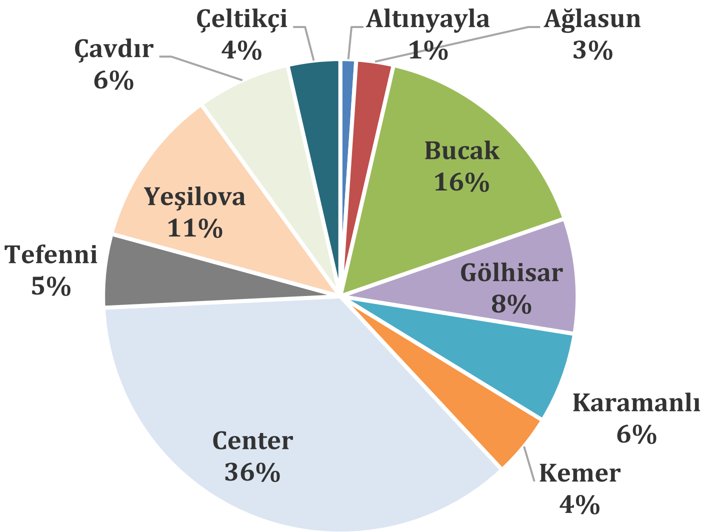

Figure 1. Distribution of total CH_4 emissions from manure by districts for 2019-2023

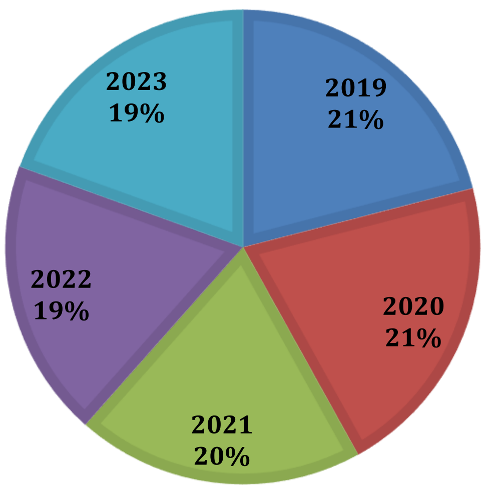

Figure 2. Change in total CH_4 emissions from manure by years 2019-2023

Between 2019 and 2023, the highest CH_4 emissions from enteric fermentation occurred in the central district, while the lowest amount was recorded in Altınyayla district. When the emission amounts of the districts by years are analyzed, Altınyayla, Ağlasun, Karamanlı in 2019; Merkez, Tefenni, Çavdır in 2020; Bucak, Kemer in 2021; Yeşilova in 2022 and Çavdır in 2023 reached the highest emission amountWhen the change in the amount of CH_4 emission from enteric fermentation between 2019 and 2023 is examined; it is seen that it decreased in Altınyayla, Ağlasun, Gölhisar, Karamanlı, Merkez and Çavdır districts and increased in other districts. In the relevant years, the highest CH_4 emission occurred in the central district, with 5188.39 tons in 2020, and the lowest in Altınyayla district, with 123.16 tons in 2022. When the total amount of emissions by years is considered, it is 13848.62 tons in 2019 and 12849.80 tons in 2023. The percentage distribution of the total amount of CH_4 emissions from manure between 2019 and 2023 by districts can be seen in Figure 3. The total amount of emissions between 2019-2023 is given in Figure 4. The global warming potential caused by CH_4 emissions from enteric fermentation and manure was 353209 tons of CO_{2e} in 2019, while this value decreased to 327735 tons of CO_{2e} in 2023. When the change in global warming potential by the district in 2019-2023 is analyzed, the highest decrease was in the Ağlasun district, with 38%, and the lowest was in the Kemer district, with 1%.

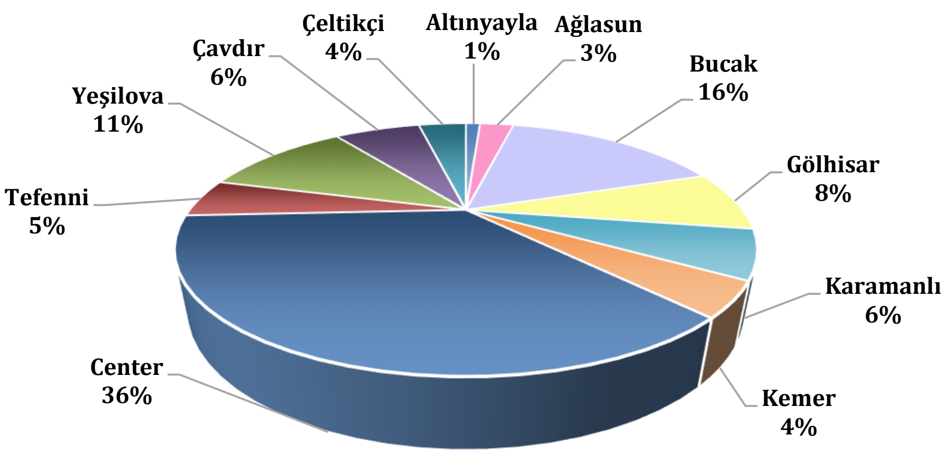

Figure 3. 2019-2023 Distribution of total CH_4 emissions from enteric fermentation by districts

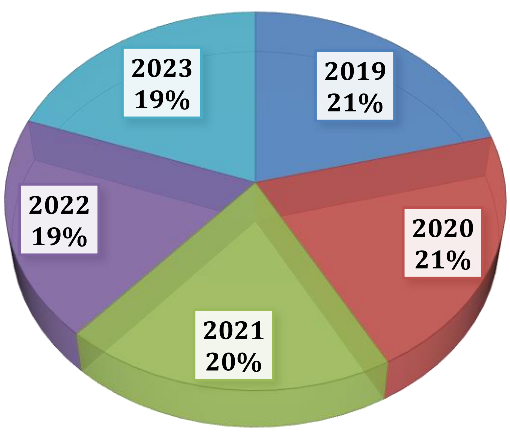

Figure 4. Yearly change in total CH_4 emissions from enteric fermentation

5. CONCLUSION

The negative impacts of global warming on agriculture and livestock further deepen food security concerns. Since animal production plays an important role in greenhouse gas emissions, sustainable policies should be developed to reduce harmful greenhouse gases such as CH_4, N_2O, CO_2 etc. The content of feed rations of dairy cattle is an important factor in enteric CH_4 formation. In addition, emissions into the air from manure management of dairy cattle farms significantly impact global warming. In order to reduce CH_4 emissions from manure, low-emission manure management systems need to be implemented, and scientists need to focus more on this issue. To reduce N_2O and CH_4 emissions from manure, low-emission manure management systems need to be implemented, and more work needs to be done by scientists in this field.

Furthermore, this study allows the comparison of GHG emissions from the dairy cattle sector with other sectors and agricultural systems in different countries. In this way, important information can be provided to analyze emission differences in the agricultural sector and develop more sustainable global practices. A better understanding of emissions from dairy cattle production can guide the development of new strategies to minimize environmental impacts.

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EXTENDED ABSTRACT

Introduction and Research Questions & Purpose

Around the world, pandemics, droughts, and unemployment are causing people to migrate, while rapidly growing populations pose a major threat to food security. The depletion of natural resources has made food production and distribution more difficult, necessitating the development of international strategies for sustainable agriculture. Climate change deeply affects agriculture, livestock, and food supply, creating global crises. In 2021, 17.850.543 cattle and 21.370.116 tons of milk production were recorded in Türkiye. The highest milk production was realized in Konya, Izmir and Erzurum provinces. GHG emissions from milk production come from CH4 from animal digestion of food and N_2O from manure. In developing countries, 39% of emissions from livestock activities come from enteric fermentation and 26% from manure management. In Türkiye, climate change adaptation efforts in the agriculture sector started in the 2000s, but these efforts are insufficient for the livestock sector. Burdur is an important dairy cattle breeding center, with 98% cultivated cattle and more than a thousand tons of milk produced daily. In this study, the carbon footprint of dairy farming in Burdur was calculated using the Tier 1 method in IPCC 2006 guidelines.

Methodology

Burdur is located in the Western Mediterranean region, and its ecological structure and economic animal husbandry activities are carried out throughout the year. While two-thirds of the population is engaged in agriculture and animal husbandry, 40% of the economy is based on milk production. In Burdur, 99% of the cattle are of cultivated breeds, and over a thousand tons of raw milk is produced daily. Burdur has undergone a major transformation with 4860 livestock enterprises and approximately 192 thousand cattle as of 2023. It has significantly progressed from small family farming to modern and technological farms. Tier 1, Tier 2, and Tier 3 methods determined by IPCC are used in carbon footprint calculations. In this study, the Tier 1 method was preferred. The Tier 1 method is a simpler and more predictive model. The emission factors in the IPCC guidelines are organized according to animal species and climate zones. The carbon footprint calculation used the number of animals in the TUIK Dairy cattle category in Burdur province between 2019-2023. In the Tier 1 approach, the equations presented in IPCC (2006) guidelines were used.

Results and Conclusions

This study determined methane (CH_4) emissions and their CO_{2e} from dairy cattle in Burdur districts for 2019-2023. Between 2019 and 2023, the highest CH_4 emissions from manure occurred in the central district and the lowest in Altınyayla. While the central district had the highest emission in 2020 with 0.104816 Gg, Altınyayla had the lowest in 2022 with 0.022488 Gg. Emissions from enteric fermentation were similarly highest in the central district and lowest in Altınyayla. In 2020, the central district had the highest CH_4 emissions, with 5188.39 tons. Global warming potential decreased from 353209 tons CO_{2e} in 2019 to 327735 tons CO_{2e} in 2023. The highest reduction was realized in Ağlasun, with 38%, and the lowest in Kemer, with 1%. Dairy cattle diets and manure management are important in reducing CH_4 and N_2O emissions. Implementation of low-emission manure management systems and further scientific studies are needed.

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