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DETERMINATION OF THE CARBON FOOTPRINT OF ANIMAL WASTE AND CLIMATE CHANGE; KARAMAN EXAMPLE

[1] Yusuf Alparslan ARGUN, [2,*] Özgür ÇAKMAKCI

Karamanoglu Mehmetbey University, Kazım Karabekir Vocational School, Karaman, TURKIYE
[1] yusufargun@kmu.edu.tr, [2] ozgurcakmakci@kmu.edu.tr

Highlights

- The results obtained using Tier 1 and Tier 2 approaches are as follows: 0.4924-0.5014 kg CO2e per 1 liter of milk for Cattle. For sheep, it is 4.5167-6.5627 kg CO2e per 1 kg of meat. For goat, it is 5.0813-6.0231 kg CO2e per 1 kg of meat. These results can be taken into account when creating strategies to reduce methane gas emissions.
- According to the findings of the study, it was observed that there were significant differences in carbon footprint values between animal categories and subcategories. When the Tier 2 approach was used, carbon footprint values were higher than the Tier 1 approach.
- Another finding of the study is that the manure management system also contributes to the carbon footprint.

***Corresponding Author:** Özgür ÇAKMAKCI, ozgurcakmakci@kmu.edu.tr

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ABSTRACT: Climate change is a major concern around the world. In this context, the carbon footprint of animal waste is of critical importance for sustainability and climate change management. The aim of this study is to estimate the carbon footprint resulting from animal breeding and animal waste in the Karaman region. In the study, 2022 data was used and there are 1019277 sheep and 81368 cattle for Karaman. In the study, Tier 1 and Tier 2 approaches were used to estimate methane gas emissions related to both enteric fermentation resulting from animal digestive processes and manure management. According to the results of the study, the results obtained using Tier 1 and Tier 2 approaches are as follows: 0.4924-0.5014 kg CO2e per 1 liter of milk for Cattle. For sheep, it is 4.5167-6.5627 kg CO2e per 1 kg of meat. For goat, it is 5.0813-6.0231 kg CO2e per 1 kg of meat. These results can be taken into account when creating strategies to reduce methane gas emissions. It is recommended to add better quality and high energy content foods to the feed ration, especially to reduce enteric fermentation. In addition, this study is a resource for relevant researchers working in the field in calculating the carbon loads of animal waste and is thought to be a guide for decision makers and practitioners.

***Keywords**: Carbon Footprint, Greenhouse Gas, Tier Approaches, Carbon Emission, Karaman*

1.INTRODUCTION

Increasing world population and human needs have led to resource depletion and environmental problems, including global warming and climate change. The Kyoto Protocol specifies greenhouse gases and emission sources responsible for global warming as carbon dioxide (CO2), methane (CH4), nitrogen oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) [1], [2]. The carbon footprint is a measure of these emissions in terms of carbon dioxide and is divided into primary and secondary categories. This study focuses on the firstly carbon footprint.

The Intergovernmental Panel on Climate Change (IPCC) has developed Tier 1-2-3 methods for calculating greenhouse gas emissions [3, 4]. According to the Food and Agriculture Organization (FAO), 18% of total greenhouse gas emissions originate from agricultural activities, with 14.5% of this figure attributed to livestock production. Livestock farms are significant sources of CH4 and N2O emissions. These gases have a much higher global warming potential than CO2 [5, 6]. In the USA, the livestock sector accounts for 28% of antropogenic methane emissions [7]. Methane gas is produced as a result of the anaerobic decay of organic compounds found in the feces and manure of farm animals, posing a global problem. The annual methane gas emission from this source is estimated at 9.3 teragrams (Tg), contributing to 5% of the total global methane emissions [8, 9].

The livestock sector significantly contributes to global greenhouse gas emissions [10]. During milk production, the major greenhouse gas released is methane (CH4), mainly produced by microbial fermentation in the digestive tracts of ruminant animals like cattle and sheep [11]. Methane is a greenhouse gas 25 times more potent than carbon dioxide (CO2) and lingers in the atmosphere for approximately 12 years [12]. Therefore, the livestock sector must develop strategies to reduce methane emissions and decrease its carbon footprint [6].

***Corresponding Author:** Özgür ÇAKMAKCI, ozgurcakmakci@kmu.edu.tr

The life cycle analysis (LCA) method can evaluate the carbon footprint of the livestock industry, calculating environmental impacts throughout a product or service's life cycle. LCA covers various stages of milk production, including feed production, animal care, manure management, milk processing, and distribution, measuring greenhouse gas emissions throughout these stages [13].

Numerous studies in the literature calculate the carbon footprint of milk production in different countries and production systems. These studies demonstrate that the carbon footprint of milk production varies depending on regional and systemic factors. For instance, studies by [4], [14-31] have reported that the carbon footprint of milk production varies depending on factors such as feed efficiency, animal productivity, manure management, energy use, transportation distance, and climatic conditions.

In conclusion, the carbon footprint of milk production is a crucial aspect of the battle against global warming. The LCA method is employed to calculate and reduce the carbon footprint of milk production. It is evident from the literature that the carbon footprint of milk production varies based on regional and systemic factors, and various strategies have been proposed to decrease methane emissions. Implementing these strategies can contribute to the sustainability of dairy production, but their cost-effectiveness, socioeconomic, and environmental impacts must also be considered.

The goal of this study is to estimate the carbon footprint resulting from animal activities in the Karaman region using Tier 1 and Tier 2 approaches.

2.MATERIAL AND METHODS

2.1. Current Situation of Karaman Province

Karaman Province is located in the south of Turkey and is situated between 37°-11' north latitude and 33°-13' east longitude. It is bordered by Mersin and Antalya to the south, and Konya to the west, north, and east. The city center is situated on a plain, with extensions of the Taurus Mountains to the south. The province is divided into 6 districts, 10 towns, and 154 villages. The geographical landscape of Karaman Province exhibits a unique characteristic where the northern part is covered with steppe vegetation, while the southern part is abundant in forests. Although the majority of the province's land is mountainous, the city center is located in a flat area [32].

The total land area of the province covers 885,100 hectares, with 39% dedicated to agricultural lands, 23% to meadow pasture areas, 27% to forested areas, and 11% to other uses. Crop production spans across 346,848 hectares throughout the province, with 62% of these areas allocated to field crops and 15% reserved for fallow lands. Specialized products such as fruit orchards cover 8.7% of agricultural lands, vineyards 1.4%, and vegetable cultivation 3.9%. Agriculture and animal husbandry are the primary sources of income for the regional economy in Karaman Province, highlighting the importance of this sector in the region [33, 34].

2.2. Data Collection

For this study, data regarding the number of animals in villages and neighborhoods were acquired from the provincial directorate of agriculture and forestry to determine the quantity of animal waste in Karaman Province and its districts. Human population and animal number data for the districts are presented in Table 1.

The geographical coordinates of Karaman Province, its districts, neighborhoods, and villages were recorded using the ArcMap 10.5 software.

The distribution of the number of animals in Karaman Province's districts was analyzed to calculate the potential carbon footprint resulting from animal waste. This data was then transferred to the ArcMap 10.5 software for density analysis.

Table 1. Population and Animal Number Data for DistrictsTable

District	Number of Cattle	Number of Sheep	Number of Goats	Human Population
AYRANCI	7138	258738	21875	7859
ERMENEK	5372	14684	35335	27417
BAŞYAYLA	1457	3681	4859	3508
KAZIMKARABEKİR	3541	24828	6219	4404
SARIVELİLER	3005	5620	7205	11232
CENTRAL DISTRICT	60855	479890	156343	247334

2.3. Business Status

In this section, the factors that are effective in the formation of climatic environmental conditions in the livestock barns where the study was conducted are explained. Additionally, various variables such as barn types, capacities, ventilation systems, manure removal methods and barn layouts vary among livestock facilities. More extensive livestock farming is done than commercial livestock farming. Therefore, the number of places where animal husbandry is carried out within the framework of a certain system is low density.

For this reason, Tier-2 data for places where livestock activities are carried out were included in the calculations based on average range values (Table 2).

Table 2 Acceptances regarding livestock activities used in Tier-2

Ym	Value			Source
	Cow	Sheep	Goat	
Ym	6,5	4,5	4,5	[35]
ASH	8%	9%	9%	[36]; [37]; [38]
Livestock weight	550 kg	45 kg	40 kg	[39]; [40]
Ca	0.17 MJ d^{-1} kg^{-1}	0.009MJd^{-1}/kg^{-1}	0.009MJd^{-1}/kg^{-1}	[35]
Daily milk production	3,2 ton/year	0,8 ton/year	0,8 ton/year	[41]; [42]
Milk Fat percentage	%3,5	%6	%4,5	[43]; [44]; [45]; [46]
C_p	0,1	0,126	0,077	[35]
Wool/Fleece quantity	-	3,6kg/yıl	-	[47]
Feed Ration	12 kg/day	0,9 kg/day	0,9 kg/day	[48]; [49]; [50]; [51]

2.4. Carbon Footprint Calculation

In this study, Tier methods published by IPCC were used to examine methane (CH4) and carbon dioxide (CO2) emissions caused by dairy cattle farming, sheep and goat breeding sub-sectors within the livestock sector [35]. The IPCC 2006 National Greenhouse Gas Inventory Guide provides methodologies to be used in estimating national inventories and is the main methodological source for this study.

In our study, sector and technology data were the main deciding factors when choosing the calculation method. Tier approaches determined by the IPCC are divided into three, but Tier 1 and Tier 2 approaches were used in this study.

When we calculate carbon footprint, the calculation is made per specific functional unit. For example, for dairy cattle farming, functional units such as 1 kg of processed milk or 1 hectare of agricultural land are taken as basis. This choice has been important in interpreting the results in regions where production is concentrated [52, 53, 4].

The carbon footprint calculation process, which is the main purpose of our study, was made on a per kg product basis. Emissions are typically corrected based on factors such as kg live weight or carcass weight for meat production systems and solids content per kg milk for dairy production systems. However, it is important to note that these rules do not apply to some special cases. In particular, different approaches are required for boneless meat and protein. Additionally, some studies also present a measure of output per domain [54, 55].

Therefore, this study calculated the carbon footprint through functional units such as 1 liter of milk in cattle enterprises and 1 kg of meat in sheep enterprises.

2.4.1. Tier 1 approach

The Tier 1 method is one of the simplest and most basic calculation methods, and in this method equations and default parameter values (e.g. emissions and stock change factors) are provided. The Tier 1 approach is based on country-specific activity data, but often sources of estimates for various parameters are available worldwide (e.g. deforestation rates, agricultural production statistics, global land cover maps, fertilizer use, animal population data, etc.) and specific values may not be available [35].

In carbon footprint calculations related to fertilizer management, the emission factor according to the Tier 1 method varies depending on the physical conditions (indoor or outdoor) and temperature conditions of the place where the manure are stored or preserved [56]. In accordance with the IPCC guidance, the Tier 1 approach is a simplified method for estimating emissions that only includes selected data for specific animal species, subcategories and climate zones or temperature ranges, together with the default emission factors found in the guidance [35]. In this study, equation 2.1 was used to calculate the carbon footprint resulting from manure management.

$$CH4_{Fertilizer} = \sum_T \frac{(EF_T.N_T)}{10^6} \quad (2.1)$$

In this equality;

$CH4_{Fertilizer}$: Methane emissions from manure management (Gg CH4/year)

$EF_{(T)}$: Emission factor for the defined livestock sector (kgCHVhead/year)

$N_{(T)}$: Number of animals in the population

T : Animal type

EF(T) values were determined using emission factors selected from Table 10.14 and Table 10.15 based on the subcategories specified in the IPCC 2006 guidance. These tables were created taking into account the differences in the development levels of the countries and the fertilizer management systems used. Additionally, another important parameter such as temperature was also taken into account. It has been noted that Turkey is evaluated in the category of developing countries and the average temperature of Karaman province is 12°C according to measurements between 1991-2020 [57]. Therefore, emission factor selections were made from the intersections of these values. Based on the data provided as reference in the IPCC guideline, methane emission factor tables resulting from manure management varying with temperature values for the Tier 1 approach are given below (Tables 3 and Tables 4).

Table 3. Methane emission factor from manure management for cattle [35].

	Cold						Temperate							Hot					
	<10°C	11°C	12°C	13°C	14°C	15°C	16°C	17°C	18°C	19°C	20°C	21°C	22°C	23°C	24°C	25°C	26°C	27°C	>28°C
Dairy Cattle	11	12	13	14	15	20	21	22	23	25	27	28	30	33	35	37	42	45	46
Other Cattle	6	6	7	7	8	9	10	11	11	12	13	14	15	16	18	19	21	23	23

Table 4. Methane emission factor due to manure management for small ruminants that varies with temperature values [35].

	Cold (<15°C)	**Temperate (15°C-25°C)**	**Hot (>25°C)**
Sheep			
Developed countries	0.19	0.28	0.37
Developing countries	0.10	0.15	0.20
Goat			
Developed countries	0.13	0.20	0.26
Developing countries	0.11	0.17	0.22

In the methane emission factor tables due to manure management, in this study, it was determined as 13 kg CH/head.year for cattle, 0.13 kg CH/head.year for goat enterprises and 0.13 kg CH/head.year for sheep pen enterprises.

Another important source of methane originating from livestock subcategories is the rumination process that animals carry out during digestion. Methane is a byproduct produced as a result of enteric fermentation that occurs in the digestive system of grazing animals. Enteric fermentation is carried out by microorganisms that carry out the digestive process by breaking down carbohydrate molecules in the bloodstream of the grazing animal into simple molecules [56]. The amount of methane produced varies depending on the animal's digestive system type, age, weight, and the quality and quantity of feed consumed [35].

In this study, the Tier 1 approach specified in the IPCC guideline was used to calculate methane (CH4) emissions from enteric fermentation. This approach uses default emission factors to estimate emissions and includes key data such as animal species, diets and annual milk yields. Additionally, equation 2.2 was used for the calculations, which is a mathematical formula used to estimate CH4 emissions from enteric fermentation. This equation is a useful tool for calculating emissions, taking into account the characteristics and feeding habits of animals [35].

$$\text{Emissions} = (EF_T) \times \left(\frac{N_T}{10^6}\right) \quad (2.2)$$

In this equality;

Emissions : Methane emissions from enteric fermentation (Gg CH4/year)
EF(T) : Emission factor for the defined livestock sector (kgCH4.head/year)
N(T) : Number of animals in the population
T : Animal type

EF(T) values are calculated using emission factors selected from Table 10.10 and Table 10.11 based on subcategories in the IPCC 2006 guidance. These tables take into account the differences in the development levels of the countries and the feed compositions used. For the Tier 1 approach, enteric fermentation-derived methane emission factor tables, which vary according to temperature values, were created as stated in Tables 5 and Tables 6.

Table 5. Methane emission factor from enteric fermentation for cattle [35].

	Animal Category	Emission Factor	Description
Eastern European Country Category	Dairy Cattle	99	Average Milk Production 2550
	Other Cattle	58	Includes cattle, bulls and young animals

Table.6. Methane emission factor from enteric fermentation for sheep [35]

Animal Category	Developed country	Developing country	Live weight
Koyun	8	5	65 kg - developed 45 kg-developing country
Keçi	5	5	40 kg

In the study, using Table 4 and Table 5, the methane emission factor originating from enteric fermentation was selected as 99 kg CH4/head.year for dairy cattle and 5 kg CH4/head.year for goat and sheep pen enterprises.

2.4.2 Tier 2 approach

The Tier 2 approach follows a similar methodological approach as Tier 1, but the key difference is the use of emission factors based on country- or region-specific data. Country-specific emission factors better adapt to factors such as climate zones, land use systems and livestock categories in that country and allow for a more accurate carbon footprint estimate. The Tier 2 approach is also more suitable for specific regions or land use/livestock categories, using more detailed data and subcategorized activity data [35].

Determining the Tier 2 approach is based on estimating the gross energy intake when calculating the enteric emissions of a particular animal species in the animal population. Gross energy is calculated by several factors and includes:

1. Net energy required for maintenance
2. Net energy required for daily activities
3. Net energy required for growth
4. Net energy required for lactation (milk production)
5. Net energy required for operation
6. Net energy required for wool production
7. Net energy required for pregnancy
8. Ratio of net energy available in the feed to digestible energy consumed (REM)
9. Ratio of net energy available for growth in nutrition to digestible energy consumed (REG)

Calculation of these factors is used to determine gross energy. In this study, equation 2.3 was used for gross energy calculation. This approach provides more detailed data to obtain more precise results and estimate enteric emissions for specific animal species [58].

$$GE=\left[\left(\frac{NEm+NEa+NEl+NEw+NEp}{REM}\right)+\left(\frac{NEg+NEwool}{REG}\right)\right]/\left(\%\frac{DE}{100}\right) \quad (2.3)$$

In this equality;

GE : Gross Energy (MJ/day)

Nem : Net energy needed by the animal for care (MJ/day)
Nea : Net energy required by the animal for activity (MJ/day)
NEl : Net energy required by the animal for lactation (MJ/day)
New : Net energy required by the animal for work (MJ/day)
NEp : Net energy required by the animal for pregnancy (MJ/day)
NEg : Net energy required by the animal for growth (MJ/day)
NEwool : Net energy required by the animal for wool production (MJ/day)
REM : The ratio of the net energy available in the feed to the digestible energy consumed
REG : The ratio of net energy available for growth in nutrition to digestible energy consumed
DE : Digestible energy expressed as a percentage of gross energy (%)

Tables used to determine gross energy for dairy cattle, sheep and goat enterprises are included in Annex 10A.1 of Chapter 10 of the IPCC 2006 guide. These tables present variables such as gross energy intake, metabolizable energy, net energy maintenance and net energy production by animal categories and subcategories. These variables can be used to calculate the values of the parameters in the formulas used to determine gross energy. For gross energy calculation, separate tables and values were taken into account for dairy cattle enterprises, separate tables for sheep farming enterprises and separate tables for goat enterprises.

After gross energy calculations were completed, equation 2.4 was used in this study to calculate methane emissions from enteric fermentation for selected livestock categories. This approach helps the study obtain more precise and specific results and aims to estimate the carbon footprint more accurately [4].

$$EF = \frac{GE \times (\frac{Ym}{100}) \times 365}{55{,}65} \quad (2.4)$$

In this equality;
EF : Emission factor from enteric fermentation (kg CH4/head.year)
GE : Gross energy (MJ/day)
Ym : Methane conversion factor (percentage of gross energy in feed converted to methane)
55.65 : Methane energy content (MJ/kg CH4)

Dairy cattle, sheep and goats vary significantly from country to country in terms of management characteristics and manure management systems. In the Tier 2 method, the calculation of methane emission factors from manure depends on the manure properties and manure management system features [35]. In this study, equation 2.5 was used to calculate the methane emission factor from fertilizer.

$$EF = (VST \times 365) \times [Bo(T) \times 0{,}67 \times (\sum \frac{MCFs,k}{100}) \times MSt,s,k \quad (2.5)$$

In this equality;
EF : Annual CH4 emission factor for the livestock category
VST : Volatile solids excreted daily from the animal category (kg dry matter/head.day)
Bo(T) : Maximum methane production capacity for fertilizer produced by animal category (m3 CH4/kg)
0.67 : m3 CHVin kg CH4 conversion factor
MCF(s,k) : Methane conversion factor (%) for each manure management system according to climate zone
MS(T,S,K) : Animal category, manure management system, climate zone fraction (dimensionless)

There is another equation that should also be used for the VS(T) parameter used in this equation. The equation to be used in the calculation is given in 2.6.

$$VS = \left(GE \times \left(1 - \frac{\%DE}{100}\right) + (UE \times GE)\right) \times \left(\frac{1-ASH}{18{,}45}\right) \quad (2.6)$$

In this equality;
VS : Volatile solids (kg VS/day)
GE : Gross energy (MJ/day)
DE% : Percentage of digestible food. It will be selected according to mortar categories and feeding diversity in Table 10.2.
(UE*GE) : Urinary energy is expressed as a fraction of gross energy. Typically 0.04GE can be considered the urinary energy excretion by most ruminants.
ASH : Ash content of manure.
18.45 : Conversion factor for gross energy per kg dry matter (MJ/kg).

The numerical data obtained in this study are the results of emission factors calculated using Tier approaches. In order for this data to be used for carbon footprint estimation, it must be multiplied by CO2 equivalent (CO2e) conversion factors. The IPCC uses equivalence factors to convert greenhouse gas emissions into CO2e. These factors are calculated based on the 100-year global warming potential of different greenhouse gases. According to IPCC data in 1997, the 100-year global warming potential of CH4 was accepted as 21, N2O as 310 and CO2 as 1 [59]. However, in subsequent updates, the equivalence factors were changed according to the update made by the IPCC [35]. After this update, the 100-year global warming potential of CH4 is accepted as 25, N2O as 298, and CO2 as 1 [55]. CO2 equivalence conversion rates are given in Table 7.

Table 7. Greenhouse gases CO2 equivalent conversion factors [55].

Greenhouse Gas	Name	CO2eq [59]	CO2 eq [35]	Main Source
CO2	Carbon dioxide	1	1	Fossil fuels, deforestation
CH4	Methane	21	25	Rice fields, animal stomachs, biomass burning, landfills, leaks in natural gas pipelines, mines
N2**O**	Nitroxide	310	298	Chemical fertilizers, fossil fuels, nylon production

In addition to methane emissions from enteric fermentation and fertilizer management, other emissions also occur in the businesses in the study area for various reasons. These reasons include emissions resulting from ventilation, heating, cooling, lighting, electricity and fuel consumption used in businesses. In the dairy cattle enterprises and sheep barn enterprises covered by the study, various operations such as milking, heating, manure cleaning and manure removal are carried out even if natural ventilation is used [6].

When calculating the carbon footprint, conversion factors used for electricity and fuel consumption are also taken into account. The emission factors used in this study are as follows: 2.66 kg CO2e/kg for diesel fuel, 2.86 kg CO2e/kg for coal heating and 0.40 kg CO2e/kW/hour for electricity used in various production activities within the enterprise (Table 8) [25].

This information was used to take into account the full scope of emissions to calculate the carbon footprint of the study. In this way, the contributions of businesses to greenhouse gas emissions are evaluated from a more holistic perspective.

Table 8. Electricity and fuel emission factors used in carbon footprint [25]

Emission Source	Coefficient	Unit
Diesel	2,66	kg CO2 eq/ kg
Electric	0,40	kg CO2 eq kW/h
Coal	2,86	kg CO2 eq/ kg

3. RESULTS AND DISCUSSION

In this study, Tier 1 and Tier 2 approaches developed by IPCC were used to calculate the carbon footprint for selected livestock facilities. The aim is to estimate the greenhouse gas emissions and carbon footprint caused by cattle and sheep farming activities in Karaman city center, districts, villages and neighborhoods. Calculating the carbon footprint and evaluating the results is important to understand the potential of animal production enterprises in Karaman province to reduce greenhouse gas emissions and to determine these measures. This study can help create and implement policies and practices to reduce greenhouse gas emissions.

The results of the study can be used to determine which livestock activities create the most emissions and in which regions these emissions are concentrated. This information can be used to identify areas where measures to reduce carbon footprint should be focused. It may also be useful to evaluate the effectiveness of measures to reduce the environmental impact of livestock enterprises.

As a result, this study should be seen as an important step to understand and reduce the environmental impacts of the animal production sector in Karaman province. This can contribute to promoting a sustainable livestock sector.

3.1. Carbon Footprint According to Tier 1 Approach

In the study, carbon footprints of livestock activities within the borders of Karaman province were determined using the Tier 1 approach of the IPCC guide. This calculation approach was made taking into account the geographical location of the region and annual average temperature data. The carbon footprint per 1 liter of milk for cattle is calculated as 0.4924 kg CO2e, and the annual total carbon footprint of these animals is determined as 227830.4 tons CO2e.

In study [58], it was mentioned that a carbon footprint of 0.4215 kg CO2e per 1 liter of milk was determined for dairy cattle in Bursa, and the total annual carbon footprint of the dairy cattle enterprise was 461 tons of CO2e. In this study, it was stated that the carbon footprint of a dairy cattle enterprise consists of four components: enteric fermentation, manure management system, fuel and electricity consumption within the enterprise. Additionally, it was stated that the values used to calculate the carbon footprint resulting from dairy farming in Ireland. In study were close to other similar studies [60], greenhouse gas emissions were expressed as CO2 equivalents. Emissions per hectare for dairy farming were calculated as 6,835 kg CO2e/year, and for beef production as 4,859 kg CO2e/year. These emission values are associated with all land areas within the scope of the study. In [23] study, Canada's dairy sector was examined and a model was developed to estimate the carbon footprint of dairy products. The carbon footprint of raw milk varies in different regions and is calculated as 0.93 kg CO2e/1 L milk in the western regions and 1.12 kg CO2e/1 L milk in the eastern regions.

All these studies show that different approaches can be used to determine and reduce the carbon footprint of the livestock sector and that geographical, climatic and operating differences can affect the results. The carbon footprint amounts calculated at the end of the study are similar to studies conducted in similar regions.

According to calculations made for Karaman province, 4.52 kg CO2e is emitted per 1 kg of meat production for sheep barns, and 5.08 kg CO2e is emitted per 1 kg of meat production for goat barns. These results show that the factors that contribute to the carbon footprint of cattle also apply to sheep and goat pens. The annual carbon footprint for sheep pens was calculated as 160,047.4 tons CO2e, and for goat pens it was determined as 47,120.7 tons CO2e.

These results are consistent with previous studies. The study conducted revealed that sheep pens emit 0.0912 kg of CO2e per 1 kg of meat production and the annual carbon footprint of the enterprise is 329 tons of CO2e [58]. This study indicates that the factors that contribute to the carbon footprint of dairy cattle enterprises are also valid for sheep enterprises. It divided carbon footprint calculations in sheep farms in Australia into two: methane emissions from manure and methane emissions from enteric fermentation [61]. According to this study, methane emissions from manure were calculated as 0.00076 kg CO2e per 1 kg of meat production, and methane emissions from enteric fermentation were calculated as 4.6 kg CO2e per 1 kg of meat production. In the research conducted by [17], a literature review was conducted on the factors affecting the size of emissions and surveys were conducted on two farms with a more intensive production system and a larger system. In the farm with a more intensive production system, 0.4 kg of methane emission per kg of sheep meat was detected, and in the farm with a larger production system, 0.9 kg of methane emission per kg of sheep meat was detected. These differences have been attributed to factors such as lambs remaining on pasture longer and the addition of more forage. The study also showed that emission amounts may vary depending on various factors such as feed composition, feed quality, age of the animals, the duration they are active, breed and gender.

The carbon footprint amounts obtained using the Tier 1 approach are given in Table 9 and the Karaman-wide CO2 distribution map is given in Figure 1.

Calculations show that the carbon footprint amounts of livestock activities in Karaman province are at different levels. These results help to identify the main reasons why emission amounts vary between livestock subcategories. Two main reasons stand out: Enteric fermentation of ruminant animals and differences in manure management systems. This information can form an important basis for developing environmental sustainability strategies and reducing emissions at the regional level. Additionally, these data can contribute to the development of better practices to reduce the environmental impact of livestock farming enterprises.

Table 9. CO2 equivalent amounts of Districts in terms of animal waste (Tier-1)

District	Cattle Total tons CO2eq	Sheep Total tons CO2eq	Goat Total tons CO2eq	Grand Total tonnes CO2eq
AYRANCI	19986,4	52588,4985	4446,09375	77020,99225
ERMENEK	15041,6	2984,523	7181,83875	25207,96175
BAŞYAYLA	4079,6	748,16325	987,59175	5815,355
KAZIMKARABEKİR	9914,8	5046,291	1264,01175	16225,10275
SARIVELİLER	8414	1142,265	1464,41625	11020,68125
CENTRAL DISTRICT	170394	97537,6425	31776,71475	299708,3573
Total	227830,4	160047,3833	47120,667	434998,4503

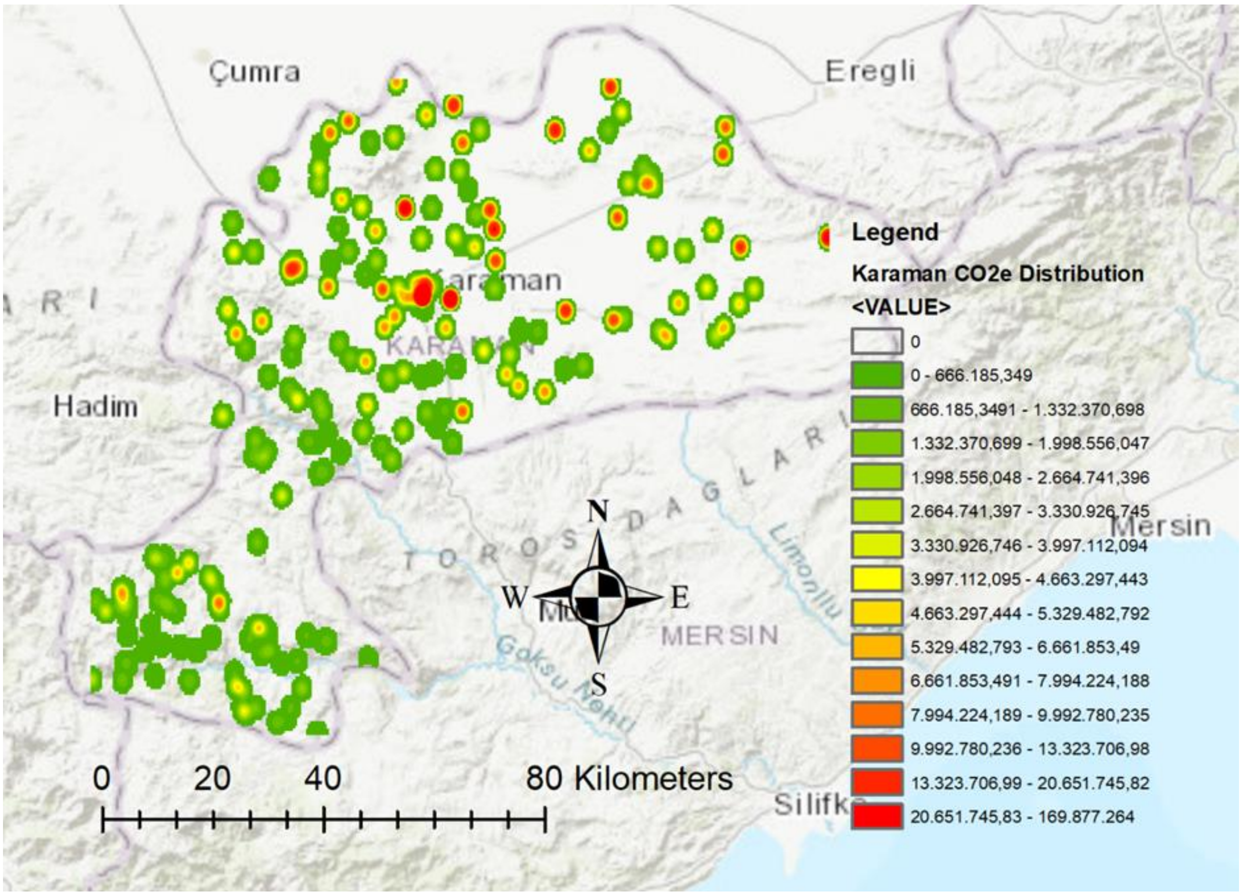

Figure 1 CO2eq distribution map across Karaman using Tier 1 approach

3.2. Carbon Footprint According to Tier 2 Approach

In this study, the carbon footprint of livestock enterprises operating in Karaman province was determined with the Tier 2 approach included in the guide published by [35]. The Tier 2 approach takes into account parameters that vary depending on the species, age group, nutritional level and climatic conditions of the animals. These parameters include factors such as live weight of the animals, daily feed consumption, nutritional value of the feed, type of digestive system of the animals, and manure management system. In this study, carbon footprint calculations were made for cattle, sheep and goats using parameters selected in accordance with the geographical location and climatic characteristics of Karaman province. According to the results of the study, the carbon footprint of milk obtained from cattle was determined as 0.5013 kg CO2e/1 L. The total annual carbon footprint of cattle was found to be 231995.7 tons CO2e. 88% of this amount comes from enteric fermentation (204,000 tons CO2e) and 12% comes from fertilizer management (27,995.7 tons CO2e). The carbon footprint of meat obtained from sheep and goats was determined as 6.5627 kg CO2e / 1 kg meat and 6.0231 kg CO2e / 1 kg meat, respectively. The annual total carbon footprint of sheep and goats was found to be 232548.1 tons CO2e and 55854.67 tons CO2e, respectively. Of these amounts, 93% (216.169% tons CO2e and 51.954% tons CO2e) comes from enteric fermentation, and 7% (16.379% tons CO2e and 5.900% tons CO2e) comes from manure management (Table 10). It has been observed that a large part of the carbon footprint originates from enteric fermentation, while manure management has a smaller share. Detailed results of the study obtained using the Tier 2 approach are presented in Table 11 and the CO2 equidistribution map of Karaman province is presented in Figure 2.

Table 10 Methane formation amounts from fertilizer and fermentation in the districts in terms of animal waste

District	CH4 from cattle manure	CH4 from SHEEP manure	CH4 from GOAT manure	CH4 from cattle fermentation	CH4 from SHEEP fermentation	CH4 from GOAT fermentation-
			EF(annual)(methane)(kg)			
AYRANCI	96109,374	192809,083	13298,393	717962,606	2863624,955	197509,419
ERMENEK	72331,123	10942,376	21481,084	540332,743	162517,561	319039,787
BAŞYAYLA	19617,730	2743,046	2953,915	146549,666	40740,067	43871,920
KAZIMKARABEKİR	47677,682	18501,588	3780,695	356164,974	274787,933	56151,363
SARIVELİLER	40460,727	4187,970	4380,110	302252,400	62200,265	65053,959
CENTRAL DISTRICT	819380,215	357609,439	95045,058	6120988,289	5311260,733	1411621,267

Table 11. CO2eq amounts of Districts in terms of animal waste (Tier-2)

District	**Cattle** **Total tons** CO2eq	**Sheep** **Total tons** CO2eq	**Goat** **Total tons** CO2eq	**Grand Total tonnes CO2eq**
AYRANCI	20351,79952	76410,85096	5270,195321	102032,8458
ERMENEK	15316,59667	4336,498448	8513,021791	28166,1169
BAŞYAYLA	4154,184911	1087,077825	1170,6459	6411,908637
KAZIMKARABEKİR	10096,06642	7332,238046	1498,301472	18926,60594
SARIVELİLER	8567,82818	1659,705889	1735,851762	11963,38583
CENTRAL DISTRICT	173509,2126	141721,7543	37666,65815	352897,6251
Total	231995,6883	232548,1255	55854,6744	520398,4882

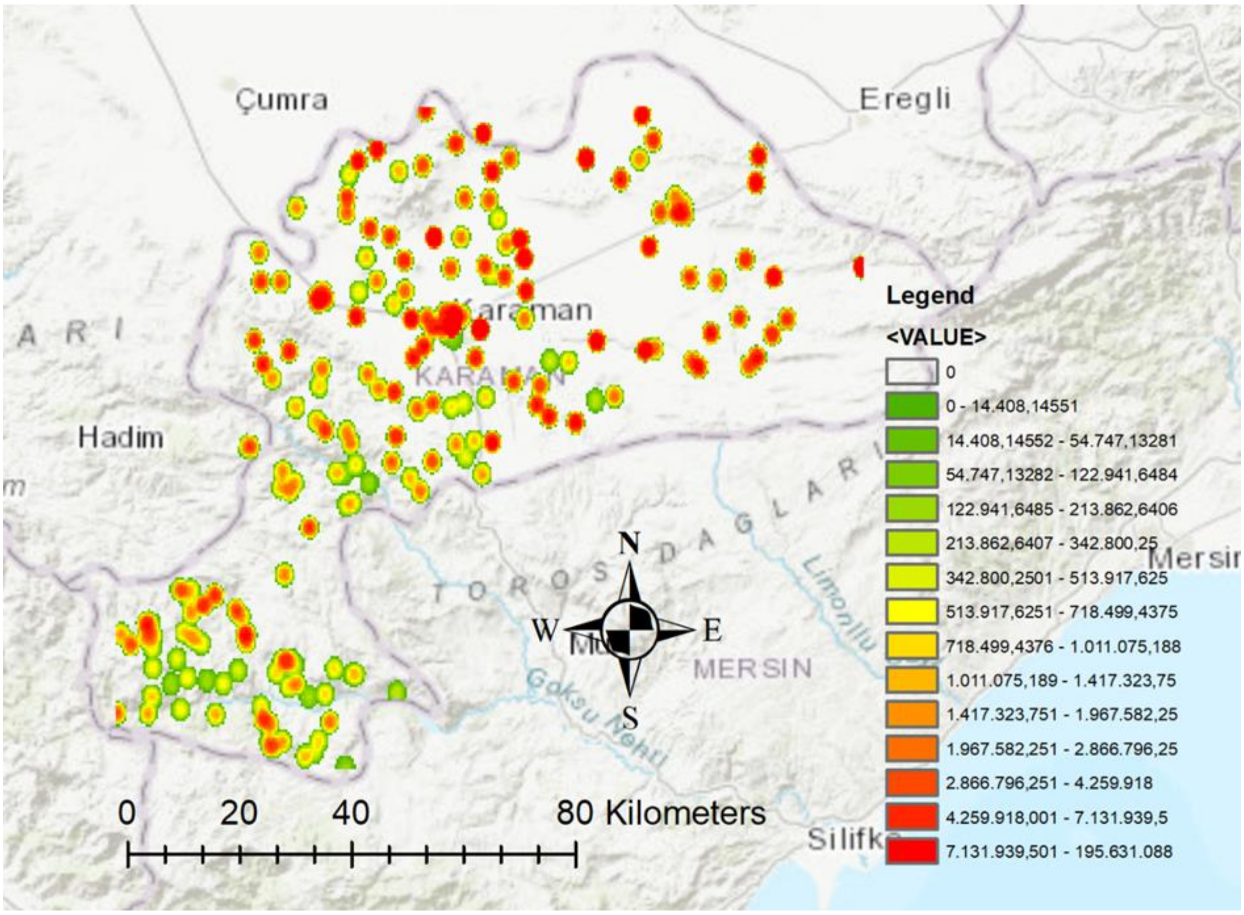

Figure 2. CO2eq distribution map across Karaman using Tier 2 approach

3.3. Comparison of Tier 1 and Tier 2 Approaches

Comparative results of carbon footprint values for BBH, Sheep and Goat enterprises as a result of calculations made using the Tier 1 and Tier 2 Approaches and parameters in the IPCC guide. Table 12 is also given.

Table 12. % change rates by Animal Type

	Tier 1 Approach Results	Tier 2 Approach Results	% Rate of change
Cattle	0,4924 kg CO2e/1 L milk	0,5014 kg CO2e/1 L milk	1,8
	5,6 kg CO2e/1 kg meat	5,7 kg CO2e/1 kg meat	
Sheep	0,1856 kg CO2e/1 L milk	0,2697 kg CO2e/1 L milk	31,17
	4,52 kg CO2e/1 kg meat	6,56 kg CO2e/1 kg meat	
Goat	0,4491 kg CO2e/1 L milk	0,5323 kg CO2e/1 L milk	15,63
	5,08 kg CO2e/1 kg meat	6,02 kg CO2e/1 kg meat	

According to the results given in Table 12, carbon footprint values calculated with the Tier 2 approach are higher than the Tier 1 approach. This is because, in the Tier 2 approach, private data of livestock enterprises and the work area are included in carbon footprint calculations. In the Tier 2 approach, parameters such as live weight of the animals, daily feed consumption, nutritional value of the feed, type of digestive system of the animals, and manure management system are taken into account. These parameters are factors that affect the carbon footprint. In the Tier 1 approach, these parameters are ignored and fixed emission factors are used depending on the type and number of animals. Therefore, the Tier 2 approach provides more realistic and accurate results.

However, carbon footprint values calculated with the Tier 2 approach increase at different rates depending on animal species. As seen in Table 12, the carbon footprint value calculated with the Tier 2 approach for cattle is 1.8% higher than the Tier 1 approach. This rate is 31.17% for sheep and 15.63% for goats. This difference is due to factors such as the feeding style of the animals, manure management characteristics and the climatic conditions of the study area. These factors affect the carbon dioxide equivalent (CO2e) emissions of animals.

The parameters used in this study are accepted data found in the guide published by the [35]. However, it should not be forgotten that these parameters may vary depending on the climatic data of the study area. Therefore, it is important to take into account the specific conditions of the work area when making carbon footprint calculations. This study shows that the Tier 2 approach is more appropriate than the Tier 1 approach in determining the carbon footprint of the livestock sector.

4.CONCLUSION

This study aimed to reveal the contribution of livestock activities in Karaman province to global warming through carbon footprint analysis. In the study, carbon footprint calculations were carried out using Tier 1 and Tier 2 approaches, taking into account the population of 81368 Cattle, 787441 Sheep and 231836 Goats in the province. Additionally, strategies proposed in the literature to reduce carbon footprint were evaluated. As a result of the study, a result of 0.4924 kg CO2e per 1 L of milk, which is the functional unit for Cattle, was reached in the Tier 1 approach. It is estimated that 88% of this result is CH4 emissions resulting from enteric fermentation as a result of the animal ruminating. It was determined that the remaining 12% was due to the fertilizer management system. The carbon footprint calculation result using the Tier 2 approach was obtained as 0.5014 kg CO2e per 1L of milk for Cattle.

When the Tier 1 approach was used in the calculations for sheep pens, it was 4.5167 kg CO2e per 1kg of meat, while as a result of the calculation using the Tier 2 approach, 6.5627 kg CO2e per 1kg meat was found. In the calculations made for goat pens, when the Tier 1 approach was used, 5.0813 kg CO2e per 1kg of meat was found, while as a result of the calculation made using the Tier 2 approach, 6.0231 kg CO2e per 1kg of meat was found.

According to the findings of the study, it was observed that there were significant differences in carbon footprint values between animal categories and subcategories. When the Tier 2 approach was used, carbon footprint values were higher than the Tier 1 approach. This shows that the Tier 2 approach provides a more realistic assessment [35]. It has been determined that most of the carbon footprint is caused by enteric fermentation. Enteric fermentation is the production of methane gas by microorganisms in the stomachs of ruminant animals during the digestive process. Methane gas is one of the most important greenhouse gases in the atmosphere and its global warming potential is 28 times greater than carbon dioxide [62]. Some strategies suggested in the literature to reduce methane emissions from enteric fermentation include adding ionophores, oils, high-quality feeds or grains to the animal's diet, or using compounds that inhibit methane production in the animals' stomachs [63, 14, 16, 42].

Another finding of the study is that the manure management system also contributes to the carbon footprint. Manure management system can be defined as the collection, storage, processing and use of animal manure. The manure management system can affect emissions of both carbon dioxide and other greenhouse gases such as methane and nitrous oxide. Some strategies suggested in the literature to reduce greenhouse gas emissions from manure include improving manure operating systems or composting [64].

As a result of the study, it was revealed that livestock activities in Karaman province make a significant contribution to global warming. To reduce this contribution, mitigation methods from both the source and the environment should be applied. Source reduction methods are activities aimed at preventing or reducing the formation of greenhouse gases. Environmental mitigation methods are activities that enable the removal or storage of greenhouse gases from the atmosphere. In this study, prevention strategies such as changing barn and coop designs or reducing the protein content of the feed ration were suggested among source reduction methods. In addition, environmental reduction methods include options such as afforestation, biomass energy, carbon capture and storage [62].

This study is important as it is the first study to evaluate the effects of livestock activities in Karaman province on global warming. It carried out a carbon footprint analysis to determine the effects of livestock activities in Karaman province on global warming. As a result of the study, carbon footprint values by animal categories and the factors affecting them were revealed. Additionally, various strategies and greenhouse gas emissions reduction methods suggested in the literature to reduce carbon footprint were evaluated. This study provides information that may be useful to both the livestock sector and all stakeholders combating global warming. However, the study also has some limitations. For example, only Cattle, Sheep and Goat populations were considered in the study. Other animal species and poultry can also contribute to the carbon footprint. Additionally, only the direct effects of livestock activities were taken into account in the study. Indirect effects of livestock activities, such as feed production, transportation and processing, can also affect the carbon footprint. Therefore, future studies should also focus on these issues.

Declaration of Ethical Standards

The authors declare that they have carried out this completely original study by adhering to all ethical rules including authorship, citation and data reporting.

Credit Authorship Contribution Statement

Author contribution rates are equal in this study.

Declaration of Competing Interest

The authors declared that they have no conflict of interest.

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Data Availability

This study does not contain any dataset.

5. REFERENCES

[1] UNFCCC, Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997.

[2] H.N. Bayraç, ''Enerji Kullanımının Küresel Isınmaya Etkisi ve Önleyici Politikalar,'' *Eskişehir Osmangazi Üniversitesi Sosyal Bilimler Dergisi,* vol. 11(2): pp. 229-259, 2010.

[3] E. Çınar, "İneklerin ekolojik ayak izi raporu," Animal Science Journal, 2013 (Rum 38): pp. 210-218., 2007.

[4] İ. Kılıç, B. Amet, ''Bir Süt Sığırı İşletmesinin Karbon Ayak İzinin Tahminlenmesi: Bursa Örneği,'' Journal of Agricultural Faculty of Gaziosmanpaşa University (JAFAG), 34(Ek Sayı), 132-140, 2017.

[5] S. Bauer, "Development of environmental impact assessment tools for livestock production systems, "Vol. 1 :Research Report, Giessen, Germany, pp.4-16, 1994.

[6] P. J. Gerber, H. Steinfeld, B. Henderson, A. Mottet, C. Opio, J. Dijkman, A. Falcucci and G. Tempio, "Tackling Climate Change through Livestock - A Global Assessment of Emissions and Mitigation

Opportunities,” Food and Agriculture Organization of the United Nations (FAO), Rome, 2013.
[7] U.S. EPA (Environmental Protection Agency), Erişim Tarihi 24.05.2022.
[8] E. Scheehle, “Emissions and Projections of Non CO2 Green House Gases from Developing Countries 1990-2020,**2022.**
[9] P. Demir, Y. Cevger, ''Küresel Isınma ve Hayvancılık Sektörü,'' *Veteriner Hekimler Derneği Dergisi,* 78(1): 13-16, 2007.
[10] FAO, “Greenhouse gas emissions from the dairy sector: A life cycle assessment,” 2010.
[11] K.A. Beauchemin, H.H. Janzen, S.M. Little, T.A. McAllister, S.M. McGinn, “ Life cycle assessment of greenhouse gas emissions from beef production in western Canada: A case study,” Agricultural Systems, 103(6), 371-379, 2009.
[12] IPCC., Climate change 2007: The physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change”, 2007.
[13] L.J. Müller, A. Kätelhön, M. Bachmann, A. Zimmermann, A. Sternberg, A. Bardow, “A guideline for life cycle assessment of carbon capture and utilization,” Frontiers in Energy Research, 8-15, 2020.
[14] D. Boadi, C. Benchaar, J. Chiquette, D. Massé, ''Mitigation strategies to reduce enteric methane emissions from dairy cows: Update review,'' Canadian Journal of Animal Science, 84(3), 319-335, 2004.
[15] R. Schils, A. Verhagen, H. Aarts, L. Şebek, ''A farm level approach to define successful mitigation strategies for GHG emissions from ruminant livestock systems,'' *Nutrient Cycling in Agroecosystems,* 71(2): 163-175, 2005.
[16] M.S. Mitsumori, ''Control of Rumen Microbial Fermentation for Mitigating Methane Emissions from the Rumen, '' *Asian Australasian Journal of Animal Sciences,* 144-154, 2008.
[17] H. Allard,''Methane emissions from Swedish sheep production,'' Swedish University of Agricultural Sciences, 2009.
[18] G. Edwards-Jones, K. Plassmann, I. Harris,''Carbon footprinting of lamb and beef production systems: insights from an empirical analysis of farms in Wales, UK,''*Journal of Agricultural Science,* 147: 707-719, 2009.
[19] S. Ledgard, M. Lieffering, J. Devitt, M. Boyes, R. Kemp, “A greenhouse gas footprint study for exported New Zealand lamb,” *Report for Meat Industry Association, Ballance Agri-nutrients, Landcorp and MAF. AgResearch, Hamilton, 2010.*
[20] G. Aydın, İ. Karakurt, K. Aydıner,''Antropojenik Metan Emisyonlarının Sektörel Analizi,'' *Tübav Bilim Dergisi,* 42-51, 2011.
[21] J. Lesschen, M. Van den Berg, H. Westhoek, H. Witzke, O. Oenema, “ Greenhouse gas emission profiles of European livestock sectors,” *Animal Feed Science and Technology,* 166: 16-28, 2011.
[22] M. Henriksson, A. Flysjö, C. Cederberg, C. Swensson, ''Variation in carbon footprint of milk due to management differences between Swedish dairy farms,'' *Animal,* 5(9): 1474-1484, 2011.
[23] X. Verge, D. Maxime, J. Dyer, R. Desjardins, Y. Arcand, A. Vanderzaag, “Carbon footprint of Canadian dairy products: Calculations and issues,” *Journal of dairy science,* 96(9): 6091-6104, 2013.
[24] S. Wiedemann, S. Ledgard, B. Henry, M. Yan, N. Mao, S. Russell, “Application of life cycle assessment to sheep production systems: investigating co- production of wool and meat using case studies from major global producers,” *The International Journal of Life Cycle Assessment,* 20(4): 463-476, 2015.
[25] R. Jacobsen, V. Vandermeulen, G. Vanhuylenbroeck, X. Gellynck, ''A life cycle assessment application: the carbon footprint of beef in Flanders (Belgium), '' *In Assessment of Carbon Footprint in Different Industrial Sectors, Volume 2,* 31-52, 2014.
[26] J. Owen, W. Silver, ''Greenhouse gas emissions from dairy manure management: a review of fıeld-based studies,'' *Global Change Biology,* 21(2): 550-565, 2015.
[27] C. Dunkley, B. Fairchild, C. Ritz, B. Kiepper, M. Lacy, ''Carbon footprint of poultry production farms in South Georgia: A case study,'' *Journal of Applied Poultry Research,* 24(1): 73-79, 2015.

[28] I. Batalla, M. Knudsen, L. Mogensen, O. del Hierro, M. Pinto, J Hermansen, ''Carbon footprint of milk from sheep farming systems in northern Spain including soil carbon sequestration in grasslands,'' *Journal of Cleaner Production,* 104: 121-129, 2015.

[29] M. Mujica, G. Blanco, E. Santalla, ''Carbon footprint of honey produced in Argentina,'' *Journal of cleaner production,* 116: 50-60, 2016.

[30] V. Cesari, M. Zucali, A. Sandrucci, A. Tamburini, L. Bava, I. Toschi, ''Environmental impact assessment of an Italian vertically integrated broiler system through a Life Cycle approach,'' *Journal of cleaner production,* 143: 94-911, 2017.

[31] R. Ibidhi, A. Hoekstra, P. Gerbens-Leenes, H. Chouchane, ''Water, land and carbon footprints of sheep and chicken meat produced in Tunisia under different farming systems,'' *Ecological indicators,* 77: 304-313, 2017.

[32] Çevre, Şehircilik ve İklim Değişikliği, 'Karaman İli 2022 Yılı Çevre Durum Raporu,'' 2022.

[33] Tarım ve Orman Bakanlığı, 2020 Yılı Organik Tarım İstatistikleri,'' 2020.

[34] URL-1 Bursa Büyükşehir Belediyesi 2017. http://www.bursa.com.tr/bursanin-cografyasi- iklimi-ve-nufusu (Erişim Tarihi:18.04.2019)

[35] IPCC, ''Guidelines for National Greenhouse Gas Inventories Chapter1: Introduction 1.1-1.21,'' 2006.

[36] I. Maj, S. Kalisz, S. Ciukaj, ''Properties of animal-origin ash—A valuable material for circular economy,'' Energies, 15(4), 1274, 2022.

[37] A. Sharma, S. Gupta, A. Bhardwaj, A. Goel, K. K. Chaubey, S.V. Singh, ''Managing Cow Manure for Clean Energy: An Approach Towards Sustainable Conservation. In Animal Manure: Agricultural and Biotechnological Applications'' (pp. 261-274). Cham: Springer International Publishing, 2022.

[38] G. Kara, İ. Yalınız, M. Sayar, ''Konya ili hayvansal gübre kaynaklı sera gazı emisyonları durumu,'' Ulusal çevre bilimleri araştırma dergisi, 2(2), 57-60, 2019.

[39] S. Tırınk, ''Hayvansal atıkların biyogaz üretim potansiyelinin hesaplanması: Iğdır ili örneği,'' Journal of the Institute of Science and Technology, 12(1), 152-163, 2022.

[40] N.K. Salihoğlu, A. Teksoy, K. Altan, ''Büyükbaş ve küçükbaş hayvan atiklarindan biyogaz üretim potansiyelinin belirlenmesi: Balikesir ili örneği,'' Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, 8(1), 31-47, 2019.

[41] URL-1:https://arastirma.tarimorman.gov.tr/tepge/Belgeler/PDF%20Durum-Tahmin%20Raporlar%C4%B1/2023%20DurumTahmin%20Raporlar%C4%B1/S%C3%BCt%20ve%20S%C3%BCT%20%C3%9Cr%C3%BCnleri%20Durum%20Tahmin%20Raporu%202023372%20TEPGE.pdf

[42] Ö. Elmaz, C. Sipahi, M. Saatci, M.Ö. Metin, ''Current trends in dairy cattle farming in the Mediterranean region of Turkey,'' Outlook on Agrıculture, 41(2), 133-138, 2012.

[43] URL-2: https://www.tobb.org.tr/SanayiMudurlugu/Documents/KapasiteKriterleri/grup3112.pdf

[44] R. Yanardag, H. Orak, ''Selenium content of milk and milk products of Turkey,'' II. Biological trace element research, 68, 79-95, 1999.

[45] M. Hadjipanayiotou, ''Composition of ewe, goat and cow milk and of colostrum of ewes and goats,'' Small Ruminant Research, 18(3), 255-262, 1995.

[46] M. Cimen, H. Topcu, ''Effect of body condition score on biochemical milk parameters having economic importance in dairy goat during the first month of postpartum period,'' International Journal of Agriculture and Biology 15(2):395-397, 2013.

[47] S. Behrem, S. Gül,'' Effects of age and body region on wool characteristics of Merino sheep crossbreds in Turkey,'' Turkish Journal of Veterinary & Animal Sciences, 46(2), 235-247, 2022.

[48] İ. Yılmaz, İ. Savaş, M. Yanar, ''Göçer ailelerin hayvancılıkta sürü yönetimi ve yaylacılık faaliyetleri: Türkiye, Iğdır ili örneği,'' Türkiye Tarımsal Araştırmalar Dergisi, 7(1), 34-40, 2020.

[49] A. Semerci, ''Süt Sığırcılığı İşletmelerinde Yem Tüketimi ve Yem Dönüşüm Oranının Belirlenmesi: Hatay İli Örneği,'' Turkish Journal of Agriculture-Food Science and Technology, 10(7), 1214-1223,

2022.
[50] F. Gençdal, M. Terin, İ. Yıldırım, ''The influence of scale on profitability of dairy cattle farms: a case study in eastern part of Turkey,'' Custos e Agronegocio 15(3), 50-63, 2019.
[51] C. Oguz, S. Kaya, ''Factors affecting milk production in dairy farming enterprises and effectiveness analysis: A case study in Konya Province of Turkey,'' Cust Agronegocio, 12, 121-136, 2016.
[52] C. Rotz, F. Montes, D. Chianese, ''The carbon footprint of dairy production systems through partial life cycle assessment,'' *Journal of dairy science,* 93(3): 12661282, 2010.
[53] A. Flysjö, C. Cederberg,, M. Henriksson, S. Ledgard, ''How does co-product handling affect the carbon footprint of milk? Case study of milk production in New Zealand and Sweden,'' *The International Journal of Life Cycle Assessment,* 16(5): 420430, 2011.
[54] C. Cederberg, M. Stadig, '' System expansion and allocation in life cycle assessment of milk and beef production,'' The International Journal of Life Cycle Assessment, 8, 350-356, 2003.
[55] P. Crosson, L. Shalloo, D. O'Brien, G.J. Lanigan, P.A. Foley, T.M. Boland, D.A. Kenny, ''A review of whole farm systems models of greenhouse gas emissions from beef and dairy cattle production systems,''Animal Feed Science and Technology, Volumes 166–167, 29-45, 2011.
[56] A. E. Ersoy,''Türkiye'nin Hayvansal Gübre Kaynaklı Sera Gazı Emisyonları Durumu ve Biyogaz enerjisi Potansiyeli,'' *Yüksek Lisans Tezi,* HÜ, Fen Bilimleri Enstitüsü,Çevre Mühendisliği Anabilim Dalı, Ankara, 2017.
[57] MGM, T.C. Tarım ve Orman Bakanlığı Meteoroloji Genel Müdürlüğü https://www.mgm.gov.tr/- (Erişim Tarihi:12.12.2022), 2022.
[58] B. Ahmet, **''**Bursa bölgesinde faaliyet gösteren bazı hayvancılık işletmelerinin karbon ayak izinin belirlenmesi,**''** Bursa Uludağ Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans, Bursa, 2019.
[59] IPCC, 1997a. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories Workbook, vol. 2.Cambridge University Press, 1997.
[60] J. Casey, N. Holden, ''Greenhouse gas emissions from Irish grassland livestock production systems''. *Grassland Productivity*, 2006.
[61] W. Biswas, J. Graham, K. Kelly, M. John, ''Global warming contributions from wheat, sheep meat and wool production in Victoria, Australia-a life cycle assessment,'' *Journal of Cleaner Production,* 18(14): 1386-1392, 2010.
[62] IPCC, **''**Mitigation of climate change. Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change, 1454, 147, 2014.
[63] AM. Taluğ, H. Özkul, **''**Ruminantların beslenmesinde iyonofor kullanımı,**''** Hayvansal Üretim, 39-40: 72-80, 1999.
[64] G. Uzel, ''Türkiye ve Bursa'da Tarımdan Kaynaklanan Sera Gazı Emisyonları Ekonomisi ve Politika Önerileri,'' Uludağ Üniveristesi, Fen Bilimleri Enstitüsü, *Yüksek Lisans Tezi,* Tarım Ekonomisi Anabilim Dalı, Bursa, 2015.