Green house gases emission of livestock sector in East Kalimantan using Tier-1 2019 refinement

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Abstract. The livestock sector is a significant contribution to Greenhouse Gas Emissions (GHG) emissions, especially methane CH₄ and nitrous oxide N₂O. Each livestock species has a specific characteristic of emission. This research aims to determine the contribution of the livestock sector to GHG emissions in 2019 in East Kalimantan and to predict GHG from this sector over the next ten years. This research estimates the amount of GHG emitted by the livestock sector using formulas and constant values from the IPCC method Tier-1 2019 Refinement. The GHG emission is calculated for each gas based on the population of each species obtained from the East Kalimantan Statistical Center. The projection of GHG is calculated based on the population growth for each livestock species. The result shows the highest emission is contributed by Kutai Kartanegara Regency, 24 % and Beef Cattle 155.14 Gg CO₂-e or 79 %. The projection shows GHG emissions increasing to 340.4 Gg CO₂-e in 2030, assuming no significant mitigation effort was conducted.

1. Introduction
Livestock as one part of the agriculture, forestry, and Land Usage sector is dynamic in its development. Population growth and diet changes increase the demand for livestock. During 2015-2018, the livestock population in East Kalimantan is growing by 5 % per year on average [1]. This value is increasing even more when the capital city relocation plan from Jakarta to East Kalimantan occurred.

The growth of the livestock population will increase the emissions of Green House Gases of CH₄ (methane) and N₂O (nitrous oxide), which contribute to global warming[2]. Those two gases are emitted from enteric fermentation and manure management activities[3]. Scientists predict that if there is no severe mitigation effort, the GHG will cause the temperature to rise to 6.5° after 100 years[4]. In 2012, the livestock sector contributed 1.87% of total GHG emissions [5].

Inventorying the GHG is one of the efforts to determine the contribution of each sector. This is important to decide on the amount of GHG emitted to make the mitigation effort appropriately. Previous studies in Java[2] and Central Sulawesi [6,7] inventoried the GHG of livestock by using IPCC 2006 Guidelines. The IPCC released a refinement of this method in 2019. There is some substantial refinement in GHG inventory, especially on the calculation of methane emitted from manure management activities. In the 2006 guidance, the only factor concerned in Tier-1 is EF (Emission Factor) for each type of livestock population and manure management system. Otherwise, the 2019 refinement required other factors, including the typical animal mass, volatile solids, to better estimate each emission
This study aims to determine the contribution of the livestock sector to the GHG emissions in East Kalimantan in 2019 and projection in the year 2030 by using the 2019 refinement of IPCC 2006 Guidelines.

2. Research methods

The GHG emissions from livestock were estimated using the 2006 IPCC Guidelines for National GHG Inventories with refinement 2019[8]. The first step is collecting livestock population data from an official government body. Then, the GHG was calculated by using the collected data, formula, and constants according to the guidelines. The projection of livestock population was used to predict the GHG emission in 2030. The flowchart of the research is shown in figure 1.

2.1. Livestock population of East Kalimantan

Livestock population data obtained from East Kalimantan Statistical Center for the year 2019 as shown in table 1.

| City/Regency     | Dairy cattle | Beef cattle | Buffalo | Horse | Goat | Sheep | Swine | Native chicken | Layer chicken | Broiler | Duck |
|------------------|--------------|-------------|---------|-------|------|-------|-------|----------------|---------------|---------|------|
| Paser            | 0            | 22444       | 851     | 0     | 10691| 110   | 5045  | 1666052        | 0             | 2954583 | 43592 |
| Kutai Barat      | 0            | 7808        | 1014    | 0     | 7943 | 0     | 36899 | 216616         | 0             | 3337820 | 20834 |
| Kutai Kartanegara| 0            | 29463       | 2466    | 0     | 10678| 0     | 3660  | 839859         | 209187        | 11086273 | 79656 |
| Kutai Timur      | 69           | 17406       | 221     | 39    | 8698 | 0     | 8614  | 330459         | 18689         | 2653146  | 43671 |
| Berau            | 0            | 15240       | 713     | 0     | 15713| 0     | 3329  | 281106         | 194423        | 2976904  | 46854 |
| Penajam Paser Utara | 18        | 17574       | 600     | 0     | 4738 | 0     | 891   | 418682         | 82601         | 2055308  | 22775 |
| Mahakam Ulu      | 0            | 579         | 0       | 0     | 269  | 0     | 4267  | 41020          | 0             | 187587   | 857  |
| Balikpapan       | 0            | 1634        | 38      | 6     | 1316 | 125   | 832   | 78287          | 368435        | 18703299 | 15822 |
| Samarinda        | 9            | 6194        | 84      | 18    | 8098 | 105   | 11947 | 737042         | 282015        | 18578683 | 33554 |
| Bontang          | 16           | 1333        | 0       | 6     | 1210 | 97    | 4094  | 109839         | 0             | 6782515  | 3321 |

Figure 1. Research methodology flowchart.
2.2. GHG emission

There are three types of GHG directly emitted by livestock activity: methane emission from enteric fermentation, methane emissions from manure management, and N\textsubscript{2}O from manure management. To calculate those GHG emissions, the formula provided by IPCC is used. This study used procedures from the 2019 refinement of the 2006 IPCC Guidelines\cite{8}.

GHG emission value for livestock is calculated as the total of CH\textsubscript{4} (methane) emissions from enteric fermentation and manure management activities, emitting N\textsubscript{2}O(nitrous oxide). Annual net CO\textsubscript{2} emissions from livestock are assumed to be zero – the CO\textsubscript{2} photosynthesized by plants is returned to the atmosphere as respired CO\textsubscript{2}. Therefore CO\textsubscript{2} emissions from livestock are not estimated\cite{9}.

CH\textsubscript{4} emitted from enteric fermentation for each livestock category was calculated by equations (1) and (2). The EF (emission factor) used in the calculation is based on the default value for Asia Region.

\[
E_T = \sum EF_T \cdot \left( \frac{N_{CH4}}{10^3} \right) 
\]  
(1)

\[
\text{Total CH}_4\text{Enteric} = \sum E_{t,p}
\]  
(2)

In equation (1), \(E_T\) is the methane emissions from Enteric Fermentation in animal category T (Gg CH\textsubscript{4} yr\textsuperscript{-1}) \(EF_T\) is the emission factor for the defined livestock population T (kg CH\textsubscript{4} head\textsuperscript{-1} yr\textsuperscript{-1}), and \(N_T\) is the number of head of livestock species/category T in the country. In equation (2), \(E_{t,p}\) is the emission for the \(t^\text{th}\) livestock categories and subcategories.

CH\textsubscript{4} emitted by manure management system was calculated by using equations (3) and (4).

\[
\text{CH}_4\text{mm} = \sum_{T,S} \left[ N_T \cdot VS_T \cdot AWMS_{(T, S)} \cdot EF_{(T, S)} \cdot 10^{-3} \right] 
\]  
(3)

\[
VS_T = \left( \frac{V\text{Rate}_{(T)} \cdot TAM_T}{1000} \right) \cdot 365 
\]  
(4)

In equation (3) and (4), \(N_T\) is the number of head of livestock species/category T, \(VS_T\) is the annual average Volatile Solids excretion per head of species/category T (kg VS animal\textsuperscript{-1} yr\textsuperscript{-1}), \(AWMS_{(T, S)}\) is the fraction of total annual VS for each livestock species/category T that is managed in manure management system S (dimensionless), \(EF_{(T, S)}\) is emission factor for direct CH\textsubscript{4} emissions from manure management system S, by animal species/category T, in manure management system S (g CH\textsubscript{4} kg VS\textsuperscript{-1}), \(V\text{Rate}_{(T)}\) is default VS excretion rate (kg VS (1000 kg animal mass)\textsuperscript{-1} day\textsuperscript{-1}), TAM\textsubscript{T} is typical animal mass for livestock category T (kg animal).

Nitrous oxide directly emitted in manure management activities is calculated using equations (5) and (6).

\[
N_2O_{direct(mm)} = \sum_{T,S} \left[ \sum T \cdot N_{CH4} \cdot AWMS_{(T, S)} \cdot EF_{(T, S)} \cdot 44 \right] / 28 
\]  
(5)

\[
N_{\text{ex}(T)} = \left( \frac{N_{\text{rate}(T)} \cdot TAM_T}{365} \right) / 1000 
\]  
(6)

In equation (5) and (6), \(N_2O_{direct(mm)}\) is direct N\textsubscript{2}O emissions from manure management (kg N\textsubscript{2}O yr\textsuperscript{-1}), \(N_T\) is the number of head of livestock species/category T, \(N_{\text{ex}(T)}\) is the annual average N excretion per head of species/category T (kg N animal\textsuperscript{-1} yr\textsuperscript{-1}), \(N_{\text{cdg s}}\) is annual nitrogen input via co-digestate (kg N yr\textsuperscript{-1}), \(AWMS_{(T, S)}\) is a fraction of total yearly nitrogen excretion for each livestock species/category T that is managed in manure management system S in (dimensionless), \(EF_{s,T}\) is emission factor for direct N\textsubscript{2}O emissions from manure management system S (kg N\textsubscript{2}O-N/kg N), 44 / 284 = conversion of N\textsubscript{2}O-
N\textsubscript{(mm)} emissions to N\textsubscript{2}O\textsubscript{(mm)} emissions. The indirect emission of N\textsubscript{2}O in the manure management system is excluded in this study.

2.3. GHG emission projection

GHG emission projection on 2030 was calculated based on the projection of the livestock population. The livestock population was extrapolated from livestock population data in the years 2015 to 2019. The suggestion for mitigation efforts to decrease the GHG emissions from

3. Results and discussion

The value of GHG emitted by the livestock sector by category and city/regency is shown in tables 2-5. Methane emission by enteric fermentation does not occur in poultry categories. The highest CH\textsubscript{4} emissions from enteric fermentation were contributed by Kutai Kartanegara regency, with beef cattle contribute the most with a total emission of 38.54 CO\textsubscript{2}-e. The mitigation that needs to be done is improving the feed composition. 40% of concentrate in feed significantly decreased CH\textsubscript{4} emission from enteric fermentation[10]. The additional meal containing silage, ammoniated straw, and UMMB (mineral) could reduce 0.1 mg CO\textsubscript{2}/gr manure per day, 0.003 mg CH\textsubscript{4}/gr manure per day, and 0.161 microgram N\textsubscript{2}O/gr manure per day compared to no addition in feed[11]. This innovation has not entirely been adopted in east Kalimantan.

| City/Regency     | Dairy cattle | Beef cattle | Buffalo | Horse | Goat | Sheep | Swine | Native chicken | Layer chicken | Broiler | Duck |
|------------------|--------------|-------------|---------|-------|------|-------|-------|----------------|---------------|---------|------|
| Paser            | -            | 25.45       | 1.36    | -     | 1.12 | 0.01  | 0.11  | -              | -             | -       | -    |
| Kutai Barat      | -            | 8.85        | 1.62    | -     | 0.83 | -     | 0.77  | -              | -             | -       | -    |
| Kutai Kartanegara| -            | 33.41       | 3.94    | -     | 1.12 | -     | 0.08  | -              | -             | -       | -    |
| Kutai Timur      | 0.11         | 19.74       | 0.35    | 0.01  | 0.91 | -     | 0.18  | -              | -             | -       | -    |
| Berau            | -            | 17.28       | 1.14    | -     | 1.65 | -     | 0.07  | -              | -             | -       | -    |
| Penajam Paser Utar| 0.03        | 19.93       | 0.96    | -     | 0.50 | -     | 0.02  | -              | -             | -       | -    |
| Mahakam Ulu      | -            | 0.66        | -       | -     | 0.03 | -     | 0.09  | -              | -             | -       | -    |
| Balikpapan       | -            | 1.85        | 0.06    | 0.00  | 0.14 | 0.01  | 0.02  | -              | -             | -       | -    |
| Samarinda        | 0.01         | 7.02        | 0.13    | 0.01  | 0.85 | 0.01  | 0.25  | -              | -             | -       | -    |
| Bontang          | 0.03         | 1.51        | -       | 0.00  | 0.13 | 0.01  | 0.09  | -              | -             | -       | -    |
| East Kalimantan  | 0.18         | -           | -       | 9.56  | 0.03 | 7.28  | 0.05  | 1.67           | -             | -       | -    |

CH\textsubscript{4} emission for manure management activity is shown in table 3. The methane emissions indicate 0.00 on beef cattle for every city/regency. It does not mean that beef cattle do not emit methane but shows that the emission is far less than the methane emitted by broilers in the region. According to [12], the methane emission from manure management is only 4% of the total methane emitted by ruminants. Manure management's methane emissions are shown the highest for broiler chicken due to its most significant population. The government encourages the use of biogas installations for ruminants, as shown in figure 2. The usage of biogas digester can decrease the CO\textsubscript{2} emission by 96 % of all biogas converted to fuel[13].
According to the default value for the Asia region in the IPCC guidance, the portion of the manure management system of beef cattle fits with the condition in East Kalimantan, which is dominated by pastures and paddocks around 38%. N₂O emissions associated with the manure deposited on agricultural soils and pasture range, padock systems are inventoried under emissions from managed soils, therefore excluded in this study.

Table 3. Emissions from CH₄ manure management.

| City/Regency       | Dairy cattle | Beef Cattle | Buffalo | Horse | Goat | Sheep | Swine | Native Chicken | Layer Chicken | Broiler | Duck |
|-------------------|--------------|-------------|---------|-------|------|-------|-------|----------------|---------------|---------|------|
| Paser             | -            | 0.00        | 0.00    | -     | 0.00 | 0.00  | 0.01  | 0.05           | -             | 0.15    | 0.00 |
| Kutai Barat       | -            | 0.00        | 0.00    | -     | 0.00 | 0.00  | 0.04  | 0.01           | -             | 0.17    | 0.00 |
| Kutai Kartanegara | -            | 0.00        | 0.00    | -     | 0.00 | 0.00  | 0.00  | 0.03           | 0.01          | 0.56    | 0.00 |
| Kutai Timur       | 0.00         | 0.00        | 0.00    | 0.00  | -   | 0.01  | 0.01  | 0.00           | 0.13          | 0.00    |      |
| Berau             | -            | 0.00        | 0.00    | -     | 0.00 | 0.00  | 0.00  | 0.01           | 0.01          | 0.15    | 0.00 |
| Penajam Paser Utara | 0.00       | 0.00        | 0.00    | -     | 0.00 | 0.00  | 0.00  | 0.01           | 0.00          | 0.10    | 0.00 |
| MahakamUlu        | -            | 0.00        | -       | -     | 0.00 | 0.00  | 0.00  | -              | 0.01          | -       | 0.00 |
| Balikpapan        | -            | 0.00        | 0.00    | 0.00  | 0.00 | 0.00  | 0.00  | 0.00           | 0.02          | 0.94    | 0.00 |
| Samarinda         | 0.00         | 0.00        | 0.00    | 0.00  | 0.00 | 0.00  | 0.01  | 0.02           | 0.01          | 0.94    | 0.00 |
| Bontang           | 0.00         | 0.00        | -       | 0.00  | 0.00 | 0.00  | 0.00  | -              | 0.34          | -       | 0.00 |
| East Kalimantan   | 0.00         | 0.01        | 0.00    | 0.00  | 0.00 | 0.00  | 0.09  | 0.15           | 0.06          | 3.49    | 0.01 |

Table 4. Emissions from N₂O direct Manure Management.

| City/Regency       | Dairy cattle | Beef Cattle | Buffalo | Horse | Goat | Sheep | Swine | Native Chicken | Layer Chicken | Broiler | Duck |
|-------------------|--------------|-------------|---------|-------|------|-------|-------|----------------|---------------|---------|------|
| Paser             | -            | 3.64        | 0.28    | -     | 0.07 | 0.00  | 0.18  | 0.11           | -             | 0.54    | 0.00 |
| Kutai Barat       | -            | 1.27        | 0.34    | -     | 0.05 | 0.00  | 1.31  | 0.01           | -             | 0.61    | 0.00 |
| Kutai Kartanegara | -            | 4.78        | 0.82    | -     | 0.07 | 0.00  | 0.13  | 0.06           | 0.01          | 2.01    | 0.01 |
| Kutai Timur       | 0.02         | 2.83        | 0.07    | 0.00  | 0.06 | -     | 0.31  | 0.02           | 0.00          | 0.48    | 0.00 |
| Berau             | -            | 2.47        | 0.24    | -     | 0.11 | -     | 0.12  | 0.02           | 0.01          | 0.54    | 0.01 |
| Penajam Paser Utara | 0.00       | 2.85        | 0.20    | -     | 0.03 | -     | 0.03  | 0.03           | 0.00          | 0.37    | 0.00 |
| Mahakam Ulu       | -            | 0.09        | -       | -     | 0.00 | -     | 0.15  | 0.00           | -             | 0.03    | 0.00 |
| Balikpapan        | -            | 0.27        | 0.01    | 0.00  | 0.01 | 0.00  | 0.03  | 0.01           | 0.02          | 3.39    | 0.00 |
| Samarinda         | 0.00         | 1.01        | 0.03    | 0.00  | 0.06 | 0.00  | 0.43  | 0.05           | 0.01          | 3.37    | 0.00 |
| Bontang           | 0.00         | 0.22        | -       | 0.00  | 0.01 | 0.00  | 0.15  | 0.01           | -             | 1.23    | 0.00 |
| East Kalimantan   | 0.03         | 19.42       | 1.99    | 0.01  | 0.48 | 0.00  | 2.83  | 0.31           | 0.05          | 12.58   | 0.04 |

Table 5. Total emissions from the livestock sector.

| City/Regency       | Dairy cattle | Beef Cattle | Buffalo | Horse | Goat | Sheep | Swine | Native Chicken | Layer Chicken | Broiler | Duck |
|-------------------|--------------|-------------|---------|-------|------|-------|-------|----------------|---------------|---------|------|
| Paser             | -            | 29.10       | 1.64    | -     | 1.20 | 0.01  | 0.29  | 0.16           | -             | 0.69    | 0.01 |
| Kutai Barat       | -            | 10.12       | 1.96    | -     | 0.89 | -     | 2.13  | 0.02           | -             | 0.77    | 0.00 |
| Kutai Kartanegara | -            | 38.19       | 4.76    | -     | 1.19 | -     | 0.21  | 0.08           | 0.02          | 2.57    | 0.01 |
Kutai Timur  0.13 22.56 0.43 0.02 0.97 - 0.50 0.03 0.00 0.62 0.01
Berau   - 19.76 1.38 - 1.76 - 0.19 0.03 0.02 0.69 0.01
Penajam Paser Utara  0.03 22.78 1.16 - 0.53 - 0.05 0.04 0.01 0.48 0.00
Mahakam Ulu - 0.75 - - 0.03 - 0.25 0.00 - 0.04 0.00
Balikpapan - 2.12 0.07 - 0.00 0.15 0.01 0.05 0.01 0.04 4.34 0.00
Samarinda  0.02 8.03 0.16 0.01 0.91 0.01 0.69 0.07 0.03 4.31 0.00
Bontang   0.03 1.73 - 0.00 0.14 0.01 0.24 0.01 - 1.57 0.00
East Kalimantan  0.21 155.14 11.55 0.03 7.76 0.05 4.59 0.46 0.11 16.07 0.04

Figure 2. The number of biogas facility installed by the province government.

The projection (table 6) shows that beef cattle still contribute the highest GHG emission. This projection assumes there is no significant improvement in the mitigation effort. The suggestion to decrease GHG emission from enteric fermentation is by improving the feed composition. The addition of tannin and saponin, unsaturated long-chain fatty acids, ferric ions, and sulfate ions and the use of the preparation of acetogenic bacteria can decrease the methane emission[12,14]. Lerak extract at level 4% to Gamal silage can reduce methane emission from enteric fermentation [15].

Table 6. The projection of livestock population and GHG Emissions.

| Population (Head) | Dairy cattle | Beef Cattle (x1000) | Buffalo (x1000) | Horse (x1000) | Goat (x1000) | Sheep (x1000) | Swine (x1000) | Native Chicken (x1000) | Layer Chicken (x1000) | Broiler (x1000) | Duck (x1000) |
|------------------|--------------|---------------------|-----------------|-------------|-------------|-------------|-------------|------------------------|------------------------|---------------|-------------|
| Population projection 2030 | 138 | 216.5 | 4.4 | 71 | 103 | 296 | 100.8 | 4651.3 | 1109.4 | 14180.6 | 73.1 |
| emission projection (Gg CO2-e/Year) | 0.26 | 280.67 | 8.49 | 0.03 | 11.55 | 0.03 | 5.82 | 0.46 | 0.11 | 32.89 | 0.11 |

4. Conclusion

East Kalimantan Province contributed GHG emissions of 196,02 Gg CO2-e/year from the livestock sector. Beef cattle dominated the emission by 79% of the total emissions. The regency of Kutai Kartanegara, who had the most beef cattle in the region, contributed the highest livestock sector GHG Emission of 38,19 Gg CO2-e/year or 24% of total livestock GHG emission.

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