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Greenhouse Gas Emissions (GHG) Estimation in the Livestock Sector in Bangka Belitung Province Ssing the IPCC Tier-2 Method

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Abstract. Greenhouse gas (GHG) emissions were a major causal factor of global warming that further impacts climate change. This study aimed to inventory the sources of greenhouse gas emissions from the livestock sector in Bangka Belitung. The GHG emissions in the livestock sector was calculated using the Tier-2 method based on guidance from IPCC 2006. Secondary data were collected from multiple sources, including livestock population, enteric CH_4 emission factors, and the production and management of local livestock manure. The results of the calculation of GHG emissions in Bangka Belitung from 2018-2022 showed a significant increase from 25.54 to 33.32 Gg CO_2 eq, with an accumulation of 139.43 Gg CO_2 eq over five years. Beef cattle became the largest contributor to GHG emissions, with enteric fermentation CH_4 emissions of 104.34 Gg CO_2 eq, accounting for 91.90% of the total CH_4 emissions from enteric fermentation sources and 74.84% of the total GHG emissions in Bangka Belitung. The largest contributor to GHG emissions was 78.62% or 109.62 Gg CO_2 eq from enteric fermentation sources of ruminants, while N_2O emissions from manure management reached 29.10 Gg CO_2 eq, and the smallest CH_4 emissions were 0.70 Gg CO_2 eq, sourced from livestock manure.

Keywords: Dinitro Oxide (N_2O), Greenhouse gas (GHG), Livestock, Methane (CH_4), Tropical

Abstrak. Emisi gas rumah kaca (GRK) merupakan salah satu faktor utama penyebab pemanasan global yang berdampak pada perubahan iklim. Penelitian ini bertujuan untuk menginventarisasi sumber-sumber emisi gas rumah kaca dari sektor peternakan di Bangka Belitung. Metode perhitungan emisi GRK sektor peternakan menggunakan metode Tier-2 berdasarkan panduan dari IPCC 2006. Data diolah menggunakan data sekunder dari berbagai sumber termasuk populasi ternak, faktor emisi CH4 enterik dan produksi dan pengelolaan kotoran ternak lokal. Hasil perhitungan emisi GRK di Bangka Belitung dari tahun 2018-2022 mengalami peningkatan yang cukup signifikan dari 25,54 menjadi 33,32 GgCO2 eq dengan akumulasi selama lima tahun mencapai 139,43 GgCO2 eq. Sapi potong menjadi penyumbang emisi GRK terbesar, dari fermentasi enterik CH4 dengan emisi sebesar 104,34 GgCO2 eq atau 91,90% dari taksiran emisi CH4 yang berasal dari sumber fermentasi enterik dan mencapai 74,84% dari total emisi GRK di Bangka Belitung. Penyumbang emisi GRK terbesar berasal dari sumber fermentasi enterik ternak ruminansia, yaitu sebesar 78,62% atau 109,62 GgCO2 eq, sedangkan emisi N2Odari pengelolaan kotoran mencapai 29,10 GgCO2 eq dan emisi CH4 terkecil berasal dari kotoran ternak sebesar 0,70 GgCO2 eq. Emisi gas rumah kaca (GRK) menjadi faktor utama penyebab terjadinya pemanasan global yang berdampak pada perubahan iklim.

Kata kunci: Gas Rumah Kaca, Peternakan, Dinitro Oxide (N_2O), Metana (CH_4), Tropis

Introduction

Climate change is a major concern around the world as the impacts of climate change increase. Climate change and land have a direct relationship; climate change can be caused by activities on land, and in turn, climate change affects land conditions (Arneth, *et al.* 2019). Climate change is partly caused by greenhouse gas (GHG) emissions generated by many sectors, including agriculture which contributes 7.8& of the total national GHG emissions, and it continues to increase by 1.3% every year (Agus, 2019) and is predicted to grow with the population, thus resulting in an increased demand for food like meat, eggs, and milk.

According to van Dijk et al. (2021), by 2050, it is predicted that the growing population will raise the world's food consumption anywhere between 35% and 56% beyond the current production level (in the past ten years). Concurrently, environmental challenges such as climate change, biodiversity loss, and degradation of soil and freshwater resources are heightening public concerns regarding agricultural practices. Activities of livestock sector that includes livestock rearing, processing of livestock products, livestock waste management, animal feed manufacture, livestock transportation, and exclusive land use for livestock purposes have collectively contributed to a global annual anthropogenic GHG emission rate of 14.5% (Agus, 2019).

Global anthropogenic GHG emissions from the livestock sector in the form of methane (CH4), nitrous oxide (N2O), and carbon dioxide (CO2) have reached 44%, 29%, and 27%, respectively (Dlamini & Dube, 2014; Rojas-Downing et al., 2017). While CH4 emissions are attributed to livestock production activities, CO2 emissions are generated from transportation of livestock products, livestock processing industry activities, and land use for animal husbandry. CH4 gas is emitted by the digestive process (enteric fermentation) of particularly ruminant animals (e.g., cows, goats, sheep, and buffalo), but cows produce a large portion (80-110 Kg/year) of the total methane gas emissions (Dirjen PKH, 2019), while the processing of livestock manure produces N2O gas and CH4 gas from both ruminants and non-ruminants. Meanwhile, Cahyaputri et al. (2021) state that environmental impacts of producing every 1 kg of fresh milk of MJM Cooperative in Cibodas range include the potential global warming, eutrophication, and acidification by 3.16 kg CO2 eq, 0.0119 kg PO43-, and 0.00639 kg SO2 eq, respectively.

It is crucial to generate the estimation of GHG emissions from the livestock sector because livestock sector is more likely to grow with the increasing demand for livestock products for food fulfillment. The livestock sector in Bangka Belitung is underprioritized and contributes insignificantly to the percentage of the national livestock population; for example, total beef cattle population in 2022 was 20.086 heads or 0.1% of the national population, and the total livestock population was <1% of the total national population (Dirjen PKH, 2023). Today, the direction of development in Bangka Belitung has started to shift to tourism and agriculture sectors because its mainstay sector (mining) has started to decline. This is marked by the launch of the 3S program: Sahang, Sapi, Sawah (Pepper, Cow, Ricefield), by the Governor of Bangka Belitung Province and the issuance of the Governor of Bangka Belitung Islands Regulation Number 43 of 2019 concerning the Development of Palm-Cattle Integration in companies that run their production in Bangka Belitung Islands Province. Identification of emission sources and the estimation of GHG emissions from the livestock sector needs to be done to identify the largest contributors to GHG emissions from livestock, and eventually, to carry out corresponding mitigation and adaptation.

Materials and Methods

The method for calculating GHG emissions was based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and updated in the 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2019). In these guidelines, the Tier 1 method is considered the simplest option when complete regional data was unavailable. In this method, GHG emission calculations relied on figures provided in the 2006 IPCC Guideline. However, the use of the Tier 1 method is deemed less suitable for calculations in Indonesia because the default values are not necessarily aligning with the specific livestock conditions in the country because it utilized the average emission factor data for the Asian region.

Table 1. Livestock Population and CH_4 Emission Factor

Livestock Type	Classifications	Population (head) *					FE CH_4 (Kg CH_4/year/ head)**	
		2018	2019	2020	2021	2022	Enteric	Feces
Dairy	Calf	60	66	34	33	23	16.55	0.52
	Growing calf	67	73	38	36	25	35.05	2.51
	Heifer	60	66	34	33	23	51.96	5.52
	Adult	90	99	51	49	34	77.14	12.18
Total Dairy Cows		277	303	157	151	104		
Beef Cattle	Calf	2,519	2,708	2,759	3,281	3,678	18.2	0.78
	Growing Calf	1,380	1,483	1,511	1,797	2,015	27.2	1.62
	Heifer	1,980	2,128	2,168	2,579	2,890	41.78	3.47
	Adult	7,880	8,470	8,629	10,263	11,503	55.89	3.64
Total Beef Cattle		13,760	14,790	15,067	17,920	20,086		
Buffalo	Calf	121	125	95	89	89	20.55	0.75
	Growing Calf	34	35	27	25	25	41.11	3.98
	Young	55	57	43	40	40	61.66	8.97
	Adult	169	175	134	124	125	82.21	15.95
Total Buffalo		378	392	299	278	279		
Goat	Lamb	1,337	1,474	1,827	1,394	1,524	2.29	0.02
	Young Goat	2,456	2,708	3,357	2,561	2,801	2.64	0.02
	Adult	2,851	3,143	3,896	2,973	3,251	3.27	0.03
Total Goat		6,644	7,325	9,080	6,928	7,577		
Sheep	Lamb	13	20	37	12	14	1.31	0.01
	Young Lamb	8	13	25	8	9	4.33	0.05
	Adult	38	58	111	36	42	5.25	0.08
Total Sheep		59	91	172	56	66		
Pig	Piglets	18,365	19,910	12,305	4,756	5,548	0.43	0.0013
	Young	3,947	4,279	2,645	1,022	1,192	1.03	0.01
	Adult	4,908	5,321	3,288	1,271	1,483	1.28	0.01
Total Pig		27,219	29,510	18,238	7,049	8,223		
Horse	Foal	11	11	11	13	14	25.98	0.596
	Young	11	11	11	14	15	53.26	2.507
	Adult	10	10	11	13	14	74.84	4.94
Total Horse		32	32	33	40	42		
Poultry								
Native Chicken (000)		1,340	1,523	1,015	1,109	1,128		0.0031
Broiler (000)		21,562	23,265	11,366	21,159	26,586		0.0039
Layer (000)		324	587	2,455	2,024	1,546		0.0043
Duck (000)		99	109	96	111	111		0.0035
		23,236	25,486	12,723	24,405	29,373		

Description: New Born: 0-1 years, Growth: 1-2 years, Young: 2-4 years, Adults: > 4 years. Source: * Directorate General of Livestock and Animal Health (2022) ** IAARD (2019)

Conversely, the Tier 2 method employs location-specific livestock data, such as a country's local emission factor and livestock population data based on sub-categories and livestock physiology levels. This approach aims to enhance the accuracy and specificity of GHG emission calculations tailored to each country's circumstances. Meanwhile, the Tier 3 method necessitates detailed data, including feed consumption, feed digestibility, metabolic energy, and other variables. Considering the livestock conditions in Indonesia, particularly in Bangka Belitung, employing the Tier 2 method in this study was deemed more appropriate. This involved utilizing specific data such as the livestock population in Bangka Belitung, enteric CH_4 emission factors, local livestock manure data in Indonesia, and activity data for calculating N_2O emissions resulting from manure management.

Livestock Population, Enteric CH4 and Livestock Manure Emission Factor

The data to calculate GHG emissions in Bangka Belitung Islands Province using the Tier 2 method consisted of livestock population data categorized by physiological levels in 2022 and emission factors for each type of livestock, both from enteric fermentation and from livestock manure, as presented in Table 1. These data were sourced from statistical records released by the Directorate General of Livestock and Animal Health in 2022, while the CH_4 emission factors for enteric fermentation and local Indonesian livestock manure management were obtained from The Indonesian Agency for Agricultural Research and Development (IAARD) (Agus, 2019).

N2O Emission Calculation Method

The calculation of GHG emissions from manure processing of each type livestock ion Bangka Belitung Island included CH4 gas and N2O gas (See Table 2) and the reference figure for the N content in manure and the average body weight of each type of livestock is presented in Table 3. The manure management system in Bangka Belitung primarily consisted of several methods: dry stacking, solid storage, spreading manure onto land, and allocation of a small portion for biogas production, particularly from ruminants like cattle, buffalo, sheep, and goats. Pig manure is primarily managed in liquid/slurry form, while poultry manure is divided into two: manure with litter and without litter.

The reference figure for nitrogen (N) content in manure indicates the amount of nitrogen excreted per 1,000 kg body weight. This figure has been established in the IPCC (2006) guidelines for each type of livestock in the Asian region. However, the body weight figures for each type of livestock do not correspond to those issued by the IPCC (2006) for the Asian region, as they are not suitable for application to average body weights of livestock in Indonesia. It is more appropriate to utilize the average body weights of local Indonesian livestock. Data on the average local body weights of Indonesian livestock were obtained from information provided by the Ministry of Environment and Forestry, sourced from the Ministry of Agriculture.

Table.2. N2O emission factors of manure management systems under various management methods

Livestock Manure Management System	Emission Factor N_2O (Kg N_2O-N)*
Dry Stacked	0.02
Kept solid	0.005
Spread on land	0
Liquid/Slurries	0
Biogas	0
Composting	0.01
Poultry manure with litter	0.001
Poultry manure without litter	0.001

Source: Table 10.19 IPCC (2006)

Table 3. Reference values for N content of livestock manure in Asia and average body weight

Livestock Type	Sub Categories	N Excretion* (kg N/1,000kg BW)	Average Livestock Body Weight ** (kg/head)
Dairy Cattle	Calf	0.47	46
	Growing calf	0.47	134.48
	Heifer	0.47	286
	Adult (> 4 Years)	0.47	400
Beef Cattle	Calf	0.34	63
	Growing Calf	0.34	134
	Heifer	0.34	200
	Adult (> 4 Years)	0.34	250
Buffalo	Calf	0.32	100
	Growing Calf	0.32	200
	Young	0.32	300
	Adult (> 4 Years)	0.32	400
Goat	Lamb	1.37	8
	Young Lamb	1.37	20
	Adult	1.37	25
Sheep	Lamb	1.17	8
	Young Lamb	1.17	20
	Adult	1.17	25
Pig	Piglets	0.5	15
	Young	0.5	60
	Adult	0.5	80
Horse	Foal	0.46	200
	Young	0.46	350
	Adult	0.46	500
Poultry Native Chicken		0.82	1.5
Broiler		1.1	1.2
Layer		0.82	2
Duck		0.83	1.5

Source: * Table 10.19 IPCC (2006) ** Directorate of Greenhouse Gas Inventory (2019)

GHG Emissions Calculation Method

The estimation of GHG emissions from the livestock sector is obtained from two factors, namely enteric fermentation of animals and emissions from animal manure, calculated using the Tier 2 method based on the guidance from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and updated in 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories. GHG emissions with the Tier 2 method using the formula, namely:

Enteric CH_4 Emissions: $\mathrm{FE}_{(\mathrm{T})} \times \mathrm{N}_{\mathrm{T}}/10^{6}$ (The formula 10.19 IPCC 2006)

Livestock Manure CH_4 Emissions: $\frac{\mathrm{FE}_{(\mathrm{T})} \times \mathrm{N}_{\mathrm{T}}}{10^{6}}$ (The formula 10.22 IPCC 2006)

N_2O emissions from manure: $[\Sigma_s[\Sigma_t(N_{(T)} \text{ x } Fex_{(h)} \text{ x } BB_{(t)})] \text{ x } FE_{t(s)}] \text{ x } 44/28 \text{ x } 365$ (Modification of equation formula 10.25 IPCC 2006 by Livestock Research and Development Center 2016)

Information:
Enteric CH_4 Emissions : CH_4 Emissions from Enteric Fermentation (Gg CH_4/year); Livestock Manure CH_4 Emissions : CH_4 Emissions from Livestock Manure (Gg CH_4/year); N_2O emissions from Livestock manure : N_2O emissions from livestock manure (kg N_2O/year), can be converted from kg N_2O/year to kg CO_2-eq/year by multiplying by 265 (IPCC 2014); $FE_{(T)}$: Emission factor (CH_4 /head/year); $N_{(T)}$: Population based on type of livestock; $Fex_{(h)}$: N excretion factor per 1,000 kg body weght t in a day (kg N/1,000 kg body weight/day); $BB_{(t)}$: average body weight (kg/head); $FE_{t(s)}$: Emission factor of N_2O from livestock manure t with S system manure management (kg N_2O-N/kg N); 365 : Number of days in a year; 44/28: Molecular weight of N_2O/molecular weight of N_2.

Results and Discussion

Emission of Methane (CH_4) from Enteric Fermentation

Methanogenic bacteria in the rumen create methane (CH_4) as a byproduct of feed fermentation. Danielsson et al. (2017) stated that these methanogenic bacteria live in the rumen fluid and attach to protozoa by working to break down crude protein, glucose and the formation of VFA (acetate) which produces methane gas. According to Herliatika & Widiawati (2021), methane production is influenced by many factors including feed ingredients, livestock nation, age, feed supplementation, and physiological status of livestock. Differences in nutritional quality generated changes in diet degradability, gas production, methane emissions, and VFAs production (Gaviria-Uribe et al., 2020). Figure 1 shows the amount of methane emissions produced by enteric fermentation, especially ruminants in Bangka Belitung.

Figure 1 shows that CH_4 gas emissions from enteric fermentation increased about 37.6% between 2018-2022 due to the increasing livestock population every year, especially beef cattle which increased by almost 100% from 10,577 heads in 2010 to 20,086 heads in 2022. Naturally, the emissions produced by beef cattle, which contributed the largest methane (CH_4) emissions from enteric fermentation, increased from 19.04 Gg CO_2 eq in 2018 to 26,19 Gg CO_2 eq in 2022, making up 91.9% of the total methane (CH_4) emissions produced by all types of livestock.

Although the exact process underlying high or low CH_4 generation in ruminants is yet unknown, one possible explanation can be the variations in passage rate brought on by variations in rumen size (Tapio et al., 2017)

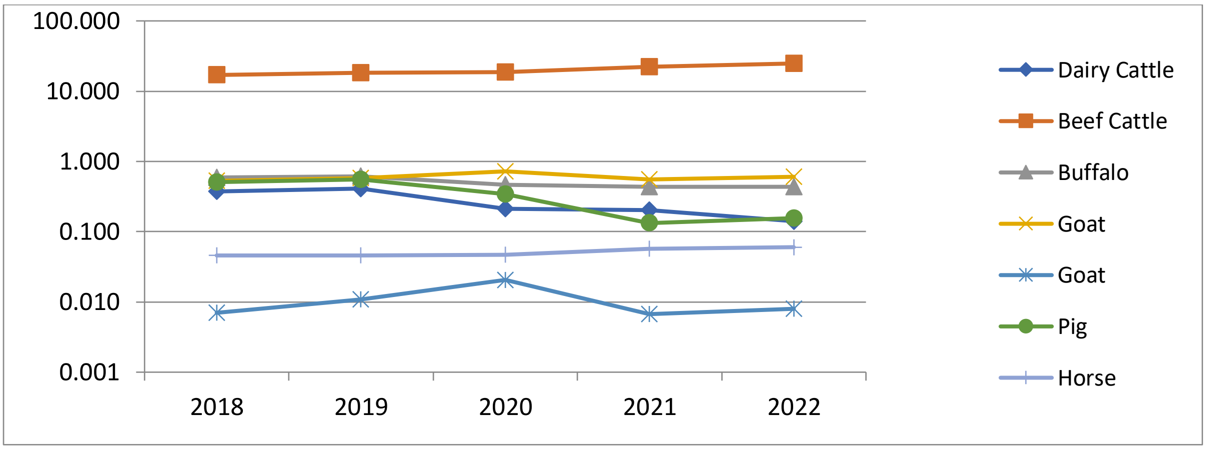

Figure 1. Total CH4 Emissions from enteric fermentation in 2018-2022 (Gg CO2 eq)

Ruminal fermentation process produces (CH_4) and cow ruminal fluid can reach 100-150 liters, which is much greater than 15 liters produced by a goat or a sheep (Nurhayati & Widiawati, 2017). Goats are perceived to be more resistant to climate change than other ruminant species (Pragna et al., 2018) because goats are morphologically flexible species with superior browsing potential that enable them to adapt to the climate change more quickly. CH_4 gas produced by cattle is higher than that of other domestic animals in addition to the highest population in Bangka Belitung.

It is in accordance with the total GHG emissions from the livestock sector in Indonesia that reach 0.97 million tons/year, dominated by emissions from enteric fermentation (99.22%) and only a small portion 0.78% of non-ruminant livestock (Arneth, *et al.,* 2019*).* In 2017, enteric fermentation became the third largest contributor (11%) after rice cultivation (37%) and N_2O emissions from managed soils (29%) to the total agricultural sector GHG emissions that reached 121,689 Gg CO_2 eq (DIRGRK 2019). This is in accordance with a previous study (Collins et al., 2018) that reducing methane gas emissions into the atmosphere can keep the earth temperature from rising 1.5°C. Therefore, efforts to reduce the contribution of methane emissions from the livestock sub-sector can help reduce the increase in the earth temperature. However, even if methane emissions are reduced steeply, it only leads to short-term climate benefits and makes long-term climate stabilization harder due to additional long-lived emissions (Ridoutt et al., 2022).

Methane (CH_4) Emissions from Livestock Manure

CH_4 or methane emissions from livestock manure in Bangka Belitung Province in 2018-2022 continued to increase by about 30% due to the higher population of livestock. The largest contributor to CH_4 emissions from livestock manure is broilers, making up 59% of total CH_4 emissions from livestock manure, followed by beef cattle with 33% of total livestock manure CH_4 emissions. Broilers contribute the most to CH_4 emissions from livestock manure due to their high population compared to other livestock in Bangka Belitung. The broiler population in 2022 was estimated to reach 26.5 million heads, which is a high jump compared to 2018 which only reached 21.5 million heads. There will be more pressure to produce livestock due to increased demand for animal products, which will lead to even higher levels of methane emissions (Skulska et al., 2022). According to Nurhayati & Widiawati (2017), monogastric livestock, especially manure handling, has made a sizeable contribution to the increase of greenhouse gas emissions.

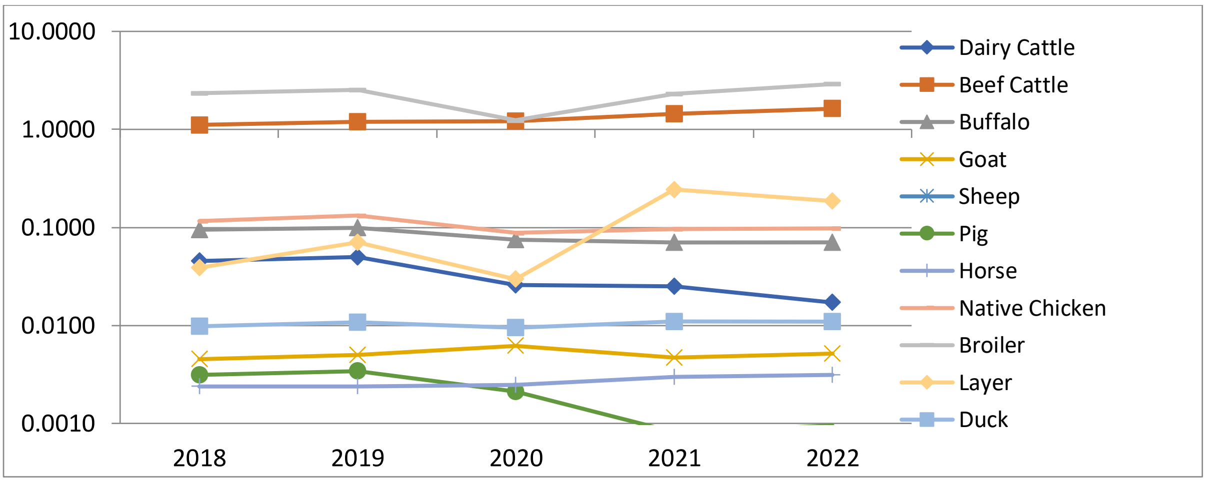

Figure 2. Methane (CH_4) Emissions from livestock manure 2018-2022 (Gg CO2 eq)

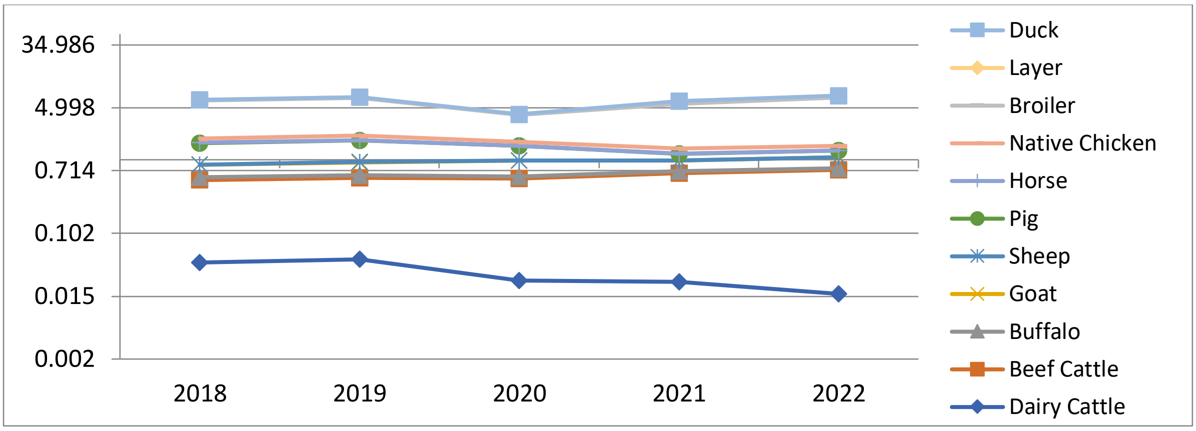

Figure 3. N_2O Emissions from livestock manure management in 2018-2022

Emissions of N_2O from the Management of Livestock Manure in Bangka Belitung

N_2O emissions from manure handling from 2018-2022 in Bangka Belitung (Figure 3) increased considerably high by about 14.5%. Broilers are the largest contributor to N_2O emissions from manure management aspect due to high N in their manure, especially broilers with 1.1 kg N/1000 kg BW manure compared to other types of livestock such as cows and buffaloes, which only express no more than 0.5 kg N/1000 kg BW N in their manure. In ruminants, addition of silage into their feed did not increase methane emissions despite a positive relationship between DMI and methane emissions, which depends on the consumed diet (Arias-Ortiz et al., 2023). Making up a population of 26.5 million, broilers are the highest contributor to N_2O gas emissions which is estimated to reach 5.33 Gg CO_2 eq in 2022. GHG emissions produced by the livestock sector in Bangka Belitung from 2018-2022 have increased from 25.54 to 33.32 Gg CO_2 eq with accumulation over 5 years reaching 139.43 Gg CO_2 eq. Table 4 show that the largest percentage of GHG emission contributors in the livestock sector is from CH_4 emissions with a total of 91,90%. Production of livestock varies depending on factors such as breed, species, grazing conditions & production systems (commercial, small-scale/communal). The management of livestock in different areas of the country affects GHG emissions (Liu & Liu, 2018).

Mitigation Opportunities and Strategies for GHG Emissions from the Livestock Sector in Bangka Belitung

The relatively low GHG emission rate in Bangka Belitung is an opportunity to take early steps to gain maximum reduction of the GHG emission considering the upward trend of livestock sector. Efforts should be taken especially on emissions from enteric fermentation of ruminants because it is the largest source of greenhouse gas emissions in Bangka Belitung. Opportunity to reduce methane gas production through improved maintenance management and genetics reaches 15-30%, while through feed and nutrition modification the opportunity to reduce methane gas production is 2.5-15%, and even smaller if using rumen manipulation (Knapp et al., 2014).

Table 4. Total GHG Emissions of the Livestock Sector in Bangka Belitung

Emission Source	Greenhouse Gas Emissions (Gg CO_2 eq)					Total
	2018	2019	2020	2021	2022	
Enteric Fermentation Emissions	19.04	20.47	20.41	23.50	26.19	109.62
Livestock Manure Emissions	0.14	0.15	0.10	0.15	0.18	0.70
Manure Management Emissions	6.37	3.55	5.87	6.37	6.95	29.10
Total	25.54	24.16	26.38	30.02	33.32	139.43

Source: Processed Data (2023)

Reducing methane production by improving feed quality.

Feed quality, especially feed containing a high crude fiber content, greatly affects the greenhouse gas emissions produced by a livestock farming. It is in line with Foley et al. (2011) that the type and quality of feed offered to cattle greatly affect the CH_4 gas emissions resulting from the enteric fermentation. Efforts to reduce methane gas emissions from enteric fermentation need to be made in Bangka Belitung, one of which is by feeding high BETN and low crude fiber. According to Casañas et al., (2015), consuming 2.777 kg of high-concentrate starch (NFE) would produce of 0.099 g/g methane, which is lower than 0.209 g/g starch consumption of livestock consuming 1.505 kg/day starch (in medium concentrate). Balanced nutrition can also reduce methane gas production, in an in vitro study with levels of C: N consumption (16.43 vs. 15.57 calculated) resulted in a 21.87% reduction in enteric methane gas production at the lower C: N balance (24): N ratio (Romero et al., 2020). An example of feed that increases consumption but does not increase methane gas production in Holstein Friesian cattle is S. peruviana and T. diversifolia silage incorporated into feed (Arias-Ortize et al., 2023). Feed substitution has been reported to reduce the production of methane gas, such as replacing cassava leaf meal with water spinach (Inthapanya et al., 2015), supplementing feed with legumes, and incorporating 0.8% DM indigofera leaf extract into feed to reduce methane production by 19.29% (Suhartati, 2021). Other strategies to help reduce the amount of greenhouse gas emissions from diets based on forages include enhancing the forage quality, harvesting forage in timely manner, using forage species with higher digestibility, using condensed tannin-containing plants, and storing the forages to preserve their digestible nutritional content (Króliczewska et al., 2023).

Reduction of methane production with feed additives.

Rumen manipulation is an effort to mitigate methane gas in ruminants using feed additives or certain feeds that can kill or inhibit the performance of methanogens as methane gas producers in the rumen (Knapp et al., 2014). The use of alternative natural ingredients from plant extracts that have antimicrobial activity like antibiotics has become more attractive to ward off health problems incurred by antibiotics. One of the ingredients in plant extracts is Terpenoids and phenylpropanoids which can inhibit bacterial growth (Griffin *et al*., 1999; Mani-López et al., 2014). In a recent study, extracts from cashew seed shells (CNSL) are also able to reduce methane with antimicrobial activity both in vitro (Watanabe et al., 2010) and in vivo (Narabe et al., 2021). Secondary metabolite compounds such as tannins and saponins are feasinble feed additives to inhibit methane production (Hidayah, 2016). An in vitro research by Tan *et al*., (2011) which added pure condensed tannins from Leucaena leucocephala plant extract at levels of 0, 10, 15, 20, 25 and 30 mg in 500 mg of sample reported that the higher the addition of pure condensed tannins, the lower the production of methane gas, total VFA, protozoa population and methanogenic bacteria, thus significantly decreased methane gas production. Meanwhile, according to Rahmat et al. (2020), adding 5% red dragon fruit skin flour and 2.5% guava leaves flour in beef cattle feed can reduce methane gas, acetic acid concentration, and butyric corrosive but increase propionic acid concentrations.

CH_4 gas is produced by livestock manure that undergoes bacterial fermentation because the manure is stacked in wet conditions for a long time. It is highly recommended to properly manage livestock manure in order by composting the manure properly to reduce CH_4 gas emissions and utilizing manure into biogas because, according to Hariyadi *et al*., (2012), methane gas (CH_4) in biogas itself has a relatively high calorific value (9,000 kcal) and is an environmentally friendly fuel because it can burn completely and does not cause harmful smoke to air quality. In addition, feed quality also affects the proportion of methane gas (CH_4) and carbon dioxide (CO_2) produced by feces because, as reported by research by Albani *et al*., (2018), high fiber content in feed can increase the proportion of methane gas (CH_4) and carbon dioxide (CO_2) produced by feces compared to feed with lower crude fiber.

Conclusions

The livestock sector in the Bangka Belitung Islands region produced greenhouse gas emissions that continued to increase from 25.54 Gg CO_2 eq to 33.32 Gg CO_2 eq between 2018 and 2022 with an accumulated 139.43 Gg CO_2 eq over five years.

The largest contributor to GHG emissions is the enteric fermentation sources of ruminant animals (109.62 Gg CO_2 eq or 78.6% of the total emissions produced), dominated by beef cattle with 104.34 Gg CO2 eq or 91,90% of the total CH_4 emission total from enteric fermentation sources, and 74.84% of total GHG emissions in Bangka Belitung

Calculation of N_2O emissions from manure management showed that poultry, especially broilers, contributed the most of total N_2O emissions from manure management, namely 60%. Efforts to reduce emissions must be made by carrying out adaptation and mitigation after the inventory, by applying quality feed technology and livestock waste processing technology, especially manure.

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