Vol. 24 No.2 (Juli 2023) 157-165
e-ISSN 2548-6101 p-ISSN 1411-318X

Jurnal Teknologi Lingkungan

Journal Homepage: ejournal.brin.go.id/JTL

Estimation of Greenhouse Gas Emission Burden of Livestock Sector in East Java Province, Indonesia

Estimasi Beban Emisi Gas Rumah Kaca dari Sektor Peternakan di Provinsi Jawa Timur, Indonesia

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INFORMASI ARTIKEL

Histori artikel:
Diterima 16 Juni 2022
Disetujui 6 Januari 2023
Diterbitkan 31 Juli 2023

Kata kunci:
Emisi gas rumah kaca
Gas metan
Dinitro oksida
Peternakan
Pemanasan global

ABSTRAK

Tujuan dari analisis ini adalah untuk memetakan kontribusi gas metana dan dinitro oksida dari sektor peternakan di setiap wilayah yang ada di Provinsi Jawa Timur sebagai dasar perencanaan dalam pengembangan kawasan peternakan yang berkelanjutan dan berwawasan lingkungan. Metode analisis menggunakan pendekatan analisis Tier 1. Data yang digunakan adalah data sekunder dari BPS Jawa Timur Tahun 2021. Hasil analisis menunjukkan bahwa beban gas rumah kaca di Provinsi Jawa Timur yaitu CH_4 sebanyak 221,80 Gg CH_4 Th^{-1} dan N_2O sebanyak 168,42 Gg N_2O Th^{-1} dengan profil beban tiap wilayah kabupaten/kota tidak merata. Beban gas rumah kaca tertinggi didapatkan di Kabupaten Malang. Penyumbang gas rumah kaca tertinggi dari sub sektor peternakan adalah ternak sapi potong sebesar 75,20% CH_4 dan 52,30% N_2O terhadap total sektor peternakan.

ARTICLE INFO

Article history:
Received 16 June 2022
Accepted 6 January 2023
Published 31 July 2023

Keywords:
emissions of greenhouse gases
methane gas
nitrous oxide
livestock sector
global warming

ABSTRACT

The purpose of this analysis is to map the contribution of methane gas and nitrous oxide from the livestock sector in each region in East Java Province as a basis for planning in the development of sustainable and environmentally friendly livestock areas. The analysis method uses a Tier 1 analysis approach. The data used is secondary data from the BPS East Java in 2021. The results of the analysis show that the greenhouse gas load in East Java Province is CH_4 as much as 221.80 Gg CH_4 per year and N_2O as much as 168.42 Gg N_2O per year where the load profile is uneven for each district/city. The highest greenhouse gas load was found in Malang Regency. The highest greenhouse gas contributor from the livestock sub-sector is beef cattle with 75.20% CH_4 and 52.30% N_2O of the total livestock sector.

1. INTRODUCTION

1.1 Background of the Study

Global warming is the process of increasing the average temperature of the land, atmosphere, and oceans. The increase in the earth's temperature causes ecosystem disturbances which in the long term have an impact on the decreased ability of the earth to absorb gases that can make the ozone layer in the atmosphere thinner. Earth's average temperature has increased by 0.74 ± 0.18 °C in the last hundred years (Chathumini *et al*., 2008; Haryuni, 2018). Climate change due to global warming is one of the trending issues that is often discussed in scientific forums. Climate change that occurs in Indonesia is a threat to national food security because climate change has a direct impact on decreasing agricultural productivity and indirectly affects food supply chain disturbances and food nutritional quality (Sapkota *et al*., 2021). Indonesia has committed to reduce national greenhouse gas (GHG) emissions by 2030 with its own efforts by 29 and 41% from international support.

Factors that trigger global warming include methane and nitrous oxide emissions. The agricultural sector accounts for about 10-12% and the livestock sector accounts for 18 to 51% of the total anthropogenic GHG emissions (Sarah, Susilawati, & Pramono, 2021). Greenhouse gases include (carbon dioxide) CO_2, (methane) CH_4, (chloro flouro carbon) CFC, (ozone) O_3, and (dinitro oksida) N_2O (Pratama, 2019). Livestock can produce all but O_3, but the most dangerous gas is metana dan dinitro oksida. Nitrogen Oxide in the stratosphere with the help of sunlight can destroy ozone, have an impact 298 absorbs more heat per unit weight than carbon dioxide, whereas methane has an effect 25 times greater than carbon dioxide (Prabowo & Budiastuti, 2017; Pratama, 2019).

In 2013 the livestock sector contributed 8.10 Gigatonnes (Gt) of global GHG emissions equivalent to carbon dioxide (CO2eq) and equivalent to 14.50% of global anthropogenic GHG emissions. The highest GHG production from the livestock sector is produced by ruminants, which is around 87.70%. These GHG emissions are generated from energy consumption, feed production, enteric fermentation and livestock manure management (Dai, Sun, & Muller, 2021; Haryuni, 2018; Maciell, Alvarenga, Campanha, & Gontijo Neto, 2021). East Java Province is one of the livestock centers in Indonesia. In 2020 the livestock population in East Java is 4,750,321 beef cattle; 298,521 dairy cows; 23,339 buffaloes; 4.13 million goats; 0.9 million sheep and in 2013 34.80 million laying hens, 20.50 million native chickens; 525.10 thousand other local chickens; 6.60 million ducks; 7.30 million quail; 241.80 thousand pigeons; 120.80 thousand geese; 3,713 turkeys and 98,972 rabbits (Subdirectorate of Livestock Statistics, 2020). In order to support the development of environmentally friendly livestock areas in East Java, it is necessary to analyze the burden of GHG emissions from the livestock sector in each district/city area which is used as a reference in developing mitigation technology in the livestock sector so that GHG production from the livestock sector in the future can be minimized.

1.2 Purpose of the Study

The purpose of this analysis is to map the contribution of methane gas and nitrous oxide from the livestock sector in each region in East Java Province as a basis for planning in the development of sustainable and environmentally friendly livestock areas.

2. METHODS

2.1 Methods

The method used in data analysis is descriptive analytical method. The descriptive analysis process is carried out by converting the profile of livestock in East Java Province in the form of animal units (AU).

2.2 Materials

The data analyzed is secondary data obtained from the Livestock Service Office of East Java Province and BPS East Java Province in 2021.

2.3 GHG emission calculation

The estimate of GHG emissions are analyzed by the Tier 1 method. Tier 1 is the simplest calculation method for estimating greenhouse gas production using the default parameters (emission factors, changes in carbon storage) available. The calculation steps follow the Guidelines for the Implementation of the National Greenhouse Gas Inventory, 2012 Volume 3, including: (a) Inventory of the population of livestock species) beef cattle, dairy cattle, and buffalo) regardless of old in each region then the real population presented in the East Java BPS data is multiplied by the correction factor (0.75 for dairy cattle; 0.72 for beef cattle and buffalo); (b) Emission factors for each type of livestock are presented in Tables 1 and 2; and (c) Analysis with a predetermined formula approach for each emission (IPCC, 2006). Calculation formula of CH_4 from digestion in equation (1), CH_4 from manure in equation (2), N_2O production directly from manure treatment in equation (3), and N_2O production indirectly from manure treatment in equation (4).

$$EF_{(Tf)} \times N_{(T)} \times 10^{-6} \quad \text{..... (1)}$$

$N_{(T)}$ = Total livestock population
$EF_{(Tf)}$ = Emission factor from digestion

$$EF_{(Tk)} \times N_{(T)} \times 10^{-6} \quad \text{..... (2)}$$

$N_{(T)}$ = Total livestock population
$EF_{(Tk)}$ = Emission factor from manure

$$\left[\sum_{S}\left[\sum_{T}(N_T \times Nex_T \times MS_{T,S}\right] \times EF_{3(S)}\right] \times \frac{44}{28} \quad \text{.....(3)}$$

$N_{(T)}$ = Total livestock population
Nex_T = $Nrate_{(T)}$ x (**Error! Reference source not found.**TAM/100) x Average annual excretion of N
MS_{TS} = the mean of total annual N excretion is 2%
EF_3 = N_2O emission factor of dry pile manure management system 0.02 (direct emission); 0.01 (indirect emission)
S = manure management system
T = type of livestock
44/48 = Conversion of emissions (N_2O)-N)(mm) into N_2O (mm) form

$$\left[\sum_S\left[\sum_T\left(N_T \, x \, Nex_T \, x \, MS_{T,S}\right]\right] x \left(\frac{Frac_{GasMS}}{100}\right)_{TS}\right] x \, EF_{3(S)} \, x \, \frac{44}{28} \quad \text{..... (4)}$$

$N_{(T)}$ = Total livestock population
Nex_T = $Nrate_{(T)}$ x (**Error! Reference source not found.**TAM/100) x Average annual excretion of N
MS_{TS} = the mean of total annual N excretion is 2%
$Frac_{GasMS}$ = missing N fraction
S = manure management system
T = type of livestock
44/48 = Conversion of emissions (N_2O)-N)(mm) into N_2O (mm) form

Table 1. CH_4 and N_2O gas emission factors from manure treatment for each type of livestock

No.	Type of livestock	[a]Digestive process (*Tf*) (Gg/head/year)	[a]Manure treatment (*Tk*) (Gg/head/year)	[a]Excretion rate factor N (T) (Gg/head/day)	[b]Body weight (TAM) (Gg/head)
1	Beef cattle	47.00	1.0	0.34	325.00
2	Dairy cows	61.00	31.0	0.47	325.00
3	Buffalo	55.00	2.00	0.32	325.00
4	Sheep	5.00	0.20	1.17	45.50
5	Goat	5.00	0.22	1.37	45.50
6	Pig	1.00	7.00	0.82	90.00
7	Horse	18.00	2.19	0.46	325.00
8	Poultry	-	0.02	0.05	1.63

Sources: [a] (IPCC, 2006)
[b] (Direktorat Perbibitan Ternak, 2015)

Table 2. Fraction of N lost for each type of livestock in the manure management system

No.	Type of livestock	$Frac_{GasMS}$ average (%)	$Frac_{GasMS}$ (%)	Information
1	Pig	45	10-65	Solid storage
2	Dairy cows	20	10-35	Dry stack
3	Poultry	40	10-60	With litter
		55	40-70	Without litter
4	(goat, sheep, horse)	12	5-20	Solid storage
	other livestock	30	20-50	Dry stack

Sources: (IPCC, 2006)

3. RESULTS AND DISCUSSION

3.1 Profile of livestock in East Java Province

The livestock profile in East Java Province can be described by converting it in animal units. The animal unit is a measure to relate body weight to feed consumption. Animal unit is a standard for converting the weight of various types of livestock in a single unit, making it easier to calculate. Each animal unit is assumed to be equivalent to one adult cow with a body weight of 325 kg or one adult horse (Direktorat Perbibitan Ternak, 2015). The population and profile of livestock in East Java Province are shown in Table 3 and Figure 1.

Table 5 illustrates that poultry and ruminant farms in East Java Province develop concurrently, of which 36.55% are poultry and 63.45% consist of beef cattle, dairy cattle, buffalo, goats, sheep and horse. It was found that the livestock profile of each district/city in East Java Province is not evenly distributed (Figure 1). According to Edi (2020), factors that play an important role in the distribution of livestock in an area are sources of feed and adaptive techno-socio-economic conditions that support the use of livestock

and the development of their potential for the prosperity of farmers.

One of the main contributors to climate change (CC) through greenhouse gas (GHG) emissions is livestock. Ruminant livestock, especially cattle, are the main contributor to GKR emissions (Menghistu et al., 2021). The main GHG emissions in the atmosphere consist of CO_2, CH_4 and N_2O (D'aurea *et al*., 2021; Doyeni, Stulpinaite, Baksinskaite, Suproniene, & Tilvikiene, 2021; Gülşen & Yapıcıoğlu, 2021; Maciell *et a*l., 2021). These gases can be produced by ruminants and poultry, except that CH_4 gas can only be produced by ruminants. The development of ruminant livestock has a greater impact on the burden of GHG emissions than poultry. Cattle produce GHG 2-7 times higher than other livestock mainly in the form of methane gas (CH_4) which is produced from enteritic fermentation (Weber, Hao, Gross, Beauchemin, & Chang, 2021). The livestock population of each region and the manure management system play an important role in the production of greenhouse gases (IPCC, 2006). Livestock manure contributes to methane (CH_4) emissions by 20% and nitrous oxie (N_2O) emissions by 30-50% (Vries, Pronk, & Adiyoga, 2021).

Table 3. Profile of livestock in East Java Province

No.	Type of livestock	Population (livestock)*	Animal unit**	Persentage (%)
1	Beef cattle	4,823,972	4,823,972	52.23
2	Dairy cows	293,556	293,556	3.18
3	Buffalo	22,975	22,975	0.25
4	Horse	10,476	10,476	0.11
5	Goat	3,645,780	510,409	5.53
6	Sheep	1,419,490	198,729	2.15
7	Pig	67,574	13,515	0.15
8	Broilers	238,218,829	2,382,188	25.79
9	Layers	52,449,429	524,494	5.68
10	Free-range chicken	37,577,656	375,777	4.07
11	Duck	7,948,665	79,487	0.86

Source: *(BPS-Statistics of Jawa Timur Province, 2021)
** Uniformity of livestock in animal units

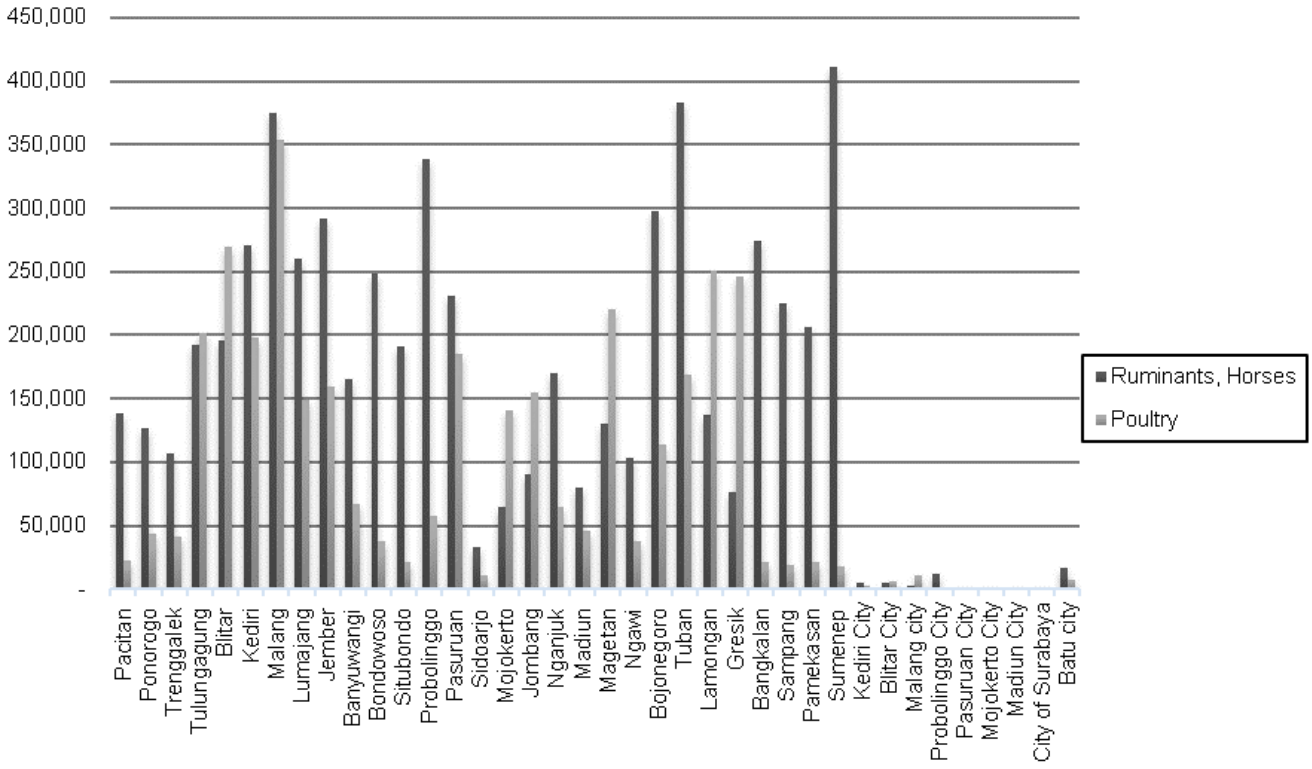

Figure 1. Profile animal unit of livestock in East Java Province (BPS-Statistics of Jawa Timur Province, 2021)

The magnitude of the GHG emission load is in line with the population and body weight of each type of livestock. In Figure 1 it can be seen that in 2020 animal units in East Java Province were 9,235,577 animal units consisting of 5,860,117 ruminants and 3,375,461 animal units. The highest animal unit in East Java Province is in the Malang Regency area with a total of 728,797 livestock units consisting of 375,392 ruminants and 353,405 poultry. Malang Regency has the potential to produce higher GHG than other areas in East Java.

3.2 Methane (CH_4) emission

Methane calculation is only based on livestock population without considering geographical conditions. The greenhouse effect produced by methane gas (CH_4) is 28 times higher than that of carbon dioxide (CO_2) (Weber *et al*., 2021). GHG emissions from methane gas (CH_4) increase significantly in line with the increase in livestock population and are estimated to reach 60% from 1990-2030 (Panchasara, Samrat, & Islam, 2021). Analysis of methane gas (CH_4) from the livestock sector in Table 4 shows that East Java Province has a load of 221.80 Gg CH_4/year. 91.60% of methane gas or 203.20 Gg CH_4/year is produced from digestion in ruminants and 8.40% from manure processing.

Table 4 shows that the highest CH_4 load contributor from the livestock sub-sector is beef cattle at 75.20%. This result is in line with the highest unit of beef cattle in East Java Province reaching 38.30% of the total farms, followed by broilers at 37.80%. Analysis of the CH_4 emission load profile in each region in East Java Province is not the same due to the unequal distribution of livestock in each region (Figure 2). The CH_4 emission load profile in East Java Province analyzed by tier 1 shows that Malang Regency is the largest producer of methane gas, reaching 22.178 Gg CH_4/year or 7.50% of the total in East Java Province. Analysis of CH_4 emissions using tier 1 is directly proportional to livestock population and livestock body weight. Malang Regency has the highest number of animal units in East Java Province (Figure 1). The number of animal units is an illustration of the population and body weight of livestock. Regional carrying capacity index (IDD) in Malang Regency is critical with a value of 0.9, this indicates that the livestock population exceeds the carrying capacity of its feed (Edi, 2020a), so it is not appropriate for the development of livestock areas in Malang Regency.

Methane gas is formed due to the acetic acid fermentation process that occurs in the rumen by rumen microbes. Through the process of methanogenesis CO_2 is reduced with H_2 to form CH_4 by methanogenic bacteria and excreted through 83% eruption, 16% respiration and 1% feces. Rumen microbes that play a role in the process of methane gas formation include Methanobrevibacter ruminantium, Methanobacterium formicicum, Methanobrevibacter, Methanosaricina barkeri, Methanomicrobium mobile, Methanosaricina mazei and others (Haryuni, 2018; Zaman, Heng, & Müller, 2021). The production of methane gas (CH_4) in ruminants illustrates the loss of energy. The high production of methane (CH_4) indicates a high energy loss (Cheng *et al*., 2021; D'aurea *et al*., 2021).

Figure 2 shows that the livestock center is concentrated in the Regency, this can be seen from the burden of CH_4 emissions from the livestock sector in the city which is lower than in the Regency. The city area is not appropriate as a center for livestock development due to several factors including rules on urban spatial planning, crowded residential areas and limited sources of animal feed. The potential for forage in urban areas in East Java is very low, namely 0.65% (city) and 99.35% (district) of a total of 16,167,651 tons/year (Edi, 2020b). The difference in methane gas (CH_4) production from the livestock sector in each region according to the (de Ondarza & Tricarico, 2021) reflects differences in the type and consumption of feed. Feed plays an important role in the production of methane (CH_4).

Table 4. Production of methane gas from the livestock sector in East Java Province

Type of livestock	Digestion (Gg CH_4 /year)	feces (Gg CH_4 /year)	Total (Gg CH_4 /year)	Persentase (%)
Beef cattle	163.20	3.50	166.70	75.20
Dairy cows	13.40	6.80	20.30	9.10
Buffalo	0.90	0.00	0.90	0.40
Horse	0.20	0.00	0.20	0.10
Goat	18.20	0.80	19.00	8.60
Sheep	7.10	0.30	7.40	3.30
Pig	0.10	0.50	0.50	0.20
Broilers	-	4.80	4.80	2.10
Layers	-	1.00	1.00	0.50
Free-range chicken	-	0.80	0.80	0.30
Duck	-	0.20	0.20	0.10
Total	203.20	18.60	221.80	100.00

The data is processed based on data from (BPS-Statistics of Jawa Timur Province, 2021)

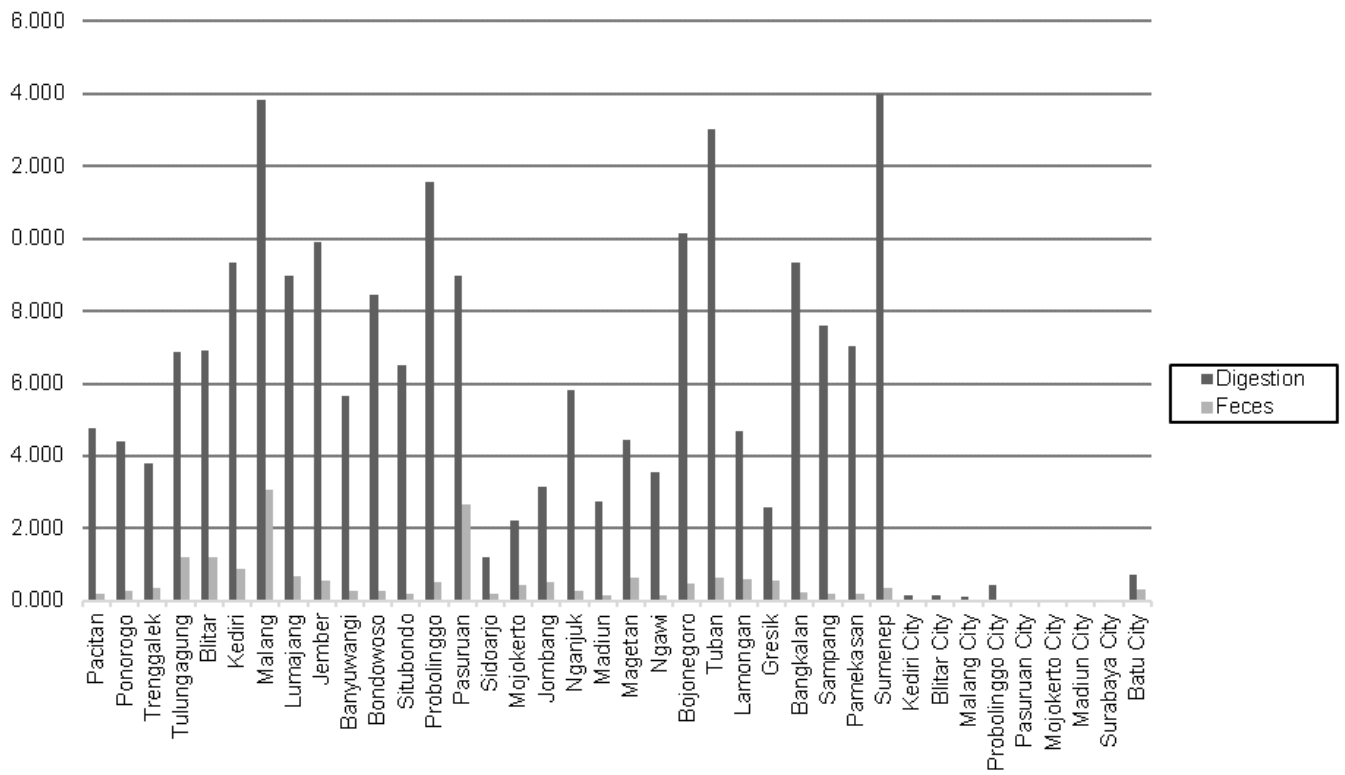

Figure 2. Profile of methane gas load in East Java Province
(BPS-Statistics of Jawa Timur Province, 2021)

3.3 Nitrous oxide (N_2O) emission

Analysis of nitrous oxide (N_2O) from the livestock sector in Table 5, regardless of geographical conditions shows that East Java Province has a load of 168,422.4 Gg N_2O/year. This result is the accumulation of production directly and indirectly from the processing of feces. Ruminants have the potential to produce higher N_2O gas than poultry, even though the number of poultry units is 3.50% more than ruminants (Table 5). Livestock business contributes to the production of nitrous oxide (N_2O) emissions of 53-65% of the total anthropogenicity. In developing countries where ruminant livestock production depends on forage as animal feed, it is a major source of emissions (Menghistu et al., 2021). The production of ruminant N_2O reaches 98.60% of the total production of N_2O gas from the livestock sector. Management, storage and transportation of ruminant manure can affect the burden of CH_4 and N_2O gas emissions. Feed and season play an important role in the production of nitrous oxide (N_2O) emissions (Cheng *et al*., 2021).

The highest N_2O production from the livestock sub-sector was found in beef cattle at 52.30% and goats at 31.00% from the total livestock sector. Ruminants have a greater potential in producing N_2O gas than poultry. These results are understandable because ruminants have different digestive systems, nutritional needs, feed and how to use the feed for production compared to poultry, so the digestion is different. Poultry manure management system uses a litter system while ruminants generally use a dry lot system, this is one of the causes of low N_2O production in poultry. Processing, storage and transportation of cow feces can emit CH_4 and N_2O. N_2O production and emissions from manure that are managed require nitrite and nitrate in an aerobic environment which is preceded by nitrification with aerobic conditions for the formation of oxidized nitrogen, so that conditions that prevent the reduction of N_2O to produce N_2 include low pH and limited water vapor (Pramono, 2016). The use of different types of litter materials can affect moisture content, ammonia levels, pH, and temperature (Metasari, Septinova, & Wanniatie, 2014).

Table 5 shows that direct N_2O production is higher than indirect. Direct N_2O production reached 62.20% while indirectly it was 37.80%, this shows that mitigation to reduce N_2O load can be applied through feces management technology. Several technologies to reduce GHG production in livestock are improving feed quality, adding feed additives and rumen modification (defaunation) and genetic selection in livestock (Haryuni, 2018; Weber *et a*l., 2021). The average N_2O contribution from the livestock sector in the Regency is higher than the City at 5758g N2O/year and 160g N2O/year from the city (Figure 3). This shows that the development of livestock centers is carried out in the Regency. The development of livestock production centers, especially ruminants, is a challenge because it requires a more in-depth study of the impact of the emerging GHG emission burden. According to (Ouatahar, Bannink, Lanigan, & Amon, 2021) development of ruminant husbandry center areas, it is necessary to consider several factors such as the type of commodity (beef, milk, etc.), housing system (pastoral based or confinement). The type of animal and/or herd size and the management of manure.

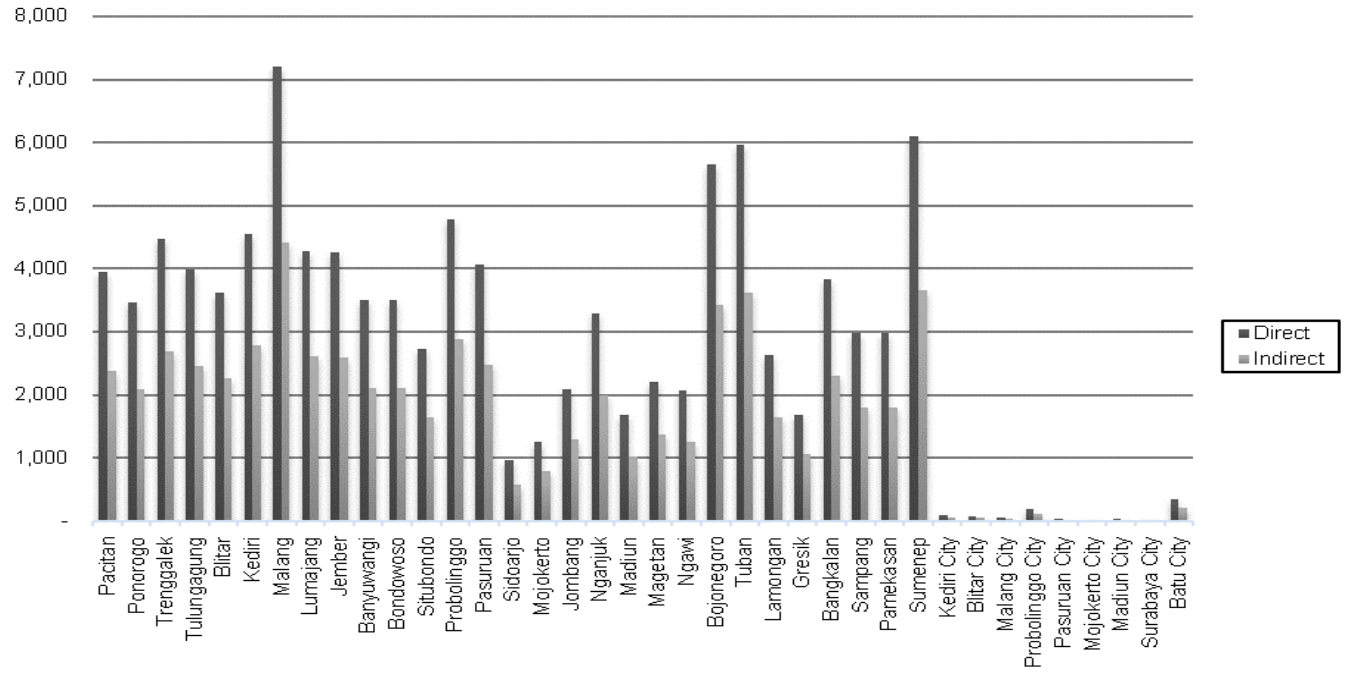

Figure 3. Production of nitrous oxide (N_2O) from the livestock sector in East Java Province

Table 5. Production of nitrous oxide (N_2O) from the livestock sector in East Java Province

Type of livestock.	N_2O production process (g N_2O/year)			Percentage (%)
	Directly	Indirectly	Total	
Beef cattle	55,033.50	33,020.10	88,053.60	52.30
Dairy cows	4,822.40	2,893.40	7,715.80	4.60
Buffalo	246.70	148.00	394.70	0.20
Horse	224.60	134.70	359.30	0.20
Goat	32,587.40	19,552.50	52,139.90	31.00
Sheep	10,835.70	6,501.40	17,337.10	10.30
Pig	715.10	429.10	1,144.20	0.70
Broilers	166.50	666.10	832.60	0.50
Layers	36.70	201.70	238.30	0.10
Free-range chicken	26.30	144.50	170.70	0.10
Duck	5.60	30.60	36.10	0.00
Total	104,700.40	63,722.00	168,422.40	100.00

The data is processed based on data from (BPS-Statistics of Jawa Timur Province, 2021)

The development of the animal husbandry center area is an integration of commodity superiority, ecological/land suitability and socio-economic characteristics as well as support for feed availability based on the potential carrying capacity of the region itself. The Regency area has a wider potential for food and land than the city. Malang Regency is the largest N_2O contributor in East Java Province from the livestock sector reaching 11,605 Gg N_2O/year or comes from direct production of 62.00% and 38.00% indirect which is in line with the highest livestock unit value in East Java Province.

4. CONCLUSION

The greenhouse gas load in East Java Province is CH_4 as much as 221.80 Gg CH_4/year and N_2O as much as 168,424 Gg N_2O/year. Beef cattle have the greatest potential in producing greenhouse gases, including 75.20% CH_4 gas and 52.30% N_2O gas compared to other livestock. The region that contributes the highest greenhouse gases is Malang Regency with 7.50% CH_4 gas and 6.90% N_2O gas to the total livestock sector.

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