Estimation of Greenhouse Gases in The Agricultural Sector at Rice land of The Central of Food Production Zones in Merauke Regency

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Abstract. Merauke Regency is the main rice-producing center in the southern region of Papua and the largest rice contributor for the provinces of South Papua and Papua, with 55,674.75 hectares of paddy field area, 76 percent (42,387 hectares) of which located in three districts, namely Kurik, Semangga and Tanah Miring District. This study aims to inventory and estimate Green House Gas (GHG) emissions and scenarios for reducing GHG emissions in order to find the mitigation and adaptation methods. The sources of GHG emissions include CH4, CO2, and N2O. The data used for GHG estimation in the paddy field agricultural sector comes from primary and secondary data. The data analysis to determine the value of potential GHG emissions generated by the 2006 IPCC calculation method, based on the guidelines for GHG Calculation of the Ministry of Environment and Forestry of the Republic of Indonesia. The analysis results shows that the total value of potential emissions (CH4) from the management of paddy fields produces *9,35 Gg CO_2eq/year (264,5 Emisi CO2 e/tahun (Gg)* CO2eq/year. The total potential value of carbon dioxide gas (CO2) emissions from the application of urea fertilizer on paddy fields produces 4.10 Gg CO2eq/year. Meanwhile, the total potential value of direct and indirect nitrous oxide gas (N2O) from soil management activities in paddy fields produces 39,15 and Emissions from incinerated straw 0,295 Gg CO2eq/year. Mitigation efforts can be applied by choosing the right and low emissions rice varieties, appropriate land and fertilizers management systems. Adaptation strategy can be carried out with innovative technology, namely a development system in the form of an integrated land management system.

Keywords: Merauke, greenhouse gases, lowland rice, agriculture

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1 INTRODUCTION

Merauke Regency is one of the districts in South Papua Province which is a food barn for the South Papua and Papua regions. Total food production, especially rice in Merauke Regency, has increased from year to year, in 2019 the area of rice planting land was 29,250 with a production of 208,206.38 tons. In 2020 the area of rice plantation is 58,874.25 Ha with a production of 327,877.71 and in 2021 there is an increase of 344,192.32 tons with an area of 61,584 Ha. In 2022, the rice harvest area was 54,612.25 (ha), rice production was 219,044.44 (tons) with rice productivity of 4.01 tons / ha 1)

The increase in agricultural production, in addition to being influential in improving community welfare, the agricultural sector also contributes as a GHG emitter. Agricultural land contributes 20% of the world's total GHG emissions 2). GHG emissions from the agricultural sector come from emissions of: (1) methane (CH4) from paddy rice cultivation (2) carbon dioxide (CO2) due to the addition of urea fertilizer, (3) nitrous oxide (N2O) from soil, including indirect N2O emissions from N addition to soil due to volatilization/precipitation and leaching, and (4) non-CO2 from biomass burned in agricultural activities 3). The agricultural sector generates about 10-12% of total global greenhouse gas emissions, which is 40% CH4 and 60% N2O 4). About 67% of methane emissions are generated from the agricultural sector, followed by 30% N2O, and 3% CO2. Total greenhouse gas emissions in the agricultural sector reached 75,419.73 Gg in 2000 and increased in 2018 to 131,642 gigagrams of carbon dioxide equivalent (CO2e). This amounted to 8% of Indonesia's total greenhouse gas emissions in 2018. Indonesia's actual GHG emission level in 2020 is 1,050.4 million tons of CO2e. When compared to agricultural activities in developing countries, greenhouse gas emissions can reach 24% 5).

Gas derivative products produced from the agricultural sector are methane gas (CH4) and nitrous oxide (N2O) whose value is higher than CO2 gas, namely CH4 gas is 25 times higher, and N2O gas is 298 times higher than CO2 gas. The source of CH4 emissions comes from rice cultivation where CH4 is produced from anaerobic decomposition of organic matter in paddy fields. CH4 gas emissions are influenced by several factors, both the physical condition of the land and the rice cultivation activities themselves. The source of N2O comes from Land Management burning of crop residues 41% and inorganic N application 18%. Rice cultivation in drylands produces 86% of N2O emissions. Emissions and production of nitrous oxide in paddy fields are determined by ecological conditions, namely the interaction between abiotic factors and biotic factors and biophysical interactions of water, soil, plants, and cultivation practices. 6)

Data from Merauke in Figures 2022 1) shows that three districts namely Kurik District, Semangga District and Tanah Miring District which are in the food center area of Merauke Regency are the largest rice producers in Merauke Regency. The total land area of the three districts is 45,421 Ha or 73.65 percent of the total rice land, with the area of each district namely Kurik District 18,917 Ha, District and Tanah Miring District 17,217 Ha and Semangga District 9,287 Ha.

Presidential Regulation No. 61 of 2011 concerning the National Action Plan for Reducing Greenhouse Gas Emissions (RANGRK) is the basis that requires each city and district to make a Regional Action Plan for GHG emission reduction (RAD-GRK). Therefore, this study aims to determine the value of GHG emissions from the paddy field agriculture sector generated in the food production center area, especially in the three main rice-producing districts in Merauke Regency, namely Kurik District, Semangga District and Tanah Miring District. The emission value data can be used by the Merauke Regency Government to make the Merauke Regency RAD-GRK and then the next step as an effort to reduce GHG emissions, especially in the wetland agriculture sector in Merauke Regency.

2 MATERIALS AND METHODS

2.1 Research Location

The location of this research is in three districts in the Food Production Center Area (Kurik District, Semangga District, and Tanah Miring District) of Merauke Regency, South Papua Province. The population of Merauke Regency in 2022 was 232,357 people with an area reaching up to 46,791.63 km2, so the population density in Merauke Regency was 4.97 people / km2. [1].

2.2 Data Collection

The data used are secondary data, namely activity data on the research object in 2021 and emission factors. Data on activities or activities include data on the area of rice fields, age of rice planting, data on the amount of nitrogen fertilizer needs applied. Data sources come from the Office of Food Crops Horticulture and Plantations, Merauke Regency and BPS Merauke Regency.

2.3 Data Processing

Data processing used the IPCC 2006 [4] and 2019 Refinement to the 2006 [7] methods with the Tier 1 approach. The Tier 1 approach is a simple calculation method based on default global or regional emission or uptake factors [3]. The calculated GHG emissions of the wetland agriculture sector are from rice planting activities, fertilizer use, and soil management. The GHG emission calculation method is presented in Table 1.

Table 1. Calculation Method of Greenhouse Gas Emissions in the Agricultural Sector of Rice Fields

No	Emission Source Activity	GHG Emissions Calculation Method	Types of Data Required	Source of Data
1	Agricultural Land	Equation 1 (IPCC 2019) CH_4 Paddy (Gg.CH_4/year) Equation 1	- Harvested Area of Irrigated and Non-	- Questionnaires and interviews - Statistics Agency of

No	Emission Source Activity	GHG Emissions Calculation Method	Types of Data Required	Source of Data
		$CH_4 = \sum_{ijk} FEijk * tijk * Aijk * 10^{-6}$ Description emission CH4 Rice : emission CH4 managing paddy fields (Gg CH4 /year) Ef : emission factor CH4 managing paddy fields (Indonesian local value 1.61 kg CH4/ha/day) from KLH (2021). A : paddy field area (Ha), from value BPS (2021). T : the rice planting period (days) is 180 days per year (interview results))	irrigated Rice Paddy Fields (ha/year) - Rice Variety - Irrigation System/Regime - Age/Planting period per growing season - Emission Factor (kg CH4/ha.day)	Merauke Regency - Merauke Regency Agriculture Office - Similar research results/articles
2.	Land Management			
	Urea Usage	$CO_2 - C = M * EF * \frac{44}{12}$ (ton/years)	- Amount of urea (tons/year) - CO2 emission factor Tier (national - subnational)	- Questionnaires and interviews - Statistics Agency of Merauke Regency - Merauke Regency Agriculture Office - Similar research results/articles

No	Emission Source Activity	GHG Emissions Calculation Method	Types of Data Required	Source of Data
	Fertilization	- N_2O directly (Gg/years) of fertilizers applied to the soil Equation (IPCC 2019) $N_2O - N = N_2O - N_{Ninputs} + N_2O - N_{Os} + N_2O - N_{PRP}$ - N_2O Indirectly (Gg/tahun) - Volatilisasi Persamaan 11.9 (IPCC 2019) $N_2O_{(ATD)} - N = [(F_{SN} * F_{GASF}) + (F_{ON} + F_{PRP}) * F_{GASM}] * EF_4$	- Harvested area of paddy rice, food crops, non-field crops, and holticulura - Consumption of inorganic and other artificial fertilizers (urea, NPK, ZA) and organic fertilizers (manure, compost, etc.) per year, both for conventional systems, and in balanced fertilization systems	- Questionnaires and interviews - Statistics Agency of Merauke Regency - Merauke Regency Agriculture Office - Similar research results/articles
3.	Biomass Combustion	- Equation (IPCC 2006) - $L_{fire} = A * M_B * C_f * G_{ef} * 10^{-3}$	- Area burned - Hay mass (harvest residue) burned (tons/ha) - Tier: biomass weight (Mb) local burn factor (Cf)	- Questionnaires and interviews - Statistics Agency of Merauke Regency - Merauke Regency Agriculture Office - Similar research results/articles

2.4 Total GHG emissions from the wetland agriculture sector

The total emissions of the paddy field agriculture sector were calculated by adding up the emissions from the cultivated land activity sector, the use of urea fertilizer, soil management from the treatment of synthetic fertilizer and organic fertilizer. To make a comparison, the CH4 and N2O emission load per year is converted into Gg CO2 equivalent per year, by multiplying with the Global Warming Potential (GWP) value 3). The Global Warming Potential (GWP) value for CH4 is 21, while the Global Warming Potential (GWP) value for N2O is 310.

3 RESULTS AND DISCUSSION

3.1 CH4 Emissions from Rice Paddy Management

Rice Paddy Cultivation Activities

The process of farming system activities in paddy fields carried out by rice farmers in the 3 districts of food production centers of Merauke Regency (Kurik District, Semangga, and Tanah miring District) can be seen in Table 2.

Table 2. Patterns of Cultivation Activities of Rice Farmers in the Food Production Center Area of Merauke Regency

No	Cultivation Activities	Agricultural Land Activities
1	Planted varieties	Inpari 32, Inpari 42, pandan wangi, ciherang, Mamberamo and cigeulis varieties
2	Rice field cultivation (I and II)	Plowing land using a tractor (hand tractor and tractor zonder) with diesel fuel
3	Planting System	Tabela system (direct seeding) with 2 planting periods
4	Crop maintenance	Fertilization (Types of fertilizers Urea, SP 36, ZA, NPK Phonska, KCL)irrigation and pest control
5	Harvesting	- Harvesting time is 90% yellowing - The tools used to harvest rice are manually using a sickle and a combine harvester machine (diesel) - Threshing grain with treser machine - Rice milling using rubber roll
6	Utilization of plant residues	- Rice stalks and husks are utilized as animal feed. - The remaining straw is buried in the soil < 1 month and used as fertilizer.

Source: Processed Data, 2022

Results of Potential Methane Gas (CH4) Emissions from the Management of Rice Paddies

The results of the calculation of CH4 emissions in each district are shown in Table 3, indicating that the cultivation of paddy fields in the study area (3 Districts) produces methane and CO2e of 9.35 Gg CH4/year and 264.5 Gg CO2 e/year, respectively. The results of the calculation of GHG emissions from paddy fields in the study area (total) for 2021 are shown in Table 3.

Table 3. Methane and CO2 Emissions of Paddy Rice Cultivation in the Study Area 2021

Distrik		Harvested Area (ha)	CH4 emissions year (Gg)	Emissions CO_2 e/tahun (Gg) (Emisi CH_4 x 21)
Kurik	Irrigation	5.107,6	4,81	134,6
	Rainfed	13.809,4	1,49	44,5
Tanah miring	Rainfed	9.287	1,07	29,9
Semangga	Rainfed	1.7217	1,98	55,50
Total			9,35	264,5

Source: Processed Data, 2022

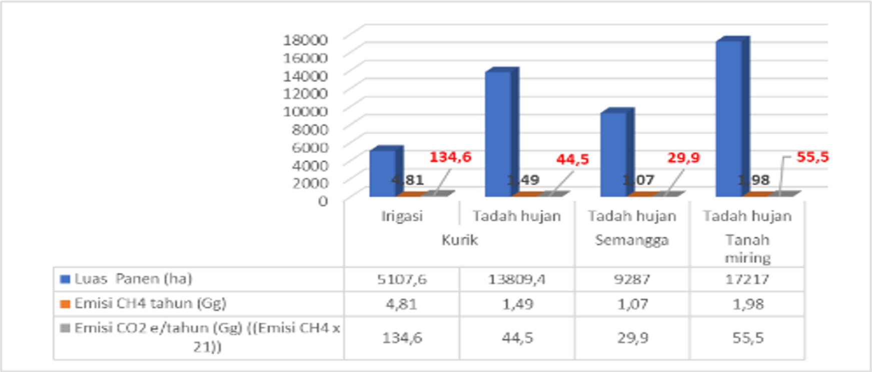

Figure 1. The results of Potential Methane Gas (CH4) Emissions from Rice Paddy Management

Figure 1 shows that the highest emissions generated by rice field agricultural activities are in Kurik district (18,916 Ha). The difference in the results of CH4 gas emissions in each district in the food center area of Merauke district is caused by several factors that affect the magnitude of CH4 production in rice paddy fields, including differences in harvest areas and water sources (irrigation) used, then the same type of rice varieties, namely the rice varieties used are generally Inpari 32, Inpari 42 Ciherang, Pandan-wangi, Cimelati and cigeulis rice varieties, different soil types in Kurik district gleisol district, Semangga district gleysol and organosol soil types, a little cambisol, Tanah Miring district organosol soil type. Therefore, Kurik District is the district that has the largest harvest area (18,916 ha), so the resulting emission burden is large..

Setyanto P;10) Wihardjaka11) stated that the factor of the magnitude of CH4 emissions is influenced by differences in harvest areas and other factors are the type of rice varieties and types of irrigation CH4 gas emissions on agricultural land are influenced by several factors, such as the type, variety, and age of plants, microorganisms (methanogen bacteria), and biophysical environmental conditions 12). Biophysical environmental conditions such as soil moisture, soil temperature, soil electrical conductivity (DHL), soil pH, and soil redox potential are factors of biophysical environmental conditions that affect CH4 gas emissions. [13)]

3.2 Results of Potential Carbon Dioxide (CO2) Gas Emissions from Urea Fertilizer Use in Rice Paddy Fields

The use of urea fertilizer can cause the release of CO2 that is bound during the fertilizer manufacturing process. The amount of urea fertilizer used is calculated based on the rice harvest area, and the dosage used by farmers in 2021 (survey results, 2022). The urea dosage used for rice is 110 kg/ha, (recommendation from MOA 2020, Merauke district). The total consumption of urea fertilizer on agricultural land is 5028.6 tons of Urea/year, so the calculation of CO2 emissions from the use of urea fertilizer for both types of land is 4.10 Gg/year as presented in Table 4.

Table 4. CO2 Emissions from Urea Fertilizer Use (Year 2021)

Distrik	Consumption Urea (ton/tahun) (M)	Emission Factor (0,2)	emission CO_2 (Gg)/year (M*0,2*10^-3)
Kurik	2087,4	0,2	1,94
Semangga	1034,1	0,2	0,76
Tanah miring	1907,1	0,2	1,40
Total	5028,6		4,10

* Emission Factor Urea =0,2 ton C/ton urea)
Source: Processed Data, 2022

Based on Table 4 above, the districts that contribute the first largest CO2 gas emissions are Kurik District, Tanah Miring District and Tanah Semangga District. The difference in the results of CO2 gas emissions in each District is due to factors that affect the amount of CO2 production in wet rice fields is the area of rice fields and the use of urea fertilizer. The area of paddy fields in Kurik District is (18,916 ha) with the use of urea fertilizer 2087.4 tons/year, Tanah Miring District is 9,287 ha with the use of urea fertilizer 1907.1 tons/year, and Semangga District is 1669 ha with the use of urea fertilizer 1,034.1 tons/year. This result shows that the larger the land area used, the more urea fertilizer will be used, which causes higher CO2 emissions released into the atmosphere.

3.3 N2O Emission from Soil Management Using Fertilizer

The addition of inorganic fertilizers as N enhancers (Urea, NPK, ZA) and organics such as from compost, manure in soil management during planting emits GHG in the form of N2O into the atmosphere. These GHG emissions to the atmosphere can be direct and indirect. The calculation of direct N2O emissions from managed land involves all types of land, namely wetlands and drylands. The wetland calculated is rice paddy cultivation and the dryland is secondary crops and vegetables. The amount of direct N2O emissions from land is differentiated between dryland and wetland. This is because N2O emissions from wetlands are much smaller than N2O emissions from drylands which are always under aerobic conditions.

Indirect N2O emissions from managed soils do not differentiate between dry and wet land use. This is because the fraction of deposition of volatilized N differs in the type of N synthesis and organic N fertilizer. The results showed that to increase the elements of N, P, K most of the wetland rice farmers in the three Districts did not use organic fertilizers (manure and compost), only using synthetic fertilizers (inorganic) namely Urea, NPK and ZA, with the content of N elements respectively 46%, 15% and 21% as nutrients. The doses of urea, NPK and ZA fertilizers added are 119, 135 and 50 tonnes/ha respectively each season.

Estimated N2O emissions from soil fertilization activities with organic fertilizers (synthetics) and organic fertilizers on wetlands (rice paddy cultivation)) in the study area (3 districts) are shown in Table 5.

Table 5. Direct and Indirect N2O-CO2 e Emissions from Soil Fertilization with Nitrogen from Synthetic and Organic Fertilizers Management Activities in 2021

Distrik	Consumption N (kg/tahun)	Emissions GRK (Gg)	
		N_2O	CO_2-e
Kurik	1913,7	0,06	17,68
Semangga	821,5	0,03	7,53
Tanah Miring	1513,1	0,05	13,94
Total	4248,3	0,14	39,15

Source: Processed Data, 2022

The table shows that the total GHG emissions (direct and indirect) in the study area are 39.15 Gg CO2. Where the highest emissions are generated from Kurik District, Tanah Miring and Semangga District.

CO2 emissions due to the use of fertilizers on agricultural land cause the release of CO2 used during the urea manufacturing process at the factory and these emissions are counted as losses in the industrial sector. Urea (CO(NH2)2) is converted into ammonium (NH4+), hydroxyl ions (OH)), and bicarbonate (HCO3-) in the presence of water and the enzyme urease 14). CO2 emissions calculated for NPK, Za and organic fertilizer types are direct and indirect N2O emissions from fertilizer use.

3.4 Non CO2 Emissions from Biomass Combustion

Non-CO2 emissions from biomass burning (mainly CH4, CO, NOx and N2O) are generally associated with agricultural residues (rice straw) being burned. CO2 emissions from combusted biomass are not calculated because the carbon released during the combustion process is assumed to be reabsorbed by the plants in the following season.

The results of the estimation of CO2 emissions e/year in 2021 from biomass burning are shown in Table 6.

Table 6. The estimated CO2 emissions/year from Biomass Combustion 2021

Distrik	Extensive	Amount (ton/thn)	Emissions CO2 Gg e/tahun
Kurik	18917	110664,45	0,152
Semangga	9827	33018,72	0,034

Tanah miring	17212	100690,2	0,109
Total			0,295

Source: Processed Data, 2022

3.5 Total Emissions from the Agriculture Sector

Total emissions from activities in the main agricultural sector are listed as coming from cultivated land activities, urea fertilizer use, soil management from synthetic and organic fertilizer treatments, straw burning in 2021 are shown in Table 7.

Table 7. Total CO2 Emissions (Gg-e) in the Agriculture Sector 2021

Distrik	Emissions CO_2-e paddy cultivation	Emissions CO_2 use of urea fertilizer	Emisi CO_2 e from managed soil through fertilization	Emissions of burnt straw	Total
Kurik	179,1	1,94	18,33	0,152	199.37
Semangga	29,9	0,76	7,83	0,034	38,49
Tanah miring	55,5	1,4	14,5	0,109	71,4
Total	305,8	5,03	50,07	0,34413	360,84

Source: Processed Data, 2022

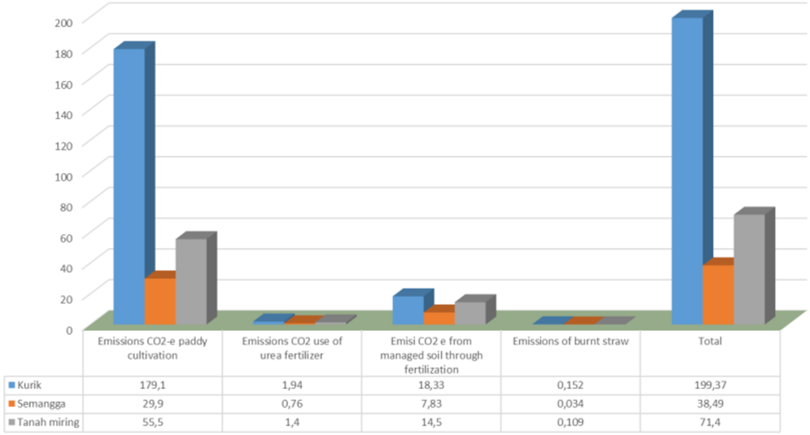

Figure 2. Contribution of CO2e Emission Sources in 2021 in the Study Area

Most GHG emissions in the study area come from CH4 emissions from rice field management, which amounted to 85.83% of total emissions. While the smallest GHG emissions come from straw burning emissions of 0.095%, and from the use of inorganic (synthetic) and organic fertilizers is 14.47%.

3.6 Mitigation Measures against GHG increase

Mitigation Measures on Methane Gas (CH4) Emissions from Rice Management

The mitigation action that can be taken is to choose the right and low-emission rice varieties. This is because rice varieties have a very important role in releasing CH4 gas. The release of oxidized CH4 gas is flowed to the roots and rhizosphere as an intermediate media pathway for the release of CH4 gas through aerenchymal vessels, then flowed from the soil to the stem to the atmosphere. In addition, the water regime is influenced by the volume of CH4 gas emissions, so water management needs to be done to save water because CH4 emissions will be greater if the rice fields are flooded. In this condition, the formation of CH4 gas is more active because in the biological process there are methanogen bacteria. Therefore, the most effective irrigation management is periodic, which can reduce GHG emissions. 15)

Mitigation Measures on Carbon Dioxide (CO2) Gas Emissions from Urea Fertilizer Use in Rice Paddy Fields

Mitigation measures that can be taken are wise use of fertilizers. It is better to apply urea fertilizer according to the dosage which is divided 3 times, namely at 7, 21 and 42 HST (Days After Planting). The use of urea fertilizer also has the potential to reduce methane emissions. This is because ammonium (NH4 +) is absorbed by plants and then balanced with the release of H + around the roots so that the acidity level in the roots of the plants decreases which will then prevent the growth of methanogenic bacteria. Another technique that can reduce CO2 emissions is to collaborate the use of organic N fertilizer and inorganic N fertilizer, namely applying N fertilizer by immersion. Therefore, the use of inorganic fertilizers to be more practical and effective is based on the needs of rice plants. While organic fertilizer is given at the time of processing the land equivalent to 2 t/ha.16).

Mitigation Measures on Nitrous Oxide (N2O) Emissions from Land Management

Mitigation actions that can be taken are the right land management system, namely agricultural land optimization by increasing productivity and cropping index through low greenhouse gas emission innovation technology. Management of N fertilizer use plays an important role in minimizing soil nitrate residues that can help reduce the increase inN2O emissions. The use of nitrification inhibitors as the nitrification process is a change from ammonia (NH3) to nitrate (NO3 -) and this nitrate is the form available to plants and the application of the use of Leaf Color Chart (BWD) for N fertilization has the potential to reduce N2O gas emissions from rice fields which can increase the efficiency of N fertilizer and also increase rice yield. This can be seen from the color of rice leaves using the leaf color chart (BWD). 16)

3.7 Greenhouse Gas Adaptation in the Agriculture Sector paddy field land

Based on the discussion and interviews with farmers and adjusted to the existing literature. Adaptation efforts in the agricultural sector are to adjust the timing and planting patterns by paying attention to weather conditions during the growing season, then selecting the type and method of planting, so that if planting is carried out by paying attention to weather and land conditions, it is likely to get quality results and the resulting emissions are lower, this is in line with research 17). In addition, other efforts can be made by using superior varieties that are resistant to drought, soaking, and salinity 18). The use of technological innovations in farming, namely the Integrated Soil Management (PTT) system in environmentally friendly-based rice paddies. PTT technology is an effort to support the sustainability of production systems and an adaptation approach so that water, soil and plant resources can be managed properly 5).

4 CONCLUSION

Based on the results of the research that has been done, the conclusions that can be drawn are:

1. The results of GHG emission inventory in the study area, GHG emission from the wetland agriculture sector in the food production center area of Merauke Regency is 297.15 Gg CO2 equivalent per year.
2. The largest contribution of GHG emissions comes from the cultivation of paddy fields, around 78%, then soil management (14%), and the use of urea < 1%.
3. Mitigation efforts made are through replacing rice varieties from Impari 32 to local rice, namely Memberamo and Ciherang Mitigation efforts by using urea fertilizer according to government recommendations.

REFERENCES

1. Badan Pusat Statistik Kabupaten Merauke. (2022). *Kabupaten Merauke Dalam Angka 2019*. Badan Pusat Statistik Kabupaten Merauke
2. Canadell, J.G., D.E. Pataki, and L. Pitelka. 2007. Saturation of the terrestrial carbon sink. Pp. 59-78. In J.G. Canadell, D.E. Pataki, and L. Pitelka (Eds.): Terrestrial Ecosystems in a Changing World. Berlin, Springer Verlag
3. Direktorat Jenderal Pengendalian Perubahan Iklim, 2017. Pedoman Penghitungan Emisi Gas Rumah Kaca Untuk Aksi Mitigasi Perubahan Iklim Berbasis Masyarakat. Kementerian Lingkungan Hidup Dan Kehutanan.
4. IPCC. (2013). Climate Change 2013: The Physical Sciences Basis. Contributing of Working Group I to the Fitfth Assessment Report of The Intergovernmental Panel on Climate Change. Cambrdige, United Kingdom and New York, NY,USA, 1535 pp: Cambridge University Press
5. Kementerian Lingkungan Hidup dan Kehutanan (KLHK). 2021. Status Lingkungan hidup Indonesia

6. Tim Sintesis Kebijakan. (2008). Dampak perubahan iklim terhadap sektor pertanian, serta strategi antisipasi dan teknologi adaptasi. Pengembangan Inovasi Pertanian, 1(2), 138–140
7. Intergovernmental Panel on Climate Change. (2006). *IPCC Guidelines for National Greenhouse Gas Inventories.* Intergovernmental Panel on Climate Change
8. Kementerian Lingkungan Hidup, 2012. Pedoman Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional, Buku II, Volume 1 Metodologi Perhitungan Tingkat Emisi Gas Rumah Kaca, Pengadaan dan Penggunaan Energi
9. Badan Perencanaan Pembangunan Nasional (BAPPENAS) 2014. Pedoman Teknis Penghitungan Baseline Emisi Dan Serapan Gas Rumah Kaca Sektor Berbasis Lahan. Buku 1. Deputi Bidang Sumber Daya Alam dan Lingkungan Hidup
10. Setyanto, P. 2008. Mengurangi Emisi Gas Rumah Kaca dari Lahan Sawah. Jurnal Iptek Tanaman Pangan Vol. 3 No. 2 - 2008.
11. Wihardjaka, A. 2007. Methane emissions from some rice cultivarsin rainfed rice field. Jurnal Biologi Indonesia4(3): 143–152
12. Lu, W.F., W. Chen, B.W. Duan, W.M. Guan, Y. Lu, and R.S. Lantin. 2000. Methane emissions and mitigation options in irrigated rice fields in Southeast China. Nutrient Cycling in Agroecosystems 58: 65–73.
13. Arif C, Setiawan BI, Widodo S,Rudiyanto, Hasanah NAI,Nurfaijah, Ega O, Masaru M. 2014.Pengembangan model jaringansyaraf tiruan untuk menduga Emisigas metana dari padi sawah. Jurnal Ilmu Komputer: Agri Informatika.3 (2): 65-73. Bogor (ID): Institut Pertanian Bogor.
14. Purnamasari, E., Sudarno, Hadiyanto. (2019). Inventarisasi Emisi Gas Rumah Kaca Sektor Pertanian di Kabupaten Boyolali. *Prosiding Seminar Nasional Geotik 2019, 384-391*
15. Snyder, C.S., Bruulsema, T.W., Jensen, T.L., Fixen, P.E., 2009. Review of Greenhouse gas Emissions from crop production system and fertilizer management effects. Agriculture, Ecosystem and Environment 133: 247-266
16. Badan Penelitian dan Pengembangan Pertanian. 2010. Road Map Strategi Sektor Pertanian Menghadapi Perubahan Iklim. Kementrian Pertanian
17. Las, I. (2008a). Menyiasati fenomena anomali iklim bagi pemantapan produksi padi nasional pada era revolusi hijau lestari. *Jurnal Pengembangan Inovasi Pertanian* 1(2), 83-104.
18. Surmaini, E., Runtunuwu, E., & Las, I. (2011). Upaya sektor pertanian dalam menghadapi perubahan iklim. *Jurnal Litbang Pertanian,* 30(1), 1-7.