

Prepared by:



GHG Baseline Study

for:

Low Carbon Rice: Reducing Climate Impact of Farmers in Indonesia

SWITCH-Asia

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BAB 1. PENDAHULUAN

1.1. Project overview

The project is funded by the SWITCH-Asia programme, through the European Commission. This programme aims to support sustainable development, contribute to economic prosperity and poverty reduction in Asia and Central Asia, and contribute to a transition towards a low-carbon, resource-efficient and circular economy.

Preferred by Nature is the lead recipient and project co-implementer. Preferred by Nature is a non-profit organisation working to support better land management and business practices that benefit people, nature and the climate in 100+ countries.

KRKP (Koalisi Rakyat untuk Kedaulatan Pangan; People's Coalition for Food Sovereignty) is a project co-implementer and is an experienced coalition that has worked on projects related to rice issues, especially in efforts to encourage policy changes. KRKP has the capacity related to lobbying and advocacy, project management, mapping and engagement of stakeholders, and campaigns. KRKP's network and members are located in each of the five districts.

Perpadi (Perkumpulan Penggilingan Padi dan Pengusaha Beras Indonesia) ; Indonesian Rice Millers and Traders Association) is a project co-implementer and is an integrated association of rice milling and trading-type companies, with national scope of operation. It has the capacity to mobilise rice milling communities and rice traders and direct their participation in developing and expanding agricultural industrialization to create the best of business comparative studies to different countries and technical assistance to improve rice milling efficiency and management of business.

1.2. Project Description

This project aims to determine greenhouse gas emissions from the main target group of rice farmers. This calculation was designed in collaboration between the Low Carbon Rice Project (LCRP) and the Ricesilience Project. The purpose of this calculation is two fold: it provides an overview of emissions for farmers working with LCR, and it also serves as a baseline for the Ricesilience Project's calculation of greenhouse gas (GHG) emissions at the farmer operational level, so that the impact of various interventions can be measured consistently and reliably.

2. METODELOGI

2.1. Selected sites

This research is located in 5 districts (Madiun, Ngawi in East Java and Sragen, Klaten, and Boyolali in Central Java). Data were collected from 116 rice farmers assisted by the Ricesilience Project. The distribution of sample locations is shown in Table 1.

Table 1. Sample location

No	District	Sub District	Village	No	District	Sub District	Village
1	Boyolali	Banyudono	Tanjung sari	3	Sragen	Masaran	Pilang
			Jongkangan				Klembon
		Boyolali	Jetis				Jati
		Selo	Kuncen				Bakung
			Saritani	4	Ngawi	Geneng	Pilang
		Mudal	Karangbulu				Perdu
			Dlingosari				Karangasem
			Mojosongo	Jomboran	5	Madiun	Saradan
2	Klaten	Cawas					
			Bogor				
			Burikan				
			Plumpungan				
		Kedungan					

2.2. Calculating methods

The calculation method uses Sustainable Rice Platform (SRP) Performance Indicator which is basically IPCC 2006 Tier 1. The correction factor used in calculating GHG is adjusted based on type of fertilizer, type of irrigation used, cultivation period.

The calculated GHG emissions from the agricultural and plantation sectors are from rice planting activities, fertilizer use, and soil management.

$$(FSN \times Efi \times 44 / 28 \times 310) \dots\dots\dots (2)$$

Where:

N₂O Direct = Direct N₂O emissions (kg CO₂);

FSN = the number of synthetic N fertilizer used to the ground in a year (kg N per year). Fertilizer consumption was obtained based on surveys and field interviews. The N content in Urea, ZA and NPK is 46%, 21% and 15% respectively ;

The EFi = the N₂O emission factor, where the N₂O emission factor from N input in irrigated rice fields (kg N input) has a value default is 0.003, while the N₂O emission factor from N input for dry land (kg N₂O) (kg N input) default is 0.010.

Methane emissions in rice fields are influenced by several key factors, two of which are the use of organic materials and water management.

First, the use of organic materials such as straw and compost that are incorporated into the soil provides a substrate for anaerobic microbes. In the absence of oxygen, these microbes break down organic matter through methanogenesis, which directly increases methane production.

Second, the practice of continuously flooding rice fields creates an anaerobic (oxygen-free) environment in the soil, which is ideal for the activity of methane-producing microbes.

When these two conditions combine—that is, high use of organic matter in constantly flooded rice fields—methane gas emissions increase significantly. This phenomenon is one of the challenges in efforts to reduce the environmental impact of rice paddy farming, given that methane is a greenhouse gas with a global warming potential far higher than carbon dioxide.

To see this, a calculation formula as shown in the figure 1. is used.

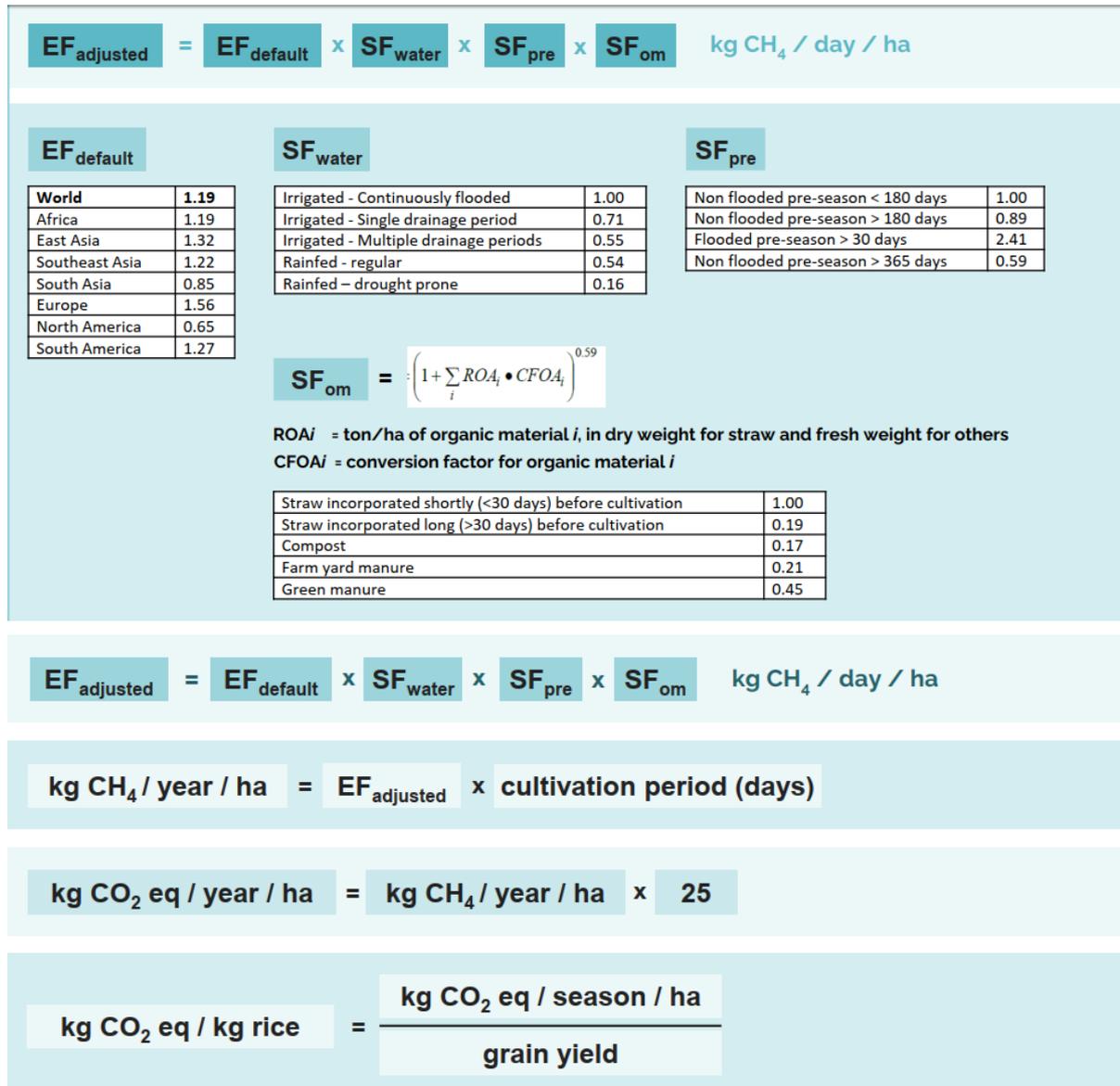


Figure 1. calculation formula

2.3. Data

Calculations were made using 2025 data for the second growing season, from June to August.

3. EMISSION ANALYSIS RESULTS IN FIVE DISTRICTS

3.1. Boyolali

3.1.1. Estimation of chemical input Emissions

Survey results in the Boyolali district show that the average area of rice fields managed by farmers is 4,768 m². Farmers carry out the rice cultivation cycle with an average plant age of 113.4 days. To support rice growth, each hectare of land is given inputs in the form of 365.4 kg/ha of urea per planting season, 186 kg/ha of Ponska per planting season, and 422 kg/ha of NPK.

Not all types of fertilizer are applied by all farmers. Data shows that 72% of farmers use a combination of urea and Ponska fertilizer, while 37% use a combination of urea and NPK. With this input composition, the average rice production (dry grain yield) reaches 5.7 tons/ha.

The emissions generated from the use of fertilizer inputs consist of:

- Urea: 695.31 kg CO₂-eq/ha
- Ponska: 125.7 kg CO₂-eq/ha
- NPK: 271.54 kg CO₂-eq/ha

Details of these emissions are presented in Table 2.

Tabel 2. NO₂ emission from farmers in Boyolali

No	Nama Petani	Nitrat				Emisi Factor (direct)	GWP	NO ₂ /N	Emisi Direct (Urea) (Kg CO ₂ eq / Ha)	Emisi Direct Phonska (Kg CO ₂ eq / Ha)	Emisi Direct NPK (Kg CO ₂ eq/Ha)
		Urea (46%)	Phonska (15%)	ZA (21%)	NPK (15%)						
1	Supardi	127,78	30,00			0,01	273	1,571	548,17	128,70	
2	Suko Rahayu	115,00	45,00			0,01	273	1,571	493,35	193,05	
3	Jamhari	268,33	7,50			0,01	273	1,571	1151,15	32,18	
4	Wardiyo	115,00	22,50			0,01	273	1,571	493,35	96,53	
5	Parno	0,00	15,00			0,01	273	1,571	0,00	64,35	
6	Sunariyanto	138,00	37,50			0,01	273	1,571	592,02	160,88	
7	Sugita	230,00	18,00			0,01	273	1,571	986,70	77,22	
8	Subiyanto	88,32	15,00			0,01	273	1,571	378,89	64,35	
9	Djumadi	276,00	22,50			0,01	273	1,571	1184,04	96,53	
10	Badrun	276,00	22,50			0,01	273	1,571	1184,04	96,53	
11	Suwarno	204,44	60,00			0,01	273	1,571	877,07	257,40	
12	Sri Wahyono	197,14	15,00			0,01	273	1,571	845,74	64,35	
13	Sugiyono	153,33	7,50			0,01	273	1,571	657,80	32,18	
14	Slamet	204,44	120,00			0,01	273	1,571	877,07	514,80	
15	Mulyanto	153,33	22,50			0,01	273	1,571	657,80	96,53	
16	Dina Kristana	115,00	15,00			0,01	273	1,571	493,35	64,35	
17	Ninik Setianingsih	92,00	37,50			0,01	273	1,571	394,68	160,88	
18	Jumi	184,00	15,00			0,01	273	1,571	789,36	64,35	
19	Mulyaman	115,00	15,00			0,01	273	1,571	493,35	64,35	
20	Natijatun	255,56	15,00			0,01	273	1,571	1096,33	64,35	
21	Amanah	191,67			93,75	0,01	273	1,571	822,25		402,19
22	Giyarni	153,33			70,00	0,01	273	1,571	657,80		300,30
23	Umi Maryatun	184,00			75,00	0,01	273	1,571	789,36		321,75
24	Jumini/Jujuk	115,00			0,00	0,01	273	1,571	493,35		0,00
25	Mahmuji	170,37			83,33	0,01	273	1,571	730,89		357,50
26	Jumadi	92,00			45,00	0,01	273	1,571	394,68		193,05
27	Didin M	191,67			75,00	0,01	273	1,571	822,25		321,75
28	Supardiyo	131,43			64,29	0,01	273	1,571	563,83		275,79

3.1.2. Estimation of methane Emissions

Survey results in the Boyolali district show that 25% of farmers use organic material in the form of straw as input, with an average amount of 2.42 tons/ha. The use of this organic material is essentially a good practice. However, the decomposition process of straw takes more than 30 days to break down completely. In practice, farmers generally replant seeds after about 10 days, so the straw decomposition process is not optimal. This condition causes the resulting emissions to be quite high

In addition, on most of the land in Boyolali, farmers still practice continuous flooding of their fields during the planting period. This practice increases the potential for methane (CH₄) formation through anaerobic decomposition.

Under these conditions, methane emissions reached 169.02 kg CH₄/ha/year, equivalent to 4.6 tons CO₂-eq/ha/year. Based on production yields, emissions per kilogram of rice amounted to 0.80 kg CO₂-eq/kg rice. More detailed information can be found in Table 3.

Table 3. Methane emissions from farmers in Boyolali

No	Nama	Hari tanam (Hari)	Kg CH ₄ / year / Ha	Kg CO ₂ eq/year/Ha	Kg CO ₂ eq / Kg rice
1	Supardi	120	146,40	3.952,80	0,69
2	Suko Rahayu	120	146,40	3.952,80	0,69
3	Jamhari	125	152,50	4.117,50	0,72
4	Wardiyo	125	152,50	4.117,50	0,72
5	Parno	115	140,30	3.788,10	0,66
6	Sunariyanto	120	146,40	3.952,80	0,69
7	Sugita	115	140,30	3.788,10	0,66
8	Subiyanto	125	152,50	4.117,50	0,72
9	Djumadi	125	152,50	4.117,50	0,72
10	Badrun	110	134,20	3.623,40	0,64
11	Suwarno	120	146,40	3.952,80	0,69
12	Sri Wahyono	120	146,40	3.952,80	0,69
13	Sugiyo	120	146,40	3.952,80	0,66
14	Slamet	120	146,40	3.952,80	0,69
15	Mulyanto	120	146,40	3.952,80	0,69
16	Dina Kristana	115	140,30	3.788,10	0,66
17	Ninik Setianingsih	120	146,40	3.952,80	0,69
18	Jumi	100	122,00	3.294,00	0,58
19	Mulyaman	120	146,40	3.952,80	0,69
20	Natijatun	120	146,40	3.952,80	0,77
21	Amanah	100	122,00	3.294,00	0,66
22	Giyarni	100	290,95	7.855,56	1,40
23	Umi maryatun	100	122,00	3.294,00	0,76
24	Jumini/Jujuk	100	122,00	3.294,00	0,53
25	Mahmuji	100	296,68	8.010,32	1,28
26	Jumadi	100	281,34	7.596,31	1,36
27	Didin M	100	310,65	8.387,63	1,21
28	Supardiyono	100	289,33	7.811,85	1,32

3.2. Klaten

3.2.1. Estimation of chemical input Emissions

Survey results in the Klaten district show that the average area of rice fields managed by farmers is 1,769 m². Farmers carry out the rice cultivation cycle with an average plant age of 111.28 days. To support plant growth, each hectare of land is given inputs in the form of 317.4 kg/ha of urea fertilizer and 342 kg/ha of Ponska fertilizer. All farmers in the sample are recorded as using a combination of these two types of inputs.

With this fertilizer composition, the average rice production (dry unhusked rice) reached 5.7 tons/ha. The emissions generated from fertilizer use included:

- Urea: 626.17 kg CO₂-eq/ha per planting season
- Ponska: 220.54 kg CO₂-eq/ha per planting season

Details of these emissions can be seen in Table 4.

Table 4. NO₂ emissions from farmers in Klaten

No	Nama Petani	Pupuk kimia				Nitrat		Emisi Direct	GWP	NO ₂ /N	Emisi urea (Kg CO ₂ eq / musim tanam / Ha)	Emisi Phonska (Kg CO ₂ Eq / musim tanam / Ha)
		Urea	Urea dalam 1 Ha (Kg/Ha)	Phonska	Phonska dalam 1 Ha (Kg/Ha)	Urea (46%)	Phonska (15%)					
1	Supadi	50	294,12	50	294,12	135,29	44,12	0,01	273	1,571	580,25	189,21
2	Supriyadi	100	400,00	75	300,00	184,00	45,00	0,01	273	1,571	789,14	193,00
3	Gunawan R	50	294,12	50	294,12	135,29	44,12	0,01	273	1,571	580,25	189,21
4	Sihono	50	294,12	50	294,12	135,29	44,12	0,01	273	1,571	580,25	189,21
5	Sutoto	50	294,12	50	294,12	135,29	44,12	0,01	273	1,571	580,25	189,21
6	Dwi Handari	60	342,86	50	285,71	157,71	42,86	0,01	273	1,571	676,41	183,81
7	Sriyatun	60	342,86	50	285,71	157,71	42,86	0,01	273	1,571	676,41	183,81
8	Endah Yuli Astuti	75	441,18	75	441,18	202,94	66,18	0,01	273	1,571	870,38	283,82
9	Sriyono	75	441,18	75	441,18	202,94	66,18	0,01	273	1,571	870,38	283,82
10	Joko Perwito	60	352,94	50	294,12	162,35	44,12	0,01	273	1,571	696,30	189,21
11	Sularmi	60	342,86	60	342,86	157,71	51,43	0,01	273	1,571	676,41	220,57
12	Murniningsih	50	294,12	50	294,12	135,29	44,12	0,01	273	1,571	580,25	189,21
13	Sugino	50	294,12	50	294,12	135,29	44,12	0,01	273	1,571	580,25	189,21
14	Kastowo	60	342,86	75	428,57	157,71	64,29	0,01	273	1,571	676,41	275,71
15	Edi Nuryanto	60	352,94	60	352,94	162,35	52,94	0,01	273	1,571	696,30	227,06
16	Irnawati	60	352,94	60	352,94	162,35	52,94	0,01	273	1,571	696,30	227,06
17	Gunarti	50	294,12	50	294,12	135,29	44,12	0,01	273	1,571	580,25	189,21
18	Parno	75	416,67	60	333,33	191,67	50,00	0,01	273	1,571	822,03	214,44
19	Sariyanto		0,00		0,00	0,00	0,00	0,01	273	1,571	0,00	0,00
20	Sri Asih	50	294,12	75	441,18	135,29	66,18	0,01	273	1,571	580,25	283,82
21	Saryanto	60	300,00	75	375,00	138,00	56,25	0,01	273	1,571	591,86	241,25
22	Yanti	50	333,33	75	500,00	153,33	75,00	0,01	273	1,571	657,62	321,66
23	Maryono	50	208,33	100	416,67	95,83	62,50	0,01	273	1,571	411,01	268,05
24	Widyati Tuturi	60	352,94	60	352,94	162,35	52,94	0,01	273	1,571	696,30	227,06
25	Trimu Suwito	45	281,25	75	468,75	129,38	70,31	0,01	273	1,571	554,87	301,56
26	Margono	50	294,12	75	441,18	135,29	66,18	0,01	273	1,571	580,25	283,82

3.2.2. Estimation of methane input Emissions

Survey results in the Klaten district show that farmers use various types of organic materials as agricultural inputs, including compost (7%) with an average of 250 kg/ha, manure (88%) with an average of 247.7 kg/ha, and straw (96%) with an amount reaching 6.2 tons/ha. The use of these organic materials is beneficial for soil fertility. However, the natural decomposition process of straw takes more than 30 days to complete. In practice, most farmers replant seeds within 10 days, resulting in suboptimal straw decomposition. This contributes to a significant increase in emissions.

In addition, farmers in the Klaten region generally still practice continuous land flooding during the planting season. This practice creates anaerobic conditions that accelerate the formation of methane gas (CH₄) from organic matter that is not completely decomposed.

Based on measurement results, methane emissions reached 442.15 kg CH₄/ha/year, which is equivalent to 11.4 tons CO₂-eq/ha/year. When normalized to production yield, the emission value per kilogram of rice is 1.96 kg CO₂-eq/kg of rice. Full details can be seen in Table 5.

Table 5. Methane emissions from farmers in Klaten

No	Nama	Hari tanam (Hari)	Kg CH ₄ / year / Ha	Kg CO ₂ eq/year /Ha	Kg CO ₂ eq/ Kg Rice
1	Supadi	105	543,81	14.682,9	2,00
2	Supriyadi	115	532,97	14.390,2	2,40
3	Gunawan R	115	351,55	9.491,9	1,82
4	Sihono	115	526,65	14.219,6	2,45
5	Sutoto	115	369,25	9.969,7	1,72
6	Dwi Handari	115	517,82	13.981,1	2,45
7	Sriyatun	115	429,77	11.603,8	1,85
8	Endah Yuli Astuti	115	527,43	14.240,6	2,42
9	Sriyono	115	394,97	10.664,3	1,65
10	Joko Perwito	115	394,97	10.664,3	1,65
11	Sularmi	115	561,50	15.160,5	2,31
12	Murniningsih	112	345,00	9.315,1	1,76
13	Sugino	110	420,71	11.359,1	1,76
14	Kastowo	110	521,92	14.091,9	2,24
15	Edi Nuryanto	115	552,53	14.918,2	2,31
16	Imawati	110	530,03	14.310,8	2,21
17	Gunarti	115	530,72	14.329,4	2,44
18	Parno	115	534,48	14.430,9	2,36
19	Sariyanto		0,00	-	
20	Sri Asih	105	373,57	10.086,4	1,49
21	Saryanto	110	489,18	13.207,9	2,40
22	Yanti	95	421,87	11.390,6	2,01
23	Maryono	105	460,93	12.445,2	2,30
24	Widyati Tuturi	115	384,80	10.389,7	1,61
25	Trimo Suwito	105	433,05	11.692,4	1,87
26	Margono	105	500,09	13.502,5	2,09

3.3. Sragen

3.3.1. Estimation of chemical input Emissions

Survey results in the Sragen region show that the average area of rice fields managed by farmers is 3,360.4 m². Farmers carry out a cultivation cycle with an average crop age of 93.3 days. To support rice growth, each hectare of land is given inputs in the form of 348 kg/ha of urea fertilizer and 378 kg/ha of Ponska fertilizer. All farmers in the sample were recorded as using a combination of these two types of fertilizer.

With this fertilizer input composition, the average rice production (dry unhusked rice) reached 7.3 tons/ha. The emissions generated from fertilizer use include:

- Urea: 686.7 kg CO₂-eq/ha per planting season
- Ponska: 243.04 kg CO₂-eq/ha per planting season

Complete details regarding emissions can be seen in Table 6.

Table 6. NO₂ emissions from farmers in Sragen

No	Nama Petani	Kg CO ₂		Emisi Direct	GWP	NO ₂ /N	Emisi urea (Kg CO ₂ eq)	Emisi Phonska (Kg CO ₂ eq)
		Urea (46%)	Phonska (15%)					
1	Yahman	306,67	100,00	0,01	273	1,57	1315,24	428,88
2	Sofyan	368,00	120,00	0,01	273	1,57	1578,29	514,66
3	Sri Waljinah	460,00	150,00	0,01	273	1,57	1972,86	643,32
4	M Slamet	230,00	53,57	0,01	273	1,57	986,43	229,76
5	Tugiman	306,67	150,00	0,01	273	1,57	1315,24	643,32
6	Pami	276,00	120,00	0,01	273	1,57	1183,72	514,66
7	Mulyanti	306,67	100,00	0,01	273	1,57	1315,24	428,88
8	Samini	306,67	125,00	0,01	273	1,57	1315,24	536,10
9	Warno	42,17	15,00	0,01	273	1,57	180,85	64,33
10	Edy Purwanto	54,76	21,43	0,01	273	1,57	234,86	91,90
11	Mulyanto	0,00	0,00	0,01	273	1,57	0,00	0,00
12	Sutimin	61,33	30,00	0,01	273	1,57	263,05	128,66
13	Sumarno	108,24	22,06	0,01	273	1,57	464,20	94,61
14	Kamto	69,00	15,00	0,01	273	1,57	295,93	64,33
15	Maulud	82,80	18,00	0,01	273	1,57	355,12	77,20
16	Suwardi	46,00	19,50	0,01	273	1,57	197,29	83,63
17	Sumardi	57,50	32,81	0,01	273	1,57	246,61	140,73
18	Warno	61,33	100,00	0,01	273	1,57	263,05	428,88
19	Agung	153,33	20,00	0,01	273	1,57	657,62	85,78
20	Parti	57,50	28,13	0,01	273	1,57	246,61	120,62
21	Sartini	53,67	25,00	0,01	273	1,57	230,17	107,22
22	Sugi	92,00	20,00	0,01	273	1,57	394,57	85,78
23	Joko Purwanto	138,00	30,00	0,01	273	1,57	591,86	128,66
24	Purwadi	204,44	44,44	0,01	273	1,57	876,83	190,61

3.3.2. Estimation of methane Emissions

Survey results in the Sragen region show that 45.8% of farmers use straw as organic material, with an average amount of 3.6 tons/ha. The use of straw as organic input in principle provides benefits in terms of increasing soil fertility. However, the decomposition process of straw takes more than 30 days to fully decompose. In practice, farmers generally replant after about 10 days, so the decomposition process is not optimal. This condition contributes to increased emissions.

In addition, on land in the Sragen region, farmers still flood their fields throughout the planting season, which creates anaerobic conditions and accelerates the formation of methane (CH₄) gas. Under these conditions, methane emissions reach 189.32 kg CH₄/ha/year, equivalent to 5.2 tons CO₂-eq/ha/year. When calculated based on production, the emission value per kilogram of rice is 0.77 kg CO₂-eq/kg rice. Complete details regarding this data can be seen in Table 7.

Table 7. Methane emissions from farmers in Sragen

No	Name	Planting (day)	Kg CH ₄ / year / Ha	Kg CO ₂ eq/year /Ha	Kg CO ₂ eq/ Kg Rice
1	Yahman	95	290,02	7830,61	1,17
2	Sofyan	95	316,20	8537,44	1,07
3	Sri Waljinah	100	305,29	8242,75	1,24
4	M Slamet	100	300,18	8104,96	1,26
5	Tugiman	95	115,90	3129,30	0,47
6	Pami	100	122,00	3294,00	0,55
7	Mulyanti	100	122,00	3294,00	0,49
8	Samini	100	122,00	3294,00	0,49
9	Warno	95	115,90	3129,30	0,38
10	Edy Purwanto	90	109,80	2964,60	0,31
11	Mulyanto	85	85,00	2295,00	0,30
12	Sutimin	95	115,90	3129,30	0,39
13	Sumarno	90	109,80	2964,60	0,34
14	Kamto	95	115,90	3129,30	0,31
15	Maulud	95	115,90	3129,30	0,31
16	Suwardi	90	109,80	2964,60	0,24
17	Sumardi	90	234,74	6338,08	1,35
18	Warno	90	241,37	6516,86	1,30
19	Agung	90	241,37	6516,86	1,30
20	Parti	90	234,74	6338,08	1,35
21	Sartini	90	334,30	9026,04	0,90
22	Sugi	90	334,30	9026,04	0,90
23	Joko Purwanto	90	241,37	6516,86	1,30
24	Purwadi	90	109,80	2964,60	0,80

3.4. Ngawi

3.4.1. Estimation of chemical input Emissions

Survey results in the Ngawi region show that the average area of rice fields managed by farmers is 8,452.4 m². Farmers carry out a cultivation cycle with an average crop age of 109.4 days. To support rice growth, each hectare of land is given inputs in the form of 283.5 kg/ha of urea fertilizer and 306 kg/ha of Ponska fertilizer. All farmers in the sample were recorded as using a combination of these two types of fertilizer.

With this fertilizer input composition, the average rice production (dry unhusked rice) reaches 6.3 tons/ha. The emissions generated from fertilizer use include:

- Urea: 559.3 kg CO₂-eq/ha per planting season
- Ponska: 197.17 kg CO₂-eq/ha per planting season

Detailed information on emissions can be found in Table 8.

Table 8. NO₂ emissions from farmers in Ngawi

No	Nama Petani	Nitrat			Emisi Direct	GWP	NO ₂ /N	Emisi Urea (Kg CO ₂ eq)	Emisi Phonska (Kg CO ₂ eq)	Emisi ZA (Kg CO ₂ eq)
		Urea (46%)	Phonska (15%)	ZA (21%)						
1	Madirun	138,0	60,0		0,01	273	1,571	591,86	257,33	
2	Tohari	138,0	60,0		0,01	273	1,571	591,86	257,33	
3	Simpem	138,0	60,0		0,01	273	1,571	591,86	257,33	
4	Yasin	0,0	0,0		0,01	273	1,571	0,00	0,00	
5	Supriyanto	138,0	60,0		0,01	273	1,571	591,86	257,33	
6	Gunawan	138,0	60,0		0,01	273	1,571	591,86	257,33	
7	Sufiyatin	138,0	60,0		0,01	273	1,571	591,86	257,33	
8	Ngari Adi	138,0	60,0		0,01	273	1,571	591,86	257,33	
9	Lasiman	138,0	60,0		0,01	273	1,571	591,86	257,33	
10	Nuryanto	138,0	60,0		0,01	273	1,571	591,86	257,33	
11	Warsito	131,4	42,9		0,01	273	1,571	563,67	183,81	
12	Mahfut Junaidi	164,3	35,7		0,01	273	1,571	704,59	153,17	
13	Suyanto	131,4	21,4		0,01	273	1,571	563,67	91,90	
14	Djonowiyono	124,3	40,5	56,8	0,01	273	1,571	533,21	173,87	243,42
15	Suradi	98,6	42,9	60,0	0,01	273	1,571	422,76	183,81	257,33
16	Hariyono	65,7	42,9	0,0	0,01	273	1,571	281,84	183,81	
17	Nursamsudin	92,0	30,0	21,0	0,01	273	1,571	394,57	128,66	90,07
18	Sriyuliani	131,4	42,9	0,0	0,01	273	1,571	563,67	183,81	
19	Subandi	230,0	37,5	52,5	0,01	273	1,571	986,43	160,83	225,16
20	Supartan	197,1	42,9	0,0	0,01	273	1,571	845,51	183,81	

3.4.2. Estimation of methane emissions

Survey results in the Ngawi region show that farmers use various types of organic materials as inputs, including straw, compost, molasses, and fresh animal manure. The patterns of combination of organic material use consist of:

- Molasses, straw, and compost: 30%
- Molasses, fresh animal manure, and straw: 10%
- Compost and straw: 15%
- Only one type of organic material, namely compost (5%), straw (20%), and fresh animal manure (5%)

The use of organic materials is essentially a good practice for improving soil quality. However, straw takes more than 30 days to decompose completely. In practice, farmers generally only leave the mixture of organic materials for about 10 days before replanting seeds. This suboptimal decomposition process causes emission factors to increase significantly.

In addition, on land in the Ngawi region, farmers still practice continuous flooding of rice fields, which creates anaerobic conditions and encourages the formation of methane (CH₄) from un decomposed organic matter.

Under these conditions, methane emissions reach 307.8 kg CH₄/ha/year, equivalent to 8.3 tons CO₂-eq/ha/year. When calculated based on production yield, the emission value per kilogram of rice is 1.34 kg CO₂-eq/kg rice. A visualization of this data can be seen in table 9.

Table 9. Methane emissions from farmers in Ngawi

No	Name	Planting (Hari)	Kg CH ₄ / year / Ha	Kg CO ₂ eq/year /Ha	Kg CO ₂ eq/ Kg Rice
1	Madirun	112	597,76	16139,64	2,02
2	Tohari	112	139,36	3762,78	0,57
3	Simpem	112	136,64	3689,28	0,74
4	Yasin	112	513,63	13867,95	2,31
5	Supriyanto	112	333,35	9000,48	1,80
6	Gunawan	112	348,51	9409,70	1,69
7	Sufiyatin	112	136,64	3689,28	0,67
8	Ngari Adi	112	163,82	4423,13	0,55
9	Lasiman	112	416,01	11232,40	2,81
10	Nuryanto	112	417,28	11266,50	1,41
11	Warsito	120	306,43	8273,62	1,45
12	Mahfut Junaidi	105	270,08	7292,21	1,23
13	Suyanto	108	322,29	8701,92	1,09
14	Djonowiyono	105	301,66	8144,82	1,08
15	Suradi	105	268,13	7239,42	1,27
16	Hariyono	105	362,70	9792,83	1,37
17	Nursamsudin	105	320,90	8664,23	1,40
18	Sriyuliani	105	244,93	6613,24	0,93
19	Subandi	105	321,91	8691,69	1,34
20	Suparlan	105	233,18	6295,78	1,00

3.5. Madiun

3.5.1. Estimation of chemical input Emissions

Survey results in the Madiun region show that the average area of rice fields managed by farmers is 3,624.3 m². Farmers carry out the rice cultivation cycle with an average crop age of 100.6 days. To support plant growth, each hectare of land is given a combination of inputs in the form of 211.3 kg/ha of urea fertilizer per planting season and 113.5 kg/ha of NPK fertilizer per planting season.

With this fertilization composition, the average rice production (dry unhusked rice) reaches 6.3 tons/ha per planting season. The emissions generated from fertilizer use include:

- Urea: 406.2 kg CO₂-eq/ha per growing season
- NPK: 72.71 kg CO₂-eq/ha per growing season

Full details regarding these emissions can be found in Table 10.

Table 10. NO₂ emissions from farmers in Madiun

No	Nama Petani	NO ₂		Emisi Direct	GWP	NO ₂ /N	Emisi Urea (Kg CO ₂ eq)	Emisi NPK (Kg CO ₂ eq)
		Urea (46%)	NPK (15%)					
1	Sulastri	115	15	0,01	273	1,571	493,22	64,33
2	Nurhayatin	115	15	0,01	273	1,571	493,22	64,33
3	Sumarsih	115	15	0,01	273	1,571	493,22	64,33
4	Yahmi	115	15	0,01	273	1,571	493,22	64,33
5	Sunarno	115	15	0,01	273	1,571	493,22	64,33
6	Untung	115	15	0,01	273	1,571	493,22	64,33
7	Dani Setyowati	115	15	0,01	273	1,571	493,22	64,33
8	Apriliani Istanti	115	15	0,01	273	1,571	493,22	64,33
9	Giman	115	15	0,01	273	1,571	493,22	64,33
10	Jaiman	115	15	0,01	273	1,571	493,22	64,33
11	Sumarno	115	15	0,01	273	1,571	493,22	64,33
12	Sasminto	115	15	0,01	273	1,571	493,22	64,33
13	Suratmin	115	15	0,01	273	1,571	493,22	64,33
14	Sukardi	115	15	0,01	273	1,571	493,22	64,33
15	Susanto	115	15	0,01	273	1,571	493,22	64,33
16	Suseno	115	15	0,01	273	1,571	493,22	64,33
17	Suradi	69	22,5	0,01	273	1,571	295,93	96,50
18	Paijan	39,43	12,86	0,01	273	1,571	169,10	55,14
19	Sayid	57,5	18,75	0,01	273	1,571	246,61	80,42
20	Edi Triyono	69	22,5	0,01	273	1,571	295,93	96,50
21	Samsu	69	22,5	0,01	273	1,571	295,93	96,50
22	Sanem	69	22,5	0,01	273	1,571	295,93	96,50
23	Suwarno	65,71	21,43	0,01	273	1,571	281,84	91,90
24	Suryadi	55,2	18	0,01	273	1,571	236,74	77,20

3.5.2. Estimation of chemical input Emissions

Survey results in the Madiun region show that farmers use organic materials such as straw and compost. A combination of straw and compost is used by 33% of farmers, while the remaining 67% use only one type of organic material, mainly compost.

The use of organic materials in principle provides benefits for improving soil fertility. However, straw takes more than 30 days to decompose completely. In practice, farmers generally only leave these organic materials on the land for about 10 days before replanting seeds, so the decomposition process is not optimal. This condition contributes to increased emissions from the decomposition of organic materials, especially in flooded fields.

In addition, farmers in the Madiun region still practice flooding their fields throughout the growing season, which creates anaerobic conditions and supports the formation of methane gas (CH₄). Based on these conditions, methane emissions reached 221.9 kg CH₄/ha/year, equivalent to 5.9 tons CO₂-eq/ha/year. When normalized to production yield, the emission value per kilogram of rice is 0.92 kg CO₂-eq/kg rice. A visualization of these results can be seen at Table 11

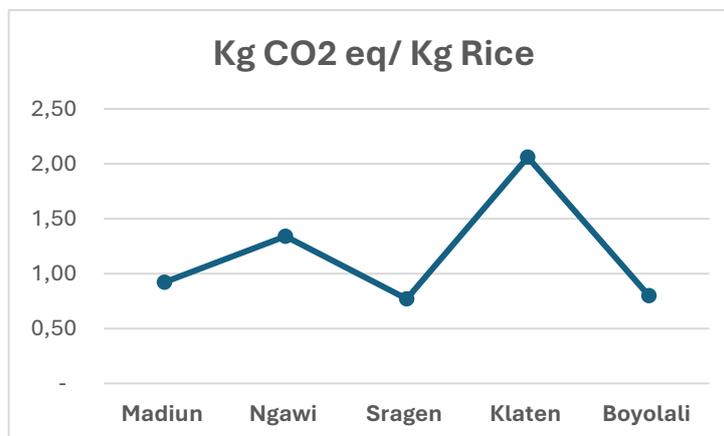
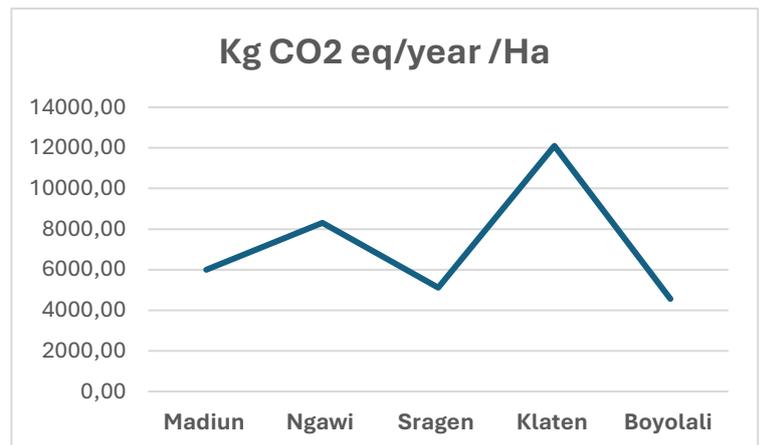
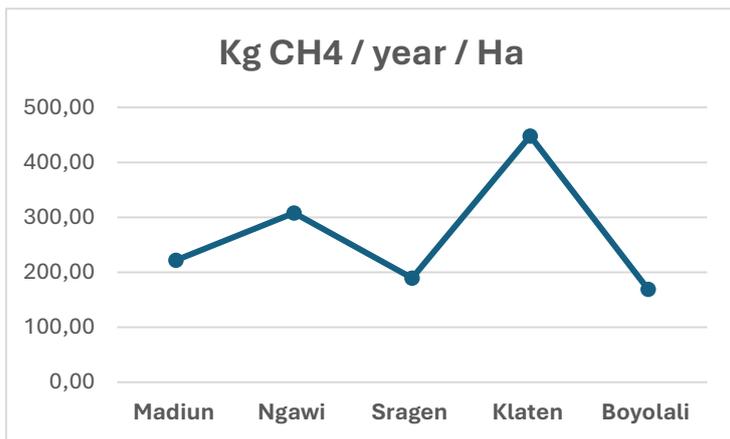
Table 11. Methane emissions from farmers in Ngawi

No	Name	Planting (day)	Kg CH ₄ / year / Ha	Kg CO ₂ eq/year /Ha	Kg CO ₂ eq/ Kg Rice
1	Sulastri	98	122,28	3301,55	0,50
2	Nurhayatin	98	124,29	3355,88	0,61
3	Sumarsih	98	124,58	3363,64	0,70
4	Yahmi	98	121,47	3279,64	0,63
5	Sunarno	98	127,38	3439,21	0,41
6	Untung	98	121,47	3279,64	0,59
7	Dani Setyowati	98	120,52	3253,95	0,54
8	Apriliani Istanti	98	122,73	3313,68	0,50
9	Giman	98	122,19	3299,05	0,51
10	Jaiman	98	122,19	3299,05	0,51
11	Sumarno	98	122,19	3299,05	0,51
12	Sasminto	98	122,19	3299,05	0,51
13	Suratmin	98	122,19	3299,05	0,51
14	Sukardi	98	122,19	3299,05	0,51
15	Susanto	98	122,19	3299,05	0,51
16	Suseno	95	116,83	3154,34	0,45
17	Suradi	98	433,68	11709,45	1,46
18	Paijan	98	408,64	11033,28	1,54
19	Sayid	90	406,90	10986,42	1,32
20	Edi Triyono	127	485,55	13109,83	2,18
21	Samsu	98	405,08	10937,20	1,56
22	Sanem	98	341,87	9230,49	1,85
23	Suwarmo	98	409,22	11049,02	1,55
24	Suryadi	125	477,90	12903,37	2,15

4. COMPARATIVE ANALYSIS OF EMISSIONS FROM MADIUN, NGAWI, KLATEN, SRAGEN, AND BOYOLALI DISTRICT

A comparative study of emission levels in five districts—Madiun, Ngawi, Klaten, Sragen, and Boyolali—shows variations influenced by differences in agricultural management practices and organic material processing systems. The emissions produced in each region reflect not only the intensity of agricultural activities, but also the methods used to process organic waste. The comparison is shown in the table below.

No	District	Kg / CH ₄ / Year / Ha	Kg CO ₂ eq/year /Ha	Kg CO ₂ eq/ Kg Rice
1	Madiun	221,90	5991,40	0,92
2	Ngawi	307,76	8309,55	1,34
3	Sragen	189,32	5111,5	0,77
4	Klaten	448,06	12097,7	2,06
5	Boyolali	169,02	4563,43	0,80



The analysis shows that Klaten Regency is the area with the highest emission levels. The dominance of emissions from Klaten is mainly due to the large amount of organic material input and the incomplete

processing of organic material, particularly in the practice of converting organic waste into fertilizer. The imperfection of the decomposition process has the potential to increase the release of greenhouse gases, especially methane (CH₄), which is formed when organic materials undergo anaerobic decomposition. This condition indicates the need to improve the quality of composting technology and organic waste management in the region.

In contrast, the other four districts showed relatively low emission levels. Contributing factors include the low use of organic fertilizers. Madiun and Boyolali districts are in the medium emission category, indicating that although organic waste management systems have been implemented, there is still room for improvement in terms of composting efficiency and agricultural residue management.

Overall, these findings confirm that the quality of organic material processing is a major determinant of interregional emission variability. Interventions through increasing farmer capacity, adopting more effective composting technologies, and implementing stricter organic waste management policies can be strategic steps to reduce emissions.

On the other hand, the calculations still use default values, which indicate that perfect management is limited to 30 days. It is possible that effective organic material management by adding local microorganisms could reduce this time and possibly reduce emissions. Therefore, direct emission calculations could also be a corrective factor, especially in Klaten Regency, which is currently the largest contributor.

5. RECOMMENDATION

1. Emissions calculations should be based on data from more than one growing season to obtain a more accurate picture of emissions variability and reduce bias due to specific conditions during a particular growing period.
2. Emissions calculations need to be made directly through field measurements, not just relying on default values. This approach will produce emission estimates that are more representative of local conditions, including differences in cultivation practices, types of inputs, and local environmental characteristics.