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**Research Article**

# Estimation of Greenhouse Gas Emission and Global Warming Potential of Livestock Sector; Lake District, Türkiye

**Kazım Kumaş*, Ali Akyüz**

Bucak Emin Gulmez Vocational School of Technical Sciences, Burdur Mehmet Akif Ersoy University, Burdur, TURKIYE

* Corresponding author: K. Kumaş
* E-mail: kkumas@mehmetakif.edu.tr

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## Abstract

The calling on livestock is increasing fast because of the population and economic broadening. In recent years, the contribution of the livestock sector to greenhouse gas emissions and climate change has been a concern. This sector accounts for the second largest share of anthropogenic greenhouse gas emissions after the energy sector. The storage of animal manure is very important in this respect. Because gases such as nitrous oxide and methane, which are important greenhouse gases, are formed during storage. Therefore, it is very important to focus on this area to make manure management systems sustainable. In this study, greenhouse gas emissions that may occur in the provinces located in the region called Türkiye's Lakes Region were estimated using the data on the number of different species of animals published in 2016-2020. Evolution by years has been evaluated on a provincial basis. The global warming potential created by greenhouse gas emissions has been determined. As an animal species in the study; dairy and beef cattle, buffalo, sheep, goat, donkey-mule, meat and laying chicken, turkey, duck, and goose were used. 1567000 tons of $CH_4$ emission has occurred due to the total enteric fermentation of animal origin. The amount of $CH_4$ calculated based on manure management is 22450 tons. The $CO_2$ equivalent amount of $CH_4$ emission due to manure management and enteric fermentation was calculated as 33380500 tons. The total amount of direct and indirect $N_2O$ emissions from manure management in 2016-2020 is 12566.10 tons. $CO_2$ emission originating from $N_2O$ emission was obtained as 555743.46 tons.

**Keywords:** GHG emissions, Global warming, Greenhouse, Manure management

## Introduction

Population growth and lifestyle changes set about the consumption of available resources over time. Many environmental problems arise due to production and consumption. Climate change and global warming are among the environmental problems. In recent years, the increase in the amount of waste due to agriculture-livestock due to industry, energy demand and consumption, and the change in the amount of methane have caused us to face the problem of global warming. In recent years, industry, energy production, consumption, the increase in the amount of waste related to agriculture-livestock, and the change in the amount of methane have caused us to face the problem of global warming (Kılıç and Boğa, 2021; Bayraç, 2010; Philipps et al., 2022). In the formation of greenhouse gas (GHG) emissions, agriculture and animal husbandry come second after fossil fuels (Akın, 2006; Ahmedoğlu and Tanıık, 2020; Nasiru et al., 2021; Ibrahım Amadou and Arouna, 2022). Methane ($CH_4$) is the second largest greenhouse gas, accounting for 20% of global emissions. Carbon dioxide ($CO_2$), $CH_4$, nitrogen oxide ($NO_2$) and chlorofluorocarbon (CFC) gases are the main GHG. The agricultural sector has a significant source of $CH_4$ and animal manure is an important source of emissions (Calvet et al., 2017; Varma et al., 2021; Rosa et al., 2022). Unconscious agriculture and livestock practices cause an increase in the emission of GHG such as $CO_2$, $CH_4$, and $N_2O$. Through the production of $CH_4$ and $N_2O$, cattle are the main sources of GHG emissions from agriculture. Globally, the livestock sector generates approximately 5.6-7.5 Gt of $CO_2$ per year. Enteric fermentation is responsible for about 2 Gt of $CO_2$ per year (Kumar et al., 2014; Herrero et al., 2016; Grossi et al., 2019). Livestock manure is a source of $CH_4$ and $N_2O$, two potent emissions with 100-year global warming potential, 34 and 298 times stronger than $CO_2$. The global value of $CH_4$ is unknown, and there is no extensive research including the contribution of livestock (Chang et al., 2019; Lunt, et al., 2019). It has been stated that $CH_4$ produced from animals by enteric fermentation constitutes about 25% of the global anthropogenic $CH_4$ emission, and this rate increases by about 50% in rural areas (Kumar et al., 2014; Jafari et al., 2019). GHG such as methane, carbon dioxide ($CO_2$), ozone gas ($O_3$), and nitrous oxide ($N_2O$) cause environmental change and cause global warming with infrared radiation in the atmosphere (Nawab et al., 2020).

According to GHG data, total GHG emissions in Türkiye in 2020 increased by 3.1% compared to 2019 and were calculated as 523.9 million tons (Mt) of $CO_2$ equivalent. Total GHG emissions per capita reached the equivalent of 4 tons in 1990, 6.2 tons in 2019, and 6.3 tons of $CO_2$ in 2020. While energy sources constitute the most important share in the formation of total GHG emissions with 70.2% for 2020, it is followed by agriculture with

14%, industry with 12.7%, and the waste sector with 3.1%. Emissions from agriculture reached 73.2 Mt $CO_2$ equivalent in 2020, increasing by 58.8% compared to 1990 and 7.5% compared to 2019. Emissions from waste increased by 48% compared to 1990 and 2.1% compared to 2019, reaching 16.4 Mt $CO_2$ equivalents. 61% of $CH_4$ emissions originate from agriculture, 22.1% from waste, 16.9% from energy, and 0.02% from industry. 80.3% of $N_2O$ emissions originate from agriculture, 9.1% from energy, 5.6% from waste, and 5% from industry. Changes by sectors between 1990 and 2020 are given in Figure 1, and $CH_4$ and $N_2O$ emissions by relevant years are given in Figure 2 (TUIK,2022a).

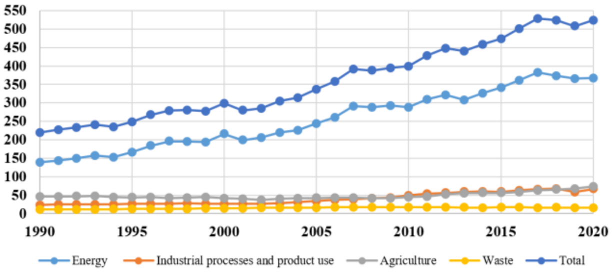

Fig. 1. The emissions variations by sectors vs years

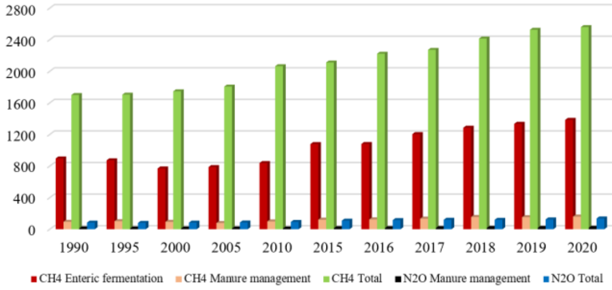

Fig. 2. $CH_4$ and $N_2O$ emissions by 1990-2020

GHG such as $CO_2$, $CH_4$, and $N_2O$, which occur as a consequence of agricultural work is considered one of the results of climate change. All things considered, approximately 2.5 billion people in developing countries get their living from agriculture, it is seen how much climate change will threaten human welfare and agricultural production. In addition, the increase in the level of water vapor in the atmosphere is seen as another factor causing global warming. These naturally produced gases do not harm the atmosphere, on the contrary, they allow some heat in the atmosphere to be kept away from the earth and to sustain life on earth. The formation of greenhouse gases in the atmosphere triggers climate change and leads to undesirable results (Koyuncu and Akgün, 2018; Leitner et al., 2021). An average of 40% of $N_2O$ emissions originating from agriculture consist of livestock activities. $N_2O$ emissions occur from nitrogen conversions in soil or manure (Kara et al., 2019). $N_2O$ emissions occur directly and indirectly (IPCC, 2006). Emissions from manure management in the livestock sector have a significant share. Processes such as manure processing and storage, grazing, and fertilizer application to the soil are counted among the emissions from manure management. Animal manure is a source of methane ($CH_4$) and nitrous oxide ($N_2O$), two potent GHG' 34 and 298 times more potent than $CO_2$, with a 100-year global warming potential (GWP100). When the literature is examined, it is seen that the subject of the study is quite interesting and has been given great importance in recent years. (Kora, 2019; Ammar, 2020; Ceyhan, 2020; Tongwane and Moeletsi, 2021; Zubir et al. 2022). Studies in the literature on GHG emissions generated by the livestock sector have also shown that the emission intensity depends on livestock, with animal species and management practices (Wei e al., 2018; Schiavonet al., 2019; González-Recio et al., 2020).

In this study, GHG emissions and global warming potential due to enteric fermentation and manure management processes originating from the livestock sector were investigated by using the number of animals covering the years 2016-2020 in the provinces located in the lakes region of Türkiye. In general, it is important to carry out such studies on a regional basis. The results of studies conducted in regions with similar ecological conditions are more objective. Conducting studies at the level of regions or provinces within the country also allows comparing the results. Comparing the results of these studies is important for the development of some policies. The Lakes region has a transitional climate between the Mediterranean climate and the Central Anatolian climate. Although the Mediterranean climate is seen in the Southern regions open to the Mediterranean, the continental climate effect is seen as you go to the North. Despite the continental climate effect, the effect of this climate has softened considerably, especially due to the lakes. The most important integrating power of the region is the common water culture. The region is in a geography where nature presents the planning boundaries; therefore, a holistic view of the region with common features is required. For a holistic perspective, a framework must first be determined. The Lakes Region is at the intersection of the Aegean, Mediterranean, and central Anatolia. Isparta, Burdur, Afyon, Konya, and Denizli have the same characteristics in terms of natural structure and culture, but Antalya has a different character than these provinces.

Livestock and agriculture are among the leading sectors of the region. It is observed that the lakes region has serious agriculture and livestock potential, and this potential is increasing with new developments. In addition, when the number of animals is examined, the Lakes Region constitutes about ten percent of the total number of animals in Türkiye in the last five years.

## Materials and Methods

The Lakes region is located in the Mediterranean Region of Türkiye, between 37°01′-38°30′N latitudes and 29°33′-32°21′E meridians. Its area is approximately 1711250 ha. Elevations range from 836 m to 2980 m, most of which have an altitude of 1000-1500 m. The region spreads over the lands of Afyonkarahisar, Isparta, Burdur, Antalya, Konya, and Denizli. Three different (Tier 1-2-3) approaches determined by the IPCC are used in calculating the amount of greenhouse gases originating from livestock. The first approach is generally simple and sufficient. This approach uses animal presence and emission factors determined by livestock and region characteristics. Access to the data used in this approach is quite easy. Data such as animal type, category, and the annual number of animals are sufficient. The Tier 2 method has the same approach as Tier 1, but country-specific emission factors and other parameters are used in this technique. Parameters such as the amount and quality of feed taken, the number of offspring, the digestion rates of the given feed, and the conversion factor are important. In Tier 3, all parameters that use country-specific data and modulate enteric and fertilizer emissions are taken into account. In this approach, precise information is needed for the feeding system, etc. In addition, although the Tier 1 method is considered rough, it still gives good results in the literature and IPCC (IPCC, 2006, Yona et al., 2020). In this study, Tier 1 approach was used for the estimation of the GHG emissions due to the presence of animals covering the provinces of Antalya, Isparta, Burdur, Afyonkarahisar, Denizli, and Konya, which are called Türkiye's Lakes Region. Due to limited data, Tier 2 or Tier 3 approaches could not be used. In the study, data on different animal species belonging to the provinces, including the years 2016-2020, were obtained from the Turkish Statistical Institute (TUIK). The animal numbers of different animal species at the provincial level used in the study for 2020 are given in Figure 3. The figure has been given in the summary form. In this study, the contribution of all animal types was taken into account. (TUIK,2022b).

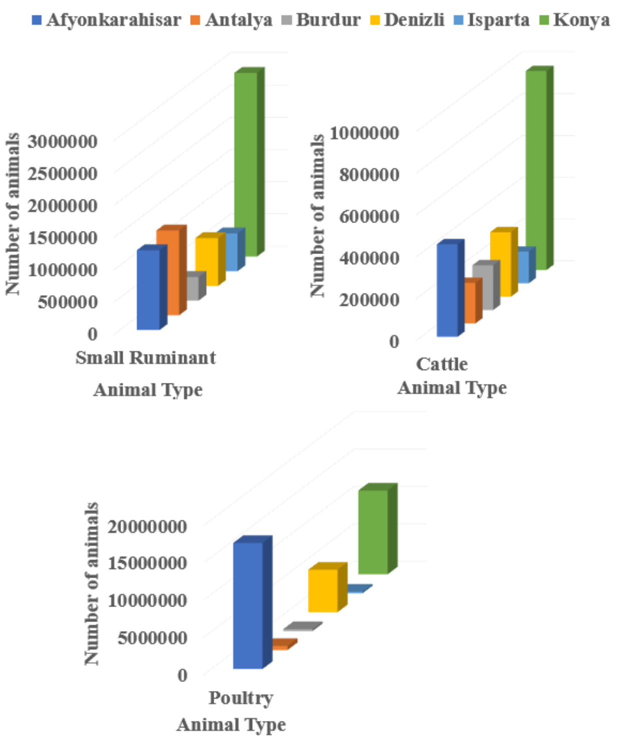


Fig. 3. Number of animals by type according to 2020 data

The effect of enteric and fertilizer management on $CH_4$ emissions was calculated using the parameters included in the IPCC (2006). $N_2O$ emissions due to manure management were calculated by two different methods, directly and indirectly. The global warming potential has been found given the $CO_2$ equivalents of $CH_4$ and $N_2O$ gas from the emissions (Ersoy and Uğurlu, 2020). In this study, it is considered that the manure is stored as a slurry, and the emissions were calculated from the equations given in Table 1 (IPCC, 2006; Kumaş and Akyüz, 2021). The physical characteristics of the animals in Türkiye were found to be more suitable for evaluation in the Eastern European country category, and the emission factor values were selected accordingly (IPCC, 2006).

Table 1. Formulas and parameters for the calculation of $N_2O$ and $CH_4$ (IPCC, 2006; Kumaş and Akyüz,2021).

| | |
|---|---|
| $Ne_{x,t} = 0.365x\, N_{r,t} x M_t$ | (1) |
| $N_2O_d = 1.5714x \left[ \sum_s \left[ \sum_t (N_t x Ne_{x,t} x MS_{t,s}) \right] x Ef_{3,s} \right]$ | (2) |
| $N_2O_g = 1.5714x(N_{v-ms} * Ef_4)$ | (3) |
| $N_{v-ms} = \sum_s \left[ \sum_t [N_t x Ne_{x,t} x MS_{t,s}\, x 0.01(Fg)_{t,s} \right]$ | (4) |
| $CH_{4_{ent}} = Ef_t x N_t x\, 10^{-6}$ | (5) |
| $CH_{4_{man}} = \sum_t Ef_t x N_t x\, 10^{-6}$ | (6) |

***$Ne_{x,t}$:*** *Annual N excretion*
***$N_{r,t}$:*** *Nexcretion rate*
***$M_t$:*** *Animal mass*
***$N_2O_d$:*** *Direct $N_2O$ emission*
***$N_{v-ms}$:*** *Manure nitrogen lost due to evaporation*
***$Ef_3$:*** *Direct emission factor*
***$N_2O_g$:*** *Indirect $N_2O$ emission*
***$N_t$:*** *Number of animals*
***$Ef_4$:*** *$N_2O$ emission factor from atmospheric nitrogen (0.01 kg)*
***$M_{,s}$:*** *The total nitrogen excretion ratio*
***$(Fg)_{t,s}$:*** *% of managed manure nitrogen*
***$CH_{4ent}$:*** *$CH_4$ from enteric fermentation; Gg $CH_4\, yr^{-1}$*
***$CH_{4man}$:*** *$CH_4$ from manure management; Gg $CH_4\, yr^{-1}$*
***$Ef_t$:*** *Emission factor for animal type; kg $CH_4$ head$^{-1}$*

Direct $N_2O$ emission amount has been calculated by equations 1 - 2 in Table 1. Indirect emissions of $N_2O$ in the form of $NH_3$ and $N_2O$ from volatility can be determined using equations 3-4. The nitrogen excretion fraction is different according to the animal species and was taken here as the solid manure storage management system. With the help of equation 5, enteric and using equation 6, $CH_4$ emissions from manure management were calculated (IPCC, 2006; Kumaş and Akyüz,2021). The parameters given in Table 2-4 were used to calculate the theoretical amount of $N_2O$ and $CH_4$ values (Table 2). The parameters given in the tables vary according to each animal species, mass, and temperature values.

Temperature is an important parameter in the calculations of methane gas emissions. The accepted temperature values of the provinces used in the study are given in Table 5. The average temperature data was obtained from the Turkish Meteorology General Directorate (MGM,2022).

Table 2. Parameters used for direct $N_2O$ calculation (IPCC, 2006; Kumaş and Akyüz,2021).

| Animal | $N_{r,t}$ [kg N.(1000 kg animal)$^{-1}$ day$^{-1}$] | $M_t$ (kg) | $MS_{t,s}$ (%) | $Ef_3$ [kg $N_2O$-N.(kg N)$^{-1}$ ] |
|---|---|---|---|---|
| Dairy Cattle | 0.35 | 550 | | |
| Other Cattle | | 391 | 100 | 0.020 |
| Water Buffalo | 0.32 | 380 | | |
| Sheep | 0.90 | 48.5 | | |
| Goat | 1.28 | 38.5 | | |
| Horse | 0.30 | 377 | | |
| Donkey+Mule | | 130 | | |
| Meat Chicken | 1.10 | 0.90 | | |
| Egg Chicken | 0.82 | 1.80 | | 0.001 |
| Turkey | 0.74 | 6.80 | | |
| Duck+Goose | 0.83 | 2.70 | | |

Table 3. Factors for enteric fermentation (IPCC, 2006)

| Animal | $Ef_4$ |
|---|---|
| Dairy Cattle | 99* |
| Other Cattle | 58* |
| Water Buffalo | 55 |
| Sheep | 8 |
| Goat | 5 |
| Horse | 18 |
| Donkey+Mule | 10 |

** Eastern European country values were used*

Table 4. Manure management factors according to temperature values (IPCC, 2006).

| Animal | Emission Factor kg $CH_4$ head$^{-1}$ year$^{-1}$ | | |
|---|---|---|---|
| | <15°C | 15°C - 25°C | >25°C |
| Dairy Cattle * | 2 | 2 | 3 |
| Other Cattle * | 1 | 1 | 1 |
| Water buffle* | 4 | 5 | 5 |
| Sheep | 0.10 | 0.15 | 0.20 |
| Goat | 0.11 | 0.17 | 0.22 |
| Horse | 1.09 | 1.64 | 2.19 |
| Donkey+Mule | 0.60 | 0.90 | 1.20 |
| Meat Chicken | | | |
| Egg Chicken | 0.01 | 0.02 | 0.02 |
| Turkey | | | |
| Duck+Goose | | | |

** According to IPCC 2006 guidelines, Eastern European country values were used*

Table 5. Average temperature values for 1929- 2020

| City | Average Temperature (°C) |
|---|---|
| Afyonkarahisar | 11.3 |
| Antalya | 18.8 |
| Burdur | 13.3 |
| Denizli | 16.2 |
| Isparta | 12.3 |
| Konya | 11.7 |

## Results and Discussion

In this study, the amounts of $CH_4$, $N_2O$, and $CO_2$ GHG were determined by using different animal species data covering the years 2016-2020 obtained from the Turkish Statistical Institute (TUIK) of the provinces in the Lakes region.

The Tier 1 method specified in the IPCC 2006 guideline was used to determine GHG emissions. Geographically, Türkiye is a country between Eastern Europe and the Middle East. For this reason, it can carry the characteristics of both geographical regions. The physical characteristics of animals are decisive in the calculation of emissions. For this reason, in the guideline, these criteria are classified according to the geographical conditions of the countries. Calculations have been made for the $N_2O$ emission originating from enteric methane and manure management, assuming the Eastern European country. In the calculation of $CH_4$ emissions originating from manure management, where the storage method of animal manure and the temperature of the storage environment are important factors, it is accepted as the Middle East country. The $CH_4$ emission due to enteric fermentation for the years 2016-2020 is given in Figure 4.

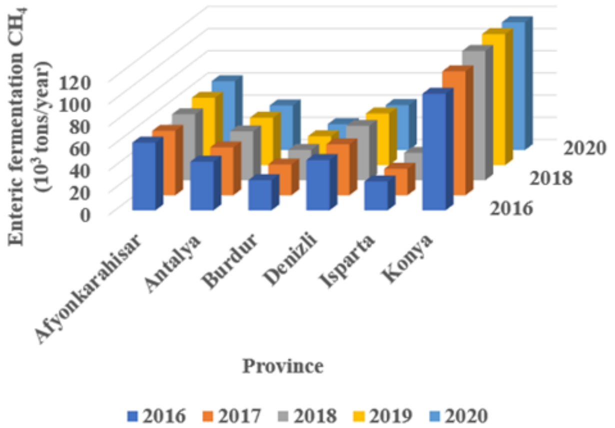


Fig. 4. Enteric fermentation $CH_4$ ($10^3$ tons/year)

Between 2016 and 2020, a total of 1567000 tons of $CH_4$ emissions were produced due to total enteric fermentation. The total emission value of the provinces by years increased by approximately four percent from 2016 to 2018 and decreased by 3.7% compared to previous years. While an increase is observed in the amount of emissions for Afyonkarahisar, there is a decrease in the provinces of Isparta, Konya, Antalya, Burdur, and Denizli. The province that contributes the most to total emissions is Konya, and the province that gives the least emissions is Isparta. Konya is followed by Afyonkarahisar, Denizli Antalya, Burdur, and Isparta, respectively. $CH_4$ emissions from manure management covering the years 2016-2020 are given in Figure 5. The total amount of $CH_4$ emissions from manure management, which was 3960 tons in 2016, increased by twenty percent in 2020. In the proportional distribution of total emissions by provinces, Konya has a ratio exceeding forty percent, while Isparta has the lowest ratio. While Konya had thirty-eight percent of the total emission amount of the Lakes Region in 2016, this rate reached forty percent within a year but decreased by about one percent in 2020. Afyonkarahisar accounted for nineteen percent of the total emissions in 2016 and this rate increased by one percent in four years. The emission values of the provinces can be listed from largest to smallest as Konya, Afyonkarahisar, Denizli, Antalya, Burdur, and Isparta. The $CO_2$ equivalent amount of $CH_4$ emission from manure management and enteric fermentation is given in Figure 6.

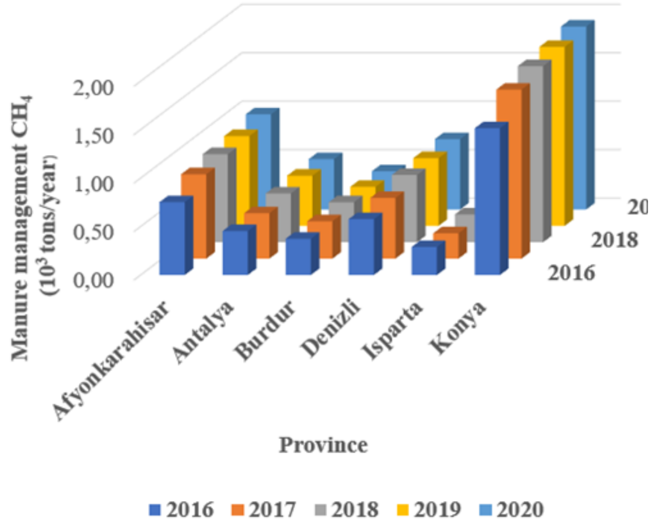


Fig. 5. Manure management $CH_4$ ($10^3$ tons/year)

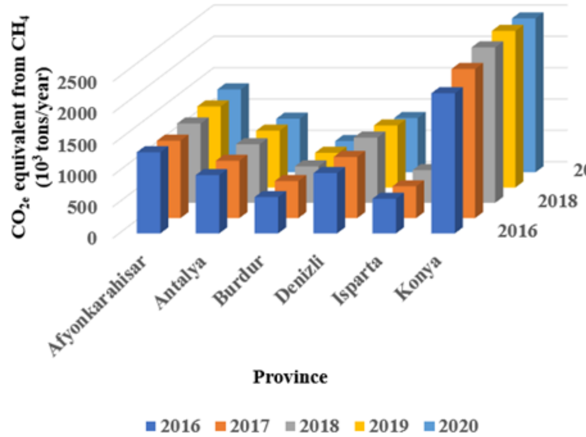


Fig. 6. $CO_{2e}$ equivalent from $CH_4$ ($10^3$ tons/year)

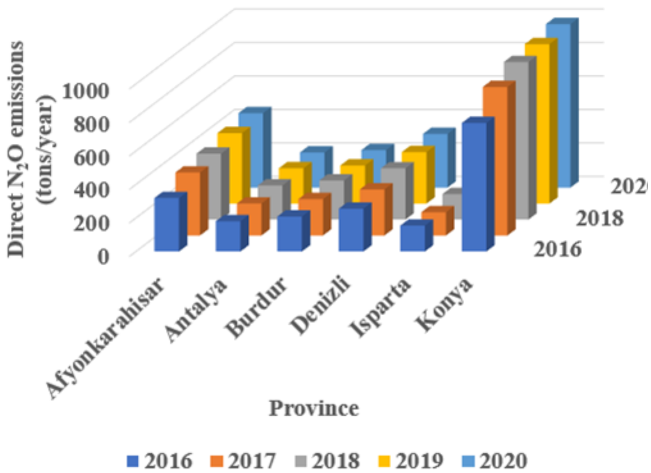


Fig. 7. Direct $N_2O$ emissions(tons/year)

For Antalya, Burdur and Denizli, emissions increased between 2016-2018 and decreased in 2018-2020. While there was a continuous increase in Afyonkarahisar and Isparta in 2016-2020, an increase was observed in Konya until 2019 and a decrease in 2020 compared to the previous year. While the minimum amount of $CO_{2e}$ was calculated for Isparta in 2016, the minimum amount of $CO_{2e}$ was calculated for Burdur in 2020. The highest amount of $CO_{2e}$ occurred in Konya and the lowest amount of $CO_{2e}$ occurred in Isparta. In this study, $N_2O$ emission was calculated in two different ways as direct and indirect emissions due to manure management.

The change in the amount of emissions resulting from direct emissions by years is given in Figure 7. The total amount of direct emissions It can be said that the total amount of direct emissions in 2020 increased by more than twenty percent compared to 2016. Over the years, the amount of direct emissions for each province has steadily increased. The highest emission occurred in Konya and the least emission occurred in Isparta. The distribution of emission amounts resulting from indirect emissions by years is given in Figure 8.

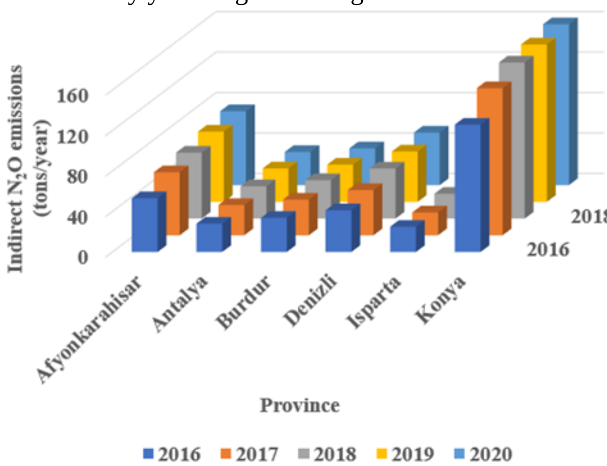


Fig. 8. Indirect N2O emissions (tons/year)

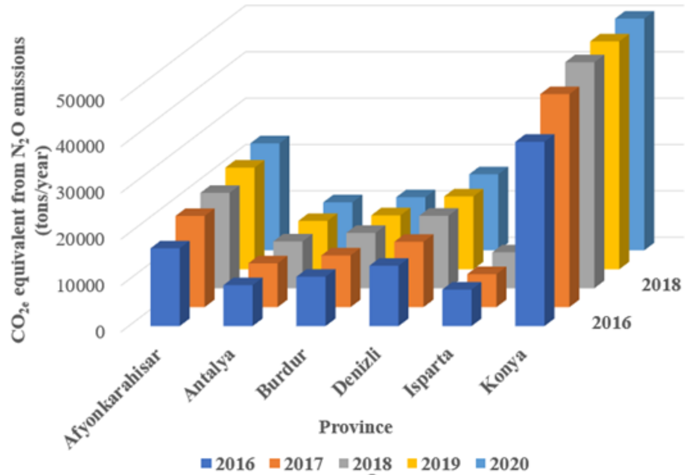


Fig. 9. $CO_{2e}$ equivalent from $N_2O$ emissions (tons/year)

The total amount of $N_2O$ emissions covering the years 2016-2020 is 1757.86 tons. When the amount of indirect emissions between 2016 and 2020 are compared, it is seen that there is a twenty-three percent increase. While the highest increase in the amount of emissions was in Konya, less increase was in Isparta. Over the years, the amount of indirect emissions for each province has steadily increased. The evolution of the global warming potential $CO_2$ amount created by direct and indirect total

$N_2O$ emissions from manure management by years is given in Figure 9.

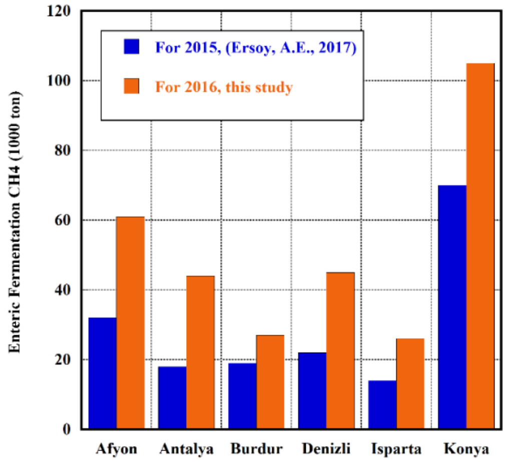


Fig. 10. Comparison of emission from enteric fermentation with the literature

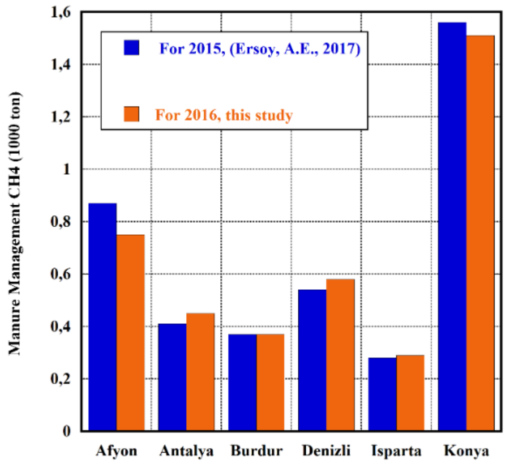


Fig. 11. Comparison of the emission from manure management with the literature

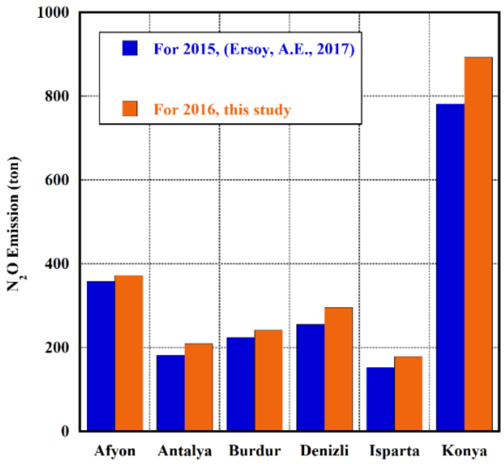


Fig. 12. Comparison of $N_2O$ emission results

Including the relevant years, the total $CO_2$ emission is 555743.46 tons. On a provincial basis, the increase in the rate of change in emissions compared to 2020 and 2016 can be listed as Afyonkarahisar, Konya, Denizli, Antalya, Burdur, and Isparta from largest to smallest. In the literature, only one detailed reference for 2015, in which the emission values from animals can be compared for the Lakes Region, could be reached (Ersoy, 2017). The comparison of the emissions resulting from the obtained enteric fermentation with the results of Ersoy (2017) is given in Figure 10.

Figure 11 gives a comparison of emissions from manure management. Figure 12 shows the comparison of emissions from $N_2O$ with the results of Ersoy (2017). Considering that there may be an increase in emissions within a year, it can be considered that all results are compatible.

## Conclusions and Recommendations

In this study, animal-based GHG ($CH_4$, $N_2O$) emissions and global warming potential were calculated using the number of animals covering the years 2016-2020 in the region called the Lakes region. The IPCC 2006 methodology Tier 1 method was used to calculate the GHG emissions of animal origin.

In Figure 13, the fractions of the total emission values calculated over the years in this study in Türkiye are given (TUIK,2022a). It can be seen that the share of total animal origin emissions in the Lakes region in Türkeye is around 10% - 11%.

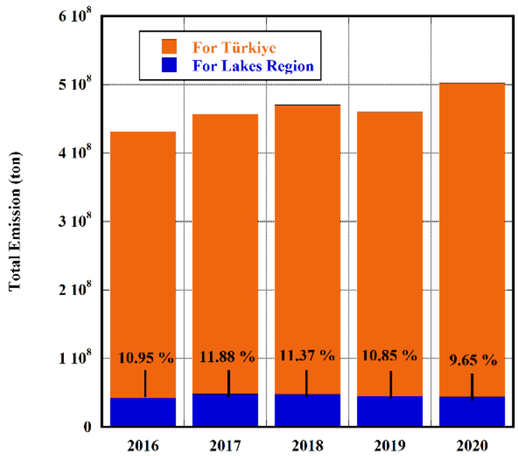


Fig. 13. The share of the Lakes Region's total emission potential in Türkiye

Animal manure that does not have a suitable storage area causes gas emissions. They can also indirectly flow into surface water or groundwater. In addition, animal manure contains various microorganisms that can cause disease outbreaks.

Agriculture and livestock are important socio-economic factors in Türkiye. Livestock is effective in the formation of greenhouse gases. For this reason, it should be aimed to find new solutions to reduce greenhouse gas emissions from animal waste by authorized persons. Sustainable manure management systems that can control processes such as waste storage, transportation, emission and pollution reduction should be followed and developed.

In the Lakes Region selected in this study, animal husbandry is in the form of family businesses and is carried out together with agricultural activities. When these activities are tried to be done at the same time, professionalization in the field of animal husbandry is limited. In the region, animal health and welfare are affected as the places where animals are kept in enterprises are closed and have a fixed bonding feature.While determining national agriculture and livestock policies, regional and product-based policies should not be ignored. Field products constitute more than half of the total agricultural land in the Lakes region. Therefore, while creating agricultural policies, the agricultural structure of this region and the conditions affecting the region's agriculture should be taken into account. Higher education institutions in Türkiye in different fields continue their activities as research universities focused on regional development. Burdur Mehmet Akif Ersoy University, which was selected as a regional development-oriented university in the field of animal husbandry by the Turkish Higher Education Institution in 2016, provides technical support and training to livestock enterprises and the people of the region. In addition, it can be suggested that the harms of emissions from animals should be explained and taught to people in this sector in detail. It may be suggested to explain animal-based emissions and harms to breeders in state-sponsored events such as the Lakes Region Agriculture and Livestock Fair, which was held on November 17, 2022.

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