Study of Methane Gas Emissions from Agricultural Activities and its Coping Strategies in Bedog Sub-watershed

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Abstract. Food production through agricultural activities needs to be intensified to meet food demand. Agricultural activities can also emit methane (CH4) emissions and thus contribute to climate change. Assessing agricultural activities can be done by measuring CH4 emissions, which we implemented in the Bedog Sub-watershed. The purposes of this paper are (1) to calculate CH4 emissions from agricultural activities, and (2) to propose strategies to deal with CH4 emissions. Emissions calculation was done by using IPCC 2006 framework. The mapping results of agricultural area in 2015 and 2020, which consists of rice field area and rice variety, were used in this study, along with Tier 1 IPCC factor. The results of this study show (1) the value of CH4 emissions from rice fields in 2015 was 0.73 Gg CH4/year and decreased by 0.64 Gg CH4/year in 2020. Meanwhile, methane emissions from a small livestock husbandry were 0.35 Gg CH4/year in 2020. This decrease was caused by land-use change in the Bedog Sub-watershed. (2) Theoretically, adaptation and mitigation strategies that can be implemented in the Bedog sub-watershed are the technology for water management and farming, capacity building, determining the appropriate variety and feed, fertilizing, regulating water regimes, method of tillage, and processing biogas.

Keywords: Agricultural Emissions, Methane Gas, Climate Change, Adaptation and Mitigation, Bedog Sub-watershed

1. Introduction

The agricultural sector is critical to the provision of food to the community. The agricultural sector is unquestionably important in a country’s food supply. Indonesia, as an agricultural country, has a diverse agricultural sector. Agricultural activities produce emissions that contribute to climate change and can lead to global warming. The agricultural sector accounts for approximately 14% of total global emissions. The impacts that high-emission production can have among others are changes in rain patterns and increases in air temperature. This will undoubtedly have an impact on the agricultural sector. As a result, it is important to overcome and implement mitigation and adaptation measures [1].

Along with population growth, food demand will increase in the future. Higher food demand may result in increased GHG emissions. Therefore, GHG emissions from the agricultural sectors must be considered. The agricultural sectors included in this paper are rice fields and animal farming. Small-scale mitigation begins with the preparation of a GHG inventory and calculation, followed by the provision of information on the status of GHG emissions to a responsible agency or government. The inventory can be considered the first step towards developing a comprehensive strategy for reducing emissions [2].
The Paris Agreement was signed in 2015 to control and address the issue of global warming. This is a global agreement, involving both developed and developing countries. Countries that have signed the Paris Agreement are obligated to contribute to the reduction of greenhouse gas (GHG) emissions. The Paris Agreement also requires each country to provide a national inventory of GHG emissions for reporting as part of the process of achieving the long-term goal of reducing global warming [3]. On a national scale, Indonesia, in Presidential Regulation no. 61 of 2011 Article 2, plans an action to reduce greenhouse gas emissions from the agricultural sector, with a target of 0.008 gigatons of GHG emissions by 2020. Following the GHG emission reduction plan, an emission inventory calculation was performed using appropriate and internationally recognized methods. An emission inventory must be completed as a basis for determining local government policies to determine emission thresholds, which will be taken into account when determining future policies. In addition, the inventory of emission production needs to be known in order for the government to formulate the right strategy in reducing and dealing with emissions that occur so that they do not increase.

One type of GHG emission is methane (CH₄). In general, CH₄ is derived from the soil through the decomposition of organic compounds by microbes under strict anaerobic conditions. Agriculture, particularly rice fields, which contribute to higher concentrations of methane emissions, and animal farming are two of the largest contributors to methane emissions. Methane emissions in rice fields are influenced by the water management regime, the amount of organic matter, and the use of organic fertilizers [4]. Methane emissions are the most significant source of pollution in the agricultural and livestock sectors [5]. This study focuses on calculating methane emissions, which are the most significant contributors to emissions in agriculture and animal farming. The purposes of this study are to calculate CH₄ emissions from agricultural activities and to propose strategies to deal with CH₄ emissions. The strategies in this paper would be in terms of climate change adaptation and mitigation plans.

2. Methods

To estimate methane emissions, this study used the IPCC 2006 Standard [6]. The area of the study was limited to the Bedog Sub-watershed. The data used were agricultural data, specifically the use of rice fields in the Bedog Sub-watershed in 2015 and 2020, obtained through mapping using Google Earth images, agricultural commodities obtained through literature studies and interviews with related agencies, and emission factor information obtained using level 1 factor of the 2006 IPCC. Other data used were the number and types of livestock per sub-district in the Bedog sub-watershed, as well as the emission factor values from the 2006 IPCC.

The methane emission factor from rice cultivation in paddy fields was calculated using the following formula:

\[ EF_i = (E_{Fc} \times SF_w \times SF_p \times SF_o \times SF_s, r) \]  

where:

- \( E_{Fi} \) = Corrected daily emission factor for a certain harvested area, kg CH₄/day
- \( E_{Fc} \) = Baseline emission factor for rice field (Indonesia's local emission factor for rice cultivation in paddy fields is 1.61 kg CH₄/ha.day)
- \( SF_w \) = Scale factor that explains differences in water regimes during the cultivation period. This scale factor depends on the type of paddy field and its irrigation system. The higher the frequency of flooding, the higher the emission factor. This is because the water regime affects the anaerobic process in paddy fields. The correction factor used for the water regime was 1 because the rice fields were irrigated with continuous inundation during planting.
- \( SF_p \) = Scale factor that describes the water regime before cultivation. The water regime before cultivation is the length of water stagnation before the rice is planted in the fields. The longer the land is waterlogged before planting, the more it will be in an anaerobic condition so that the factor is even greater. Because the existing conditions indicated that it was not flooded before planting, the SFp value used was 1.
- SFo = Scale factor that describes the type and amount of organic matter used in paddy fields during the cultivation period. The scale factor for organic matter data is as follows:

\[ S_{fo} = (1 + ROAi + CFOAi)^{0.59} \]  

Where:
- SFo = The scale factor for the type of organic matter used.
- ROAi = Amount of organic matter used in dry weight/fresh weight (tons/ha). The average value used was 2.
- CFOAi = The conversion factor of organic matter. Conversion factor for the use of various types of organic materials using the IPCC (2006) factor. Because the condition of the organic material used was compost, a value of 0.05 was used.

- SFs = The scale factor of the soil types. Types of soil found in the Bedog sub-watershed include alfisol soil, which has an SFs value of 1.93, Andisol soil with an SFs value of 1.02, Entisol soil with an SFs type value of 1.02, Histosol soil with an SFs value of 2.39, Inceptisol soil with an SFs value 1.12, Oxisol soil with a value of 0.229, Ultisol soil with an SFs value of 0.29, and Vertisol soil, which has a value of 1.06.

- SFr = Scale factor for the rice variety. The average variety of rice used was the Ciherang variety. This calculation assumed that only one variety was planted in the rice fields. The value of the scale factor for the Ciherang variety is 0.57

To calculate the annual \( CH_4 \) emission from paddy field cultivation, the following formula was used:

\[ CH_4_{Rice} = \sum_{ijk} (E_{Fi} x T_{ijk} x A_{ijk} x 10^{-6}) \]  

**keterangan:**
- \( CH_4_{Rice} \) = Methane emissions from lowland rice cultivation, (Gg CH4/year)
- \( ijk \) = representing different ecosystems I: water regime, j: type and amount of return of soil organic matter, and k: other conditions under which \( CH_4 \) emissions from lowland rice can vary.
- \( E_{Fi} \) = Daily emission factor using EFI value
- \( T_{ijk} \) = Planting time required in one year (Days)
- \( A_{ijk} \) = Planted Area (Hectares)

There are several stages to the calculation process of the enteric fermentation method and manure management. Differences in emission factors between livestock can also cause different emission values.

The following formula can be used to calculate enteric fermentation.

Enteric Fermentation Emissions = \( EF(t) x N(t) x 10^{-6} \)  

Enteric fermentation emissions = methane emissions (Gg CH4/year)
- \( EF(t) \) = methane emission factor for certain livestock species
- \( N(t) \) = number of certain livestock population

Methane emissions from waste management are calculated using the following formula

Manure Management Emissions = \( EF(t) x N(t) x 10^{-6} \)  

Manure management emissions = methane emissions (Gg CH4/year)
- \( EF(t) \) = methane emission factor for certain livestock species
- \( N(t) \) = number of certain livestock population

Determination of mitigation and adaptation plans was done through literature studies and interviews with relevant policyholders in the Bedog Sub-watershed. The literature study focused on the issue of methane emissions from agricultural land. Discussion was used to see the form of policies that have been implemented, as well as plans to be implemented. This study provides mitigation plans that are feasible to implement.

This study was conducted in the Bedog sub-watershed. Regionally Bedog sub-watershed is part of the Merapi Volcano Geomorphological systems. The processes that occur in the Bedog Sub-
watershed are derived from the volcanism process, so that the materials found are mostly volcanic. The dominant process governing the middle of the sub-watershed is the fluvial process originating from the Merapi Volcano, resulting in an interconnected system in the Bedog sub-watershed. In terms of land use, the conditions in the Bedog Sub-watershed have been heavily affected by urban activities, causing numerous land-use conversions, particularly from agricultural to urban areas.
3. Results and Discussions

3.1 Methane Emissions from Bedog Sub-watershed in Year 2015 and 2020.

Table 1. Methane Emissions from agriculture activities in Bedog Sub-watershed

| Sub-district | Rice field | Animal Farm |
|--------------|------------|-------------|
|              | Methane Emissions (Gg CH$_4$/year) |             |
|              | 2015 | 2020 | 2020 |
| Turi         | 0.10 | 0.04 | 0.04 |
| Sleman       | 0.16 | 0.14 | 0.04 |
| Mlati        | 0.14 | 0.13 | 0.03 |
| Godean       | 0.01 | 0.01 | 0.01 |
| Gamping      | 0.12 | 0.10 | 0.06 |
| Kasihan      | 0.11 | 0.12 | 0.05 |
| Sewon        | 0.02 | 0.02 | 0.01 |
| Pajangan     | 0.04 | 0.04 | 0.08 |
| Bantul       | 0.01 | 0.01 | 0.01 |
| Pandak       | 0.02 | 0.02 | 0.02 |
| Total        | 0.73 | 0.64 | 0.35 |

Agricultural emissions from the Bedog Sub-watershed in 2015 were 0.73 Gg CH$_4$/year and 0.64 Gg CH$_4$/year in 2020. Changes in rice fields area from 2015 to 2020 caused differences in the calculation results. The total emissions produced have decreased along with a decrease in rice fields area in 2020. The values shown in 2015 and 2020 tend to fall. This decrease was caused by a reduction in the total area of rice fields, with the processing assumption remaining unchanged. This implies that, when reducing the number of emission values, it is necessary to consider the existence of various management functions [7]. This management consideration can be done through the use of technological developments or by assessing it economically.

Fertilizer is an important component of sustainable agricultural activities. In agriculture, organic fertilizers or urea fertilizers are used as a substitute for livestock manure. The use of urea fertilizer in agriculture can result in the release of CO$_2$ that has been bound during the fertilizer manufacturing process. The calculation of emissions from the use of urea fertilizer that produces CO$_2$ needs to be calculated because the CO$_2$ fixation process from the atmosphere during the manufacture of urea fertilizer is considered in the industrial sector [8].

Methane emissions from livestock activities include emissions from enteric fermentation and sewage treatment. The calculation of livestock emissions was carried out in 2020 by weighing the number of livestock by the area that enters the watershed. The value of livestock emissions in 2020 was 0.35 Gg CH$_4$/year. The high and low values of enteric emissions and livestock manure processing are caused by several factors, including the type of livestock, the content of organic matter in the feed, the content of fiber components, as well as the value of the degradability of fiber components by rumen microbes and rumen environmental conditions. Different animal species contribute to varying emissions because of their effectiveness in digesting feed. Cattle fed with higher fiber feeds have higher methane gas production as well. Then the lower ambient temperature will also contribute to higher emissions. Another factor is that the amount and types of supplements given to livestock will contribute to varying emissions. The age of the livestock also plays a role in methane emissions; the older the livestock, the greater the contribution of methane emissions. The amount of emissions is also affected by physiological factors [9].
Methane emissions in agriculture and animal husbandry have a wide range of values. Overall, the total value of agricultural emissions in the Bedog sub-watershed was 0.64 Gg CH$_4$/year in 2020. The emission value in agriculture was higher than the emission value in the livestock sector, which was 0.35 Gg CH$_4$/year. Total livestock emissions were the sums of emissions from enteric fermentation and manure management. In some sub-districts, the emission value in the livestock sector was higher than in the agricultural sector, such as in the Turi sub-district, the Pajangan sub-district, and the values were relatively the same in the Bantul and Pandak sub-districts. The value difference was quite large in Pajangan District because the number of livestock in Pajangan District was the greatest when compared to other sub-districts in Bedog Sub-watershed.

The value of methane emissions in the Bedog Sub-watershed appears to have accumulated in the middle part of the watershed. This is evident from the fact that the emission class is quite high. The emission class division is based on a weighted division of the obtained results, and three classes were generated: low (< 0.04 Gg CH$_4$/year), medium (0.04 – 0.13 Gg CH$_4$/year), and high (> 0.13 Gg CH$_4$/year). Agricultural land use is more common in the middle and bottom parts of the watershed. The larger area indicates the larger emission magnitude due to more massive activity. The slope of the middle part of the watershed tends to be flat and heavily influenced by fluvial processes makes it easy for agricultural activities to develop. Water resources are abundant in the middle of the watershed because the area is flat. The regional nutrient deposition is also common in the middle area as a result of deposition from the Upper and Mount Merapi.

Figure 2. Graphic of Emission from rice field and husbandry at Bedog Sub-Watershed 2020
Figure 3. Result of methane emissions from agriculture activites at Bedog Sub-Watershed 2020

3.2 Climate Adaptation and Mitigation Plan due to Agriculture Activities

3.2.1 Adaptation

Climate change adaptations plans can be implemented in many aspects. In general, plans in the agricultural and animal farm sector can take the form of improvements in the management aspect of agricultural activities. Programs that can be implemented include water management technology, capacity building, empowerment of farmers in the face of ongoing conditions, and farming technology.

The development of water management technology is related to water resource management so that it is available all year. The existence of the Selokan Mataram aids in the preservation of water resources throughout the year. Irrigation conditions play an important role in controlling the number of methane emissions produced. Drought forecasting can also be used as a form of adaptation to climate change. Harvesting rainwater or building irrigation canals are two examples of adaptations strategies that can be done [10].

Education related to planting time can also be a form of adaptation. To maximize agricultural yields and agricultural activities, planting time must be adjusted to the ongoing climatic conditions. This adjustment can also help overcome crop failures. Forming an appropriate planting pattern is one way to make adjustments [11].

Farming communities must be empowered in order to increase their resilience to climate change. Climate change information must be disseminated so that farmers can make informed decisions. Farmers play an important role because they carry out agricultural activities. Government press releases and television can be used to provide useful information [12].

Adaptation is done by fixing the housing system and controlling the heat received and released by the livestock. By creating favorable conditions in the cage, livestock can be more productive. Improving the quality of animal feed is another important aspect because climate change will also affect the appetite of livestock, thus impacting their productivity. Implementing a communal livestock system and
integrated livestock management, that is, carrying out an integrated livestock system by optimally integrating livestock with agricultural commodities so that zero waste is produced [13].

3.2.2 Mitigation

Climate change mitigations aim to reduce greenhouse gas emissions directly. Reducing greenhouse gas emissions needs to be implemented in tandem with climate change adaptation. This type of mitigation activity is generally directly related to the conditions that occur in the field. Mitigation activities can include determining the right variety, fertilizing, regulating water regimes, method of tillage, choosing the appropriate feed for animal farm, and processing biogas from their livestock manure.

The use of low emissions varieties can help reduce the number of agricultural emissions produced. Each variety can produce different emissions because there are differences in aerenchyma cavities, number of tillers, biomass, root patterns, and metabolic activity [14]. According to KLHK the emission factor value of Ciherang is 114.8 kg CH₄/ha/season, Maros is 74 kg/ CH₄/ha/season, and Way Rarem is 91.60 kg/ CH₄/ha/season. One type of adaptation is the use of high-yielding varieties that are resistant to drought, soaking, and salinity by modifying the variety so that it can harvest well and meet the targets set [15]. This variety can be modified using genetic engineering or biomolecular models. Superior varieties that can withstand salinity include Way Apo Buru, Margasari, and Lambur. Dodokan and Silugonggo varieties are also drought-resistant varieties [16].

The availability of irrigation networks can be used as a method of mitigating methane emissions. The use of irrigation must be adjusted to the current seasonal conditions, for example, intermittent irrigation can reduce the number of methane emissions produced [17]. A continuous supply of available water needs to be combined with an appropriate drainage time to reduce the planned emissions.

Proper use of fertilizers is required to reduce emissions directly. It has been shown that the addition of substances such as calcium carbide, NH₄(SO₄), and Na₂SO₄ can reduce methane emissions by up to 35% [18]. The use of ZA fertilizer can reduce emissions by up to 62% [16]. Organic fertilizers are also able to reduce the number of methane emissions produced. Organic farming utilizes organic fertilizers as materials for agriculture. Organic farming activities have the potential to reduce the number of methane emissions in the long run [19].

Agricultural processing methods could be used as a possible mitigation measure. Excessive tillage can produce high methane emissions due to the decomposition of organic matter, resulting in higher carbon emissions [20]. Agricultural activities without tillage can reduce the number of methane emissions produced because the decomposition process of organic matter is not accelerated [21].

Mitigation strategies carried out in the livestock sector to reduce the impact of CH₄ gas emissions include the selection of the type of feed. The type of animal feed will determine the size of the greenhouse gases produced by livestock. The addition of the concentrate composition of pap in animal feed is one method to reduce greenhouse gases from livestock digestion because it can increase the digestibility of feed [22], for example, by adding legumes to animal feed in the form of legumes, which include foraged foods that contain high levels of protein, amino acids, and minerals.

Mitigation actions can be carried out by processing biogas. Biogas production is an environmentally friendly activity. The process of making biogas involves the use of biodigester. The gas produced in biogas can be used for fuel needs [23]. Then make compost by biological decomposition and aerobic manufacture. Composting only uses animal manure without being mixed with other materials, allowing the compost to be used for livestock rearing and plant fertilizers [23]. In addition to conducting community socialization in the form of counseling about greenhouse gas knowledge and mitigation and adaptation actions, giving awards to people who have implemented the mitigation measures is also crucial [24].

4. Conclusion

Emission is one of the byproducts of human activity that can interfere with environmental conditions because it can affect the effect of greenhouse gases. Emissions inventories must be carried out as a
strategy to determine appropriate policy recommendations for addressing emission issues. The calculation of emission values is carried out based on the guidelines from the IPCC. The agricultural sector, which includes agricultural and livestock activities, is one of the human activities that can contribute to high emission values. The emission inventory carried out is the calculation of methane (CH$_4$) and urea fertilizer emissions from agricultural activities, and the calculation of CH$_4$ emissions from livestock activities in the form of enteric fermentation and manure processing. The value of agricultural emissions in 2015 was 0.73 Gg CH$_4$/Year and 0.64 Gg CH$_4$/Year in 2020. Meanwhile, the value of methane emissions from the animal farm in 2020 was 0.35 Gg CH$_4$/year. The reduction in agricultural emissions is still caused by land conversion to non-agriculture, so management methods must be considered. Adaptation strategies that can be implemented in the Bedog sub-watershed are the technology for water management, capacity building, farmer empowerment, and farming technology. Mitigation strategies proposed include determining the appropriate variety, fertilizing, regulating water regimes, method of tillage, choosing the right feed for animal farm, and processing biogas from their livestock manure.

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