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Research Article

Prediction of Anthropogenic Greenhouse Gas Emissions via Manure Management in Indonesia and Alternative Policies for Indonesian Livestock Development

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ABSTRACT

The percentage of production and utilization of hydrocarbon resources from the livestock sector has raised concerns regarding the worldwide issue of global warming. A total of CH_4 emissions from enteric fermentation and waste management has been estimated at 78.3 %. Meanwhile, N_2O emissions are 75-80 % of total agricultural emissions. This raises questions about the extent of global warming due to increased CO_2 resulting in changes in weather and global warming. This research aims to predict Green House Gas (GHG) emissions from manure management and present policy alternatives for Indonesian livestock development. Secondary data was taken from a related website (fao.org) with coverage throughout Indonesia from 1961 to 2021, containing 12,480 rows and 5 column features including item, Element, Year, Unit, and Value emission. LSTM and GRU are used to predict the trend of emission from manure management to provide alternative policies on greenhouse gas mitigation in Indonesia. The results showed that based on 15 types of livestock that emit GHG emissions, 3 types of livestock produce the highest emissions from 1961 to 2021: (a) cattle, (b) cattle and non-dairy, and (c) poultry. Significant reduction in the emission of carbon dioxide (CO_2eq) in 2020 is indicated by reduced public consumption and hampered supply chains with large-scale social restrictions (covid-19 pandemic policy). Based on these results, fertilizer storage duration can be used as a policy to reduce CO_2eq emissions, hence it is desired that fertilizer management techniques can be properly regulated. Mitigation can also be accomplished by utilizing livestock waste as biogas and upgrading animal feed additives with chitosan or potassium nitrate.

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1. INTRODUCTION

Livestock is one contributor among many to emissions from enteric fermentation of manure as excretory waste and methane as a byproduct of digestion (Broucek, 2014). Enteric fermentation of plant-eating animals is produced via the digestive process in the form of methane. The amount of methane released from animals depends on their weight, age, and quality and quantity of the consumed feed. For example, cattle and sheep are animals with moderate methane production compared to pigs and horses (Gitarskiy, 2019).

One of the largest contributors to the world's agricultural sector is the livestock sector. 78.3 % of total anthropogenic CH_4 emissions result from both enteric fermentation and waste management (FAOSTAT Agriculture Total Online Database, 2020). N_2O emissions represent 75-80 % of the total emissions from agriculture (Ambazamkandi et al., 2015). The percentage of production and utilization of hydrocarbon resources raises concerns about the issue of global warming (Whelan et al., 2013). This is evidenced by increase in CO_2 levels resulting in changes in weather and global warming.

Scholars and international organizations suggest implementing a carbon dioxide tax to reduce greenhouse gases. With the carbon tax, companies can control CO_2 emissions by changing prices. Its application can also be adapted to existing taxes so that correct positions can be provided to negotiate on climate change in the future (Zhao et al., 2013).

Various efforts such as the implementation of carbon taxes have been made so far to overcome global warming issues. With the carbon tax, the source of air pollution will be more controlled and energy consumption will be better (Fang et al., 2016). This long-term implementation can be carried out in stages and becomes a concern for international organizations from environmental, economic, and energy conservation perspectives (Zhao et al., 2013). The development of organic fertilizers and biogas is also an effort to develop an alternative energy to develop renewable energy (Anderson et al., 2016) so that it can reduce greenhouse gas emissions by regional development targets.

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Previous research has mentioned that one of the efforts to reduce methane emissions is the provision of aloe vera waste supplements to the Bali cattle diet (Mahardika et al., 2011). In addition, feed plays an important role in meeting the energy needs of livestock. In its processing, adding chitosan to animal feed has been shown to reduce enteric methane emissions and change the rumen fermentation profile in a favorable direction (Harahap et al., 2020).

Several alternatives to reducing GHG emissions have been adopted by previous studies in terms of animal feed (Herawati, 2012; Ambazamkandi et al., 2015; Pachauri & Leo Meyer, 2014). It is implied that animal feed not only contributes to animal waste emissions but also plays a role in producing GHG emissions in other sectors such as agriculture, forestry, livestock farming, and transportation (Herawati, 2012; Le Quéré et al., 2020; Miranti Ariani, Ardiansyah, 2015; Utaminingsih & Hidayah, 2012). Research on GHG has not been widely carried out in Indonesia. Therefore, there has not been much discussion about GHG emission factors caused by animal waste and prediction methods (LSTM and GRU) have been employed to determine the level of GHG emissions in the future. LSTM and GRU are methods for predicting emissions that are popular and successful because they provide simulation results in the form of GHG emission predictions that have been quite accurate in previous studies (Chlingaryan et al., 2018).

Indonesia is currently committed to reducing GHG emissions by 29 % by 2030. As much as 60 % of GHG is produced in the forestry sector and 36 % in the energy sector (Limanseto, 2021). Livestock also contributes to national GHG emissions. Although the figure is still below 2 % of the total national GHG emissions, it will continue to increase in line with the increase in the livestock population (Widiawati et al., 2021).

Based on the explanation above, this research takes advantage of machine learning to predict manure management that has been carried out so far and proposes policies to regulate and reduce greenhouse gas emissions in Indonesia in the livestock sector.

2. MATERIAL AND METHODS

This study uses secondary manure management data from FAO (FAOSTAT Agriculture Total Online Database, 2020) with coverage throughout Indonesia. The annual data were derived, starting from the year 1961 to 2021, containing 12,480 rows. These raw data consist of 5 column features: (a) item, (b) Element, (c) Year, (d) Unit, (e) Value emission. The collected data were then divided into datasets. The datasets have value and time attributes as included in the time series data category, which can be used as input to machine learning. The datasets are divided into training datasets ranging from 70 % to 80 % of the total datasets. LSTM and GRU are used to predict GHG emission trends from manure management to provide alternative solutions for GHG emission mitigation in Indonesia.

2.1. Data management and data analysis

The data that have been collected are analyzed using descriptive methods and the results of the system prediction become the basis for policy formulation so that the conducted mitigation can properly reduce the impact of GHG emissions in Indonesia as intended. The tier 1 methodology was used to calculate CH_4 and N_2O emissions from the 2006 IPCC guidelines. This method was utilized because it could be tabulated based on temperature, type of animal, location, and manure management (Ambazamkandi et al., 2015).

In substance, the initial step of this experimentation begins with the input of the dataset and the next step is data cleansing that cleans up duplicate, missing, outlier, and null data, followed by pre-processing, namely the stationary transformation, differencing, polynomial, and decomposition processes. It is followed by autoregressive, moving average, graph, and RMSE processes. The next step is data analysis consisting of data training and data testing, by which the results are shown in graphical visualization and RMSE values. The experimental flow is shown in Figure 1.

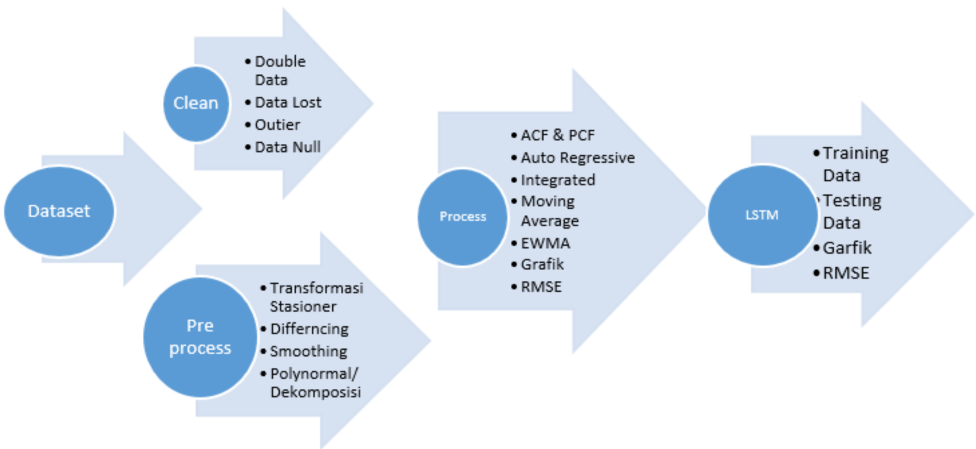

Figure 1. Experimental flow

2.2. Long Short-Term Memory (LSTM) method

This Long Short Term Memory (LSTM) method is usually used in combination with several learning architectures. The LSTM is a type of neural network that can predict time series (Van Houdt et al., 2020). Forget gate, input gate, and output gate are controlling the gates. Each gate has sigmoid and pointwise intervals [0..1]. This method can also read the input vector x = {x_1, x_2, . . . , x_t, . . .}, where $X_t \in R^m$ comes from the m-dimensional vector.

According to Figure 2, it can be seen that the LSTM formula is as follows:

$$h_t = O_t + \tanh(C_t) \quad (1)$$

where h_t is othe utput final, O_t othe utput gate, tanh the hyperbolic tangent function, and C_t value of the memory cell state. The output gate task controls the number of activations of each functional unit. Then, the LSTM can store the required information from each unit.

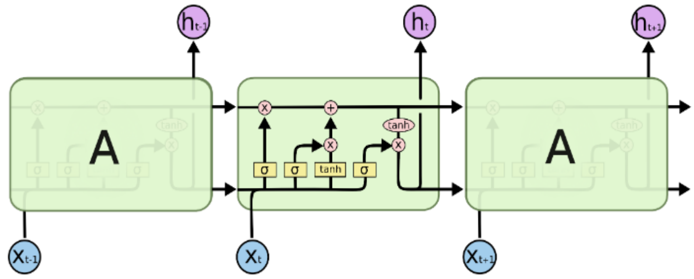

Figure 2. Four layers of activation in the LSTM cell

2.3. Gated Recurrent Unit (GRU) method

The Gated Recurrent Unit (GRU) consists of two gates: a reset r gate and a z gate. The output status contained at time (t) is calculated in the hidden state at time t-1, which is entered into the time series value at time t; the equation can be seen as follows (2).

$$h_t = f(h_{t-1}, x_i) \qquad (2)$$

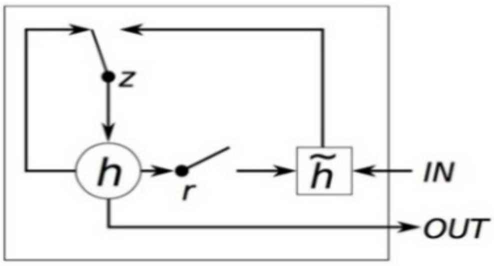

Figure 3. Illustration of GRU

2.4. Mean Squared Error (MSE) and Root Mean Squared Error (RMSE)

Root Mean Squared Error (RMSE) was used to see the difference between the estimated value and the actual value of the model parameters. Previously, the MSE calculation was carried out to check the error value in the prediction. Then, the result is the square root. The smaller or closer to zero the resulting number is, the more accurate the prediction results are. The formula of RMSE and MSE is as follows:

$$\mathrm{RMSE} = \sqrt{\sum_{i=1}^{n} \frac{(y_1 - \widehat{y_1})^2}{n}} \quad \text{and} \quad \mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}(y_1 - \widehat{y_1})^2 \qquad (3)$$

where $\widehat{y_1}, \widehat{y_2}, \ldots\ldots, \widehat{y_n}$ = values predicted, $y_1, y_2, \ldots, y_n$ = values observed and n = number of data sets observed.

3. RESULTS

The datasetw collected from the year 1961 to 2021 are used in machine learning to predict the level of greenhouse gas emissions. The datasets are divided into 'training datasets' ranging from 70 % to 80 % of the total data and 'test datasets' ranging from 20 % to 30 %. The results of the predicted test dataset measure the error value with respect to the value of the real testing dataset (target data). The obtained error value is used to update the weight value. The new weight value is applied to the prediction of the next iteration.

Based on the results of machine learning, it was found that for CO_2eq emissions that consist of 15 categories of livestock (Figure 4), three categories emit the highest emissions, namely (a) cattle, (b) cattle and non-dairy, (c) poultry (Figure 5).

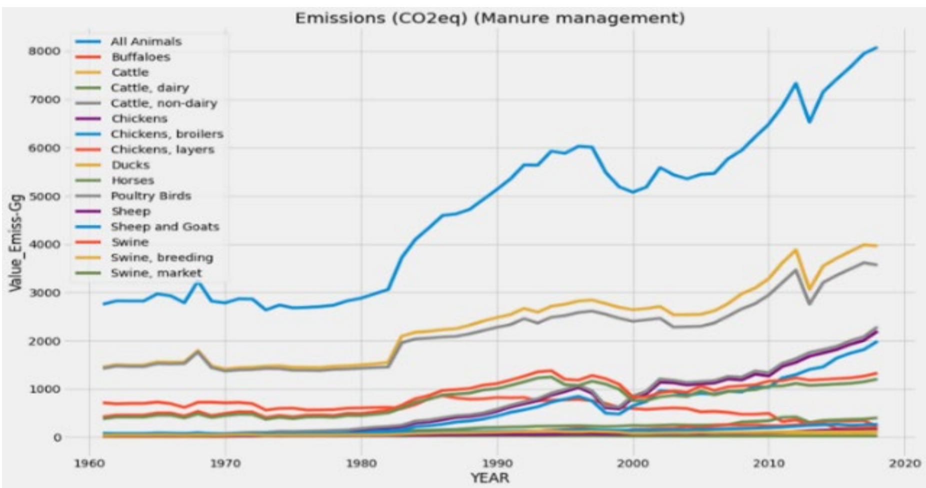

Figure 4. Training dataset of CO_2eq emission in Indonesia by livestock category

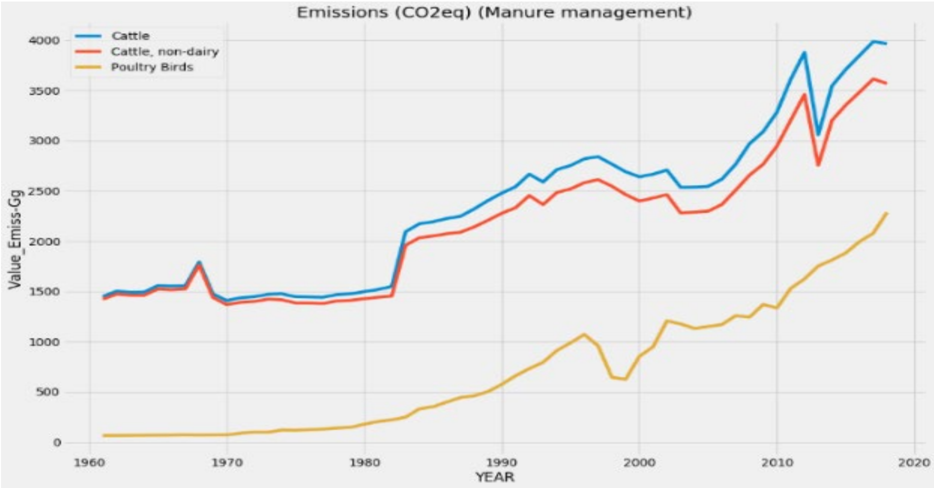

Figure 5. CO_2eq emission in Indonesia based on the highest emission

The results of manure management optimization in the three livestock categories with the highest emissions using machine learning are shown in Table 1. In the 10th epoch, the lowest RMSE of the cattle category is 4.25 %. Meanwhile, in the cattle non-dairy category, the RMSE is the lowest at 3.61 in the 15th epoch and 3.25 % in the polluter bird's category at the same epoch. This shows that the smaller the resulting RMSE value, the more accurate the prediction results will be.

Table 1. Combinatorial optimization of cattle hidden layer

Epoch	**RMSE**		
	Cattle (%)	Cattle, non-dairy (%)	Poultry Birds (%)
5	9.56	5.51	9.69
10	**4.25**	3.70	3.45
15	4.37	**3.61**	**3.25**
20	5.87	3.67	3.76

The graph of the predicted futures has a downward trend starting from the late 2019 and reaching the lowest point in 2021. This is because the pandemic entered Indonesia in 2020 and continued until 2021 as the second year of the pandemic. Among the factors are the decline in people's purchasing power during the pandemic due to the soaring price of beef and the increase in the rupiah exchange rate. Similar to the cattle category, GHG emission predictions in the non-cattle category begin to decline from the end of 2019 to 2020, reaching 50 % (Figures 6 and 7).

One example of the category of poultry is broilers. At the beginning of the pandemic, the price of broilers fell drastically, far below the cost of goods sold (COGS); the influencing factor was the large-scale social restriction that resulted in a drastic reduction in public consumption. This had an impact on reduction of CO_2eq emissions from the poultry sector. Consumption of broilers continues to rise from the end of 2021 to 2025.

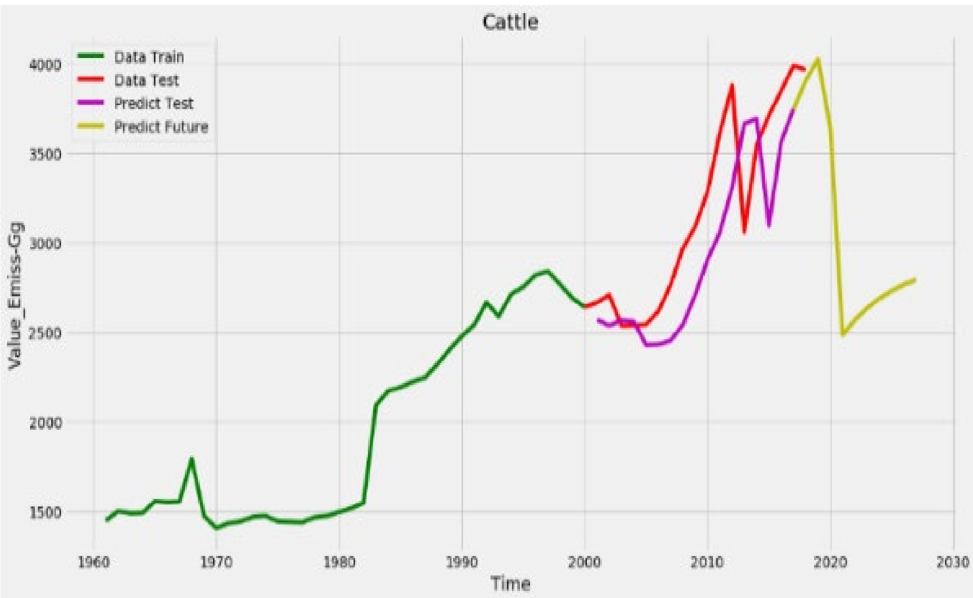

Figure 6. Prediction of future cattle

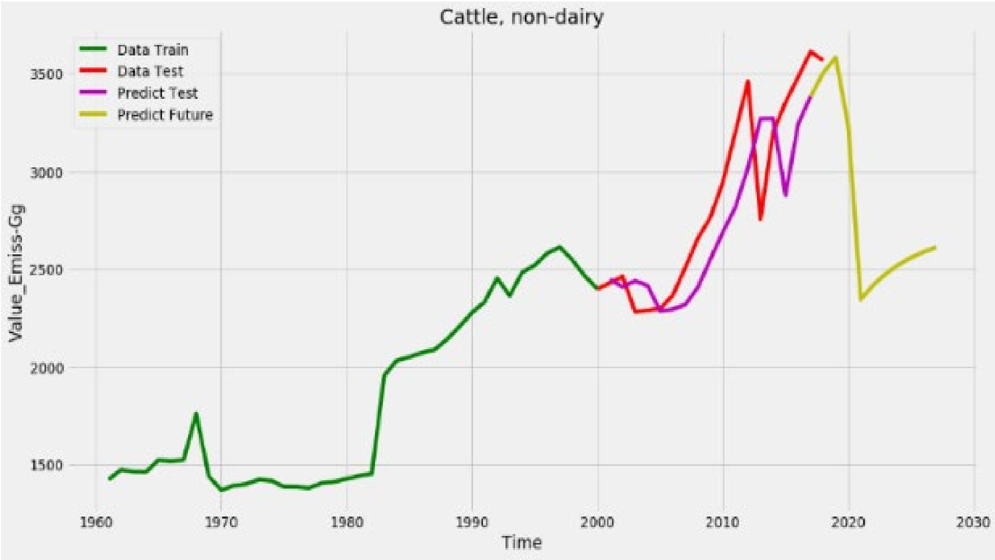

Figure 7. Prediction of future cattle, non-dairy

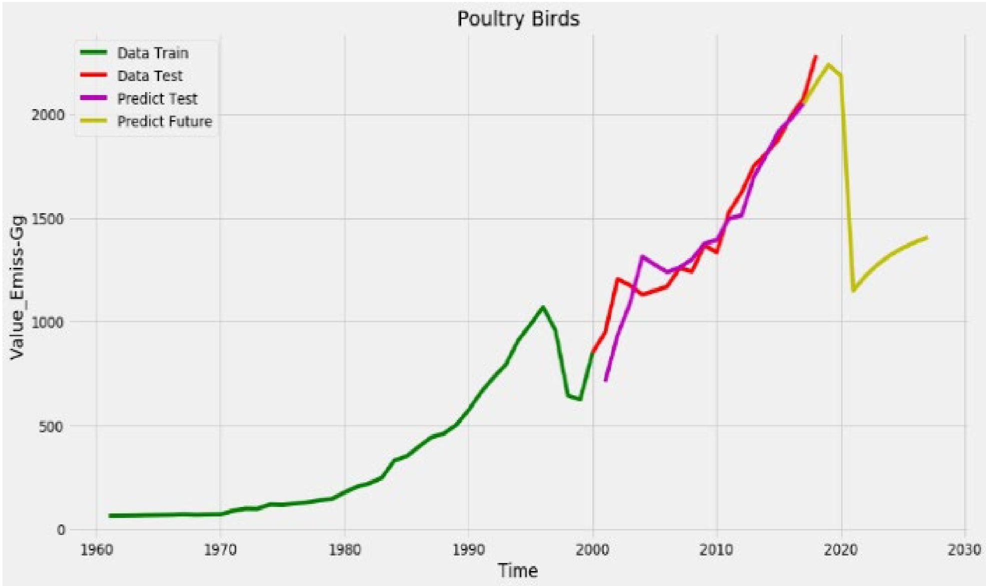

Figure 8. Prediction of future poultry

4. DISCUSSION

The LSTM method was also applied in (Hamrani et al., 2020) for optimization of 9 Machine Learning Methods; (1) LASSO, (2) Random Forest (RF), (3) SVM, (4) ExNN, (5) RBFNN, (6) FNN, (7) DBN, (8) LSTM, and (9) CNN. Using the LSTM model as another method of machine learning to predict GHG emissions can provide a new perspective on future assessments and decisions and generate the most suitable LSTM for predicting future CO_2 and N_2O. Another case study by (Chlingaryan et al., 2018) discussed the prediction of nitrogen emission status using a machine learning approach. Nitrogen (N) plays an important role in the process of photosynthesis, essential for plant health and development. At the same time, environmental and cost factors require a prudent application of N. Because of these factors, the problem of optimal N management has attracted the attention of many researchers.

The use of fossil fuels, deforestation, and land use change are all activities that increase anthropogenic GHG emissions. IPCC considers the effect of GHG emissions on climate change (Pachauri & Leo Meyer, 2014). Manure management is a source of N_2O and CH_4 emissions. Nitrogen oxide emissions are produced as part of the nitrogen-nitrification and denitrification cycle of organic nitrogen substances contained in manure. N_2O emissions are associated with the use of manure as fertilizer before added to the soil.

Manure management is produced from methane (CH_4) emissions during the anaerobic decomposition of manure. In the end, the basic element to consider is the limited livestock management facilities (Ambazamkandi et al., 2015). Greenhouse gas emissions of CO_2, CH_4, and N_2O have an important role as a major contributor to climate change because they are included in long-lived greenhouse gases (World Meteorological Organization & Atmosphere Watch Global, 2017).

Table 2. The atmospheric lifetime of greenhouse gases (Masson Delmotte et al., 2018)

Compound	Time (years)
CO_2	5-2.000
CH_4	12
N_2O	144

According to findings (Pachauri, Leo Meyer, 2014), Global Warming Potential (GWP) can be used to calculate greenhouse gases assocaited with CO_2. The value of GWP can be seen in the following table.

Table 3. Global warming potential value (Masson Delmotte et al., 2018)

Compound	Value
CO_2	1
CH_4	28
N_2O	265

Inventory of GHG emissions on agricultural land in Grobogan and Tanjung Jabung Timur regencies using the 2006 IPCC method for calculating N_2O & CH_4 emissions directly from the soil (2006-2017) shows that the main GHG emission source based on gas type is CH4 gas (wetland management, enteric fermentation, and manure management), which is > 50 % (in CO_2eq) (Miranti Ariani, Ardiansyah, 2015).

Based on research from (Anderson et al., 2016) states that the Pathway Scenario (RCP), RCP 2.6, and 8.5 determined greenhouse gas and aerosol emissions. Mitigation needs to be done by using renewable energy and nuclear power, which are the main ingredients, and using new technology in carbon storage. Meanwhile in Indonesia, to deal with the problem of greenhouse gas emissions, the Government is following up on the Copenhagen Accord agreement from the 15th Conference of Parties (COP-15) in Copenhagen and at the G-20 Pittsburgh, Indonesia commits to reducing greenhouse gas emissions by 26 %. This commitment was strengthened by the ratification of (Peraturan Presiden Republik Indonesia No 61 Tahun 2011 Tentang Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca, 2011; Peraturan Presiden Republik Indonesia No. 71 Tahun 2011 Tentang Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional, 2011) points a and b concerning Reducing Greenhouse Gas Emissions. As stated in the attachment of Presidential Decree No. 61/2011 that the agricultural sector must reduce the level of GHG emissions by 0.008 Gt CO_2eq.

To minimize future GHG emissions, appropriate policies and decisions are needed. On this issue, the IPCC has prepared a special report (IPEC 2000) that will assist in making GHG mitigation policies (Missanjo & Kadzuwa, 2021). One of the proposed policies is to implement a carbon tax. With the addition of a carbon tax to the budget, the income can be used to assist the environmental tax reform process and help mitigate the regressive impact of price increases due to carbon taxes (if they occur) on low-income households and industries in the form of proportional reductions of other tax, so that the level of tax progressivity is maintained.

In addition, Government can direct Indonesia's economy to a low-carbon path by allocating a portion of revenue to research and development and providing investment support for renewable energy. Investments in biofuel-fueled public transportation and electric vehicle technology are also needed to encourage the reduction of energy consumption and carbon emissions. An alternative approach involves offering a lump sum direct discount, with or without conditions, to encourage emission reductions among low-income households, the elderly, and the unemployed (Ratnawati, 2016).

Another alternative to tackling the problem of greenhouse gas emissions lies in the transportation sector. The study (Le Quéré et al., 2020) illustrated that GHG emissions could be reduced by providing policy changes and economic shifts such as walking and cycling. These activities help reduce half of the world's CO_2 emissions. Large cosmopolitan cities such as Bogota, New York, Paris, and Berlin have implemented countermeasures by providing pedestrian and bicycle areas to stay safe.

In the livestock sector, several factors determine the amount of GHG emissions, namely livestock husbandry including housing, feeding, sanitation, and utilization of manure. Research (Herawati, 2012) was conducted in West Java (Cikole, Lembang, Canning, Ciampea, Cisarua, Bogor, Ciracas, and Cakung), Central Java (Semarang, Boyolali, and Magelang), and East Java (Batu, Pujon, Pasuruan, and Malang) as model locations for biogas production and the mitigation technique used to reduce methane emissions is the provision of supplements such as aloe vera waste as a feed supplement in Bali cattle. This practice reduces feed consumption and methane production, but increases metabolized energy and energy utilization efficiency and raises nitrogen uptake so that protein retention can be increased (Mahardika et al., 2011).

Processing of feed ingredients can reduce methane emission using the fermentation of feed. Potassium nitrate reduces methane production compared to the addition of urea. This effect persists for an incubation period of 6 to 48 days. If sulfur is added, reduction in methane production will be greater than that if only nitrate is added (Phuong et al., 2012).

Utilization of chitosan as a feed additive in ruminant diets can reduce enteric methane emissions and change the rumen fermentation profile in a favorable direction (Harahap et al., 2020). Chitosan changes the fatty acid profile of Volatile Fatty Acids (VFA) by increasing the concentration of propionate (C_3) and, thereby, reducing CH_4 production (Jayanegara et al., 2020). Furthermore, the addition of a chitosan source from black soldier flies at a 2 % concentration of feed substrate resulted in a sharp reduction in CH_4 emissions (Jayanegara et al., 2020).

The next method is composting and without realizing its effects and potentials, farmers have been utilizing it to reduce emissions. In addition, biogas production is one of the uses of “green energy”, which is associated with global warming and is an environmentally friendly activity. This form of green energy must be developed, considering that this type is a source of renewable fuel for alternative energy produced by livestock farmers (Herawati, 2012).

What is important and needs to be done is the socialization of GHG mitigation by providing appropriate directions such as fertilization, composting, biogas production, and sanitation to farmers. If the mitigation efforts can be implemented properly, it will generate economic value that incentivizes farmers such as composting, direct use of fertilizers, or gas production (Herawati, 2012).

In the forestry sector, interventions that cause a sustainable decline include reforestation and natural regeneration; protected area conservation; identification of diseases and pests; and biological control (Missanjo & Kadzuwa, 2021). Meanwhile, research on the cultivation aspect of reducing CO-eq emissions in the Mrican Kanan Irrigation Area of 13,102 ha indicates that the application of intermittent irrigation for rice cultivation can reduce emissions by 44.67 %

with CH_4 by 33.18 % compared to conventional rice cultivation (Utaminingsih & Hidayah, 2012).

5. CONCLUSIONS

The results show that machine learning using a combination of hidden layers can generally simulate and predict GHG emissions for GHG mitigation options in manure management. From a total of 15 livestock emiting GHG emissions, 3 livestock that emit the highest emissions from 1961 to 2021 were selected, namely (a) Cattle, (b) Cattle and non-dairy, and (c) Poultry. Significant reductions in CO_2eq emissions in 2020 were demonstrated through reduced public consumption and supply chain obstructions reinforced by large-scale social restrictions (Covid-19 pandemic policy). This experiment was expected to provide added value for developing better decision-making supporting tools and models to assess emission trends in the livestock sector as well as to reinforce the idea of developing CO_2eq emission mitigation strategies during manure storage, leading to more sustainable fertilizer management practices. The policy in the livestock sector regarding the mitigation of CO_2eq emissions remained viable during the storage of manure, leading to more sustainable fertilizer management practices. Mitigation to reduce methane emissions can also be done by utilizing livestock waste as biogas and improving livestock feed using chitosan or potassium nitrate.

The limitation of this study does not include the total number of 15 livestock in Indonesia that emit GHG emissions but only the selected three livestock that emitted the highest emissions from 1961 to 2021, namely (a) cattle, (b) cattle and non-dairy, and (c) poultry. Hence, in the future, the next researcher can predict 15 types of livestock to determine each emission released.

6. CONFLICT OF INTEREST

The author conveys that this research does not contain conflicts between organizations or individuals, both from finances or relationships with other people.

7. ACKNOWLEDGEMENT

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NOMENCLATURE

CH_4	Methane
N_2O	Nitrous Oxide
CO_2	Carbon Dioxide

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