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Assessing Environmental Impact and Farmers' Awareness in Irrigated and Rainfed Rice Farming for Sustainable Agriculture in Yogyakarta, Indonesia

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ABSTRACT

The agricultural sector still playing a significant role in Indonesia's economy; however, it also has an environmental impact, particularly due to the use of chemicals. Yogyakarta is one of the regions in Indonesia with substantial rice production, but unfortunately the awareness regarding the environmental impact of the rice farming is still low. Therefore, this study aims to analyze the environmental impact of irrigated and rainfed rice farming systems in Yogyakarta, as well as the farmers' awareness of the environmental consequences of their farming practices. This study result can help to raise the awareness of environmental impact from rice farming. Data were collected through interviews with 150 irrigated rice farmers in Sleman Regency and 100 rainfed rice farmers in Gunungkidul Regency. The analytical tool used for environmental impact assessment was the Life Cycle Assessment (LCA) approach, and awareness was analyzed descriptively. Environmental awareness revealed relationships with farmer characteristics such as age, income, and land area. The environmental impact analysis indicated that irrigated farming has a lower total impact (23 Pt) compared to rainfed farming (25.7 Pt). In the climate change impact category, irrigated rice farming had a lower value of 6.34 Pt compared to rainfed land of 11.3 Pt. Although the environmental impact produced is relatively small compared to the industrial sector, it still needs attention from relevant stakeholders to ensure that the environmental impact of rice farming does not develop in a more negative direction.

1. INTRODUCTION

The agricultural sector plays a crucial role in supporting the nation's economy [1, 2]. This is due to the large number of Indonesians who rely on agriculture for their livelihoods, particularly in rice cultivation [3]. In 2022, the harvested area for rice spanned 10.61 million hectares, an increase from 10.41 million hectares in 2021. The distinction between rice fields and upland serves as a basis for the rice farming system, where rice fields often utilize irrigation systems, and upland areas rely on rain-fed systems [4].

Rice farming activities, while positively contributing to food security [2, 5], also have negative environmental impacts, such as the use of chemical fertilizers or fuel-powered agricultural machinery [6]. The increased usage of these inputs results in greater environmental impacts [7]. If left unaddressed, these environmental impacts, such as the rise in CO_2 levels, will exacerbate greenhouse gas effects. The increase in greenhouse gases can impact the atmosphere and damage the ozone layer [8-10]. Climate change is also a consequence of environmental changes induced by human activities [11, 12]. And in fact, many farmers are already aware of the impact of climate change on their farming activities [13-15] show that the carbon footprint in Yogyakarta is quite low compare to the other area in Indonesia, but due to the growing of rice production may increase the environmental impact late or sooner. And research by Triyono et al. [16] suggest that Yogyakarta need to implement sustainable agriculture to support the environment. These prove that Yogyakarta face environmental issue for rice farming.

In Indonesia, there are two types of irrigation systems for rice farming: rain-fed and irrigated [17, 18]. Each system has distinct characteristics. Some regions are suitable for irrigation development, but certain areas, such as mountainous or arid regions, have not yet benefited from irrigation channels and thus rely solely on rain-fed systems [19, 20]. These two systems may have differing environmental impacts, considering the varying characteristics of rain-fed and irrigated farmers, as well as differences in the type and quantity of inputs used [21]. In Yogyakarta, both irrigation and rain-fed rice farming systems are present, each generally impacting the environment [16].

The environmental impacts of rice farming activities are not widely recognized by farmers [22], including in Yogyakarta. Increased environmental awareness among farmers can help mitigate these impacts by reducing the use of chemical inputs [23, 24]. Partially, the research about carbon footprint and heavy metal of agricultural practices have been conducted [25, 26], however there is still limited that focus on rice farming which dominating the agricultural practice in Yogyakarta. Therefore, this study aims to analyze the environmental impacts of irrigated and rain-fed rice farming systems in Yogyakarta, as well as farmers' awareness of the environmental impacts resulting from their farming activities.

2. RESEARCH METHOD

2.1 Research location

The selection of research locations was conducted purposively, focusing on Minggir Subdistrict in Sleman Regency and Bantul Subdistrict in Bantul Regency, considering that the land in these areas consists of irrigated rice fields. For rain-fed land, the research was conducted in Panggang Subdistrict, Gunung Kidul Regency. The location was also chosen purposively, taking into account that all rice farmers in area practicing the rain-fed system.

2.2 Sampling procedure and data collection

Data for this study were obtained through interviews with 250 farmers. This included 75 irrigated rice farmers from each location, Minggir District in Sleman Regency and Bantul District in Bantul Regency, resulting in a total of 150 respondents for irrigated rice farming. Additionally, in Panggang District, Gunungkidul Regency, 100 rain-fed rice farmers were interviewed (Table 1).

Table 1. Sample location

Farming Type	Location	Respondents
Irrigation	Minggir Subdistrict, Sleman Regency	75
	Bantul Subdistrict, Bantul Regency	75
Rainfed	Panggang Subdistrict, Gunungkidul Regency	100
Total		250

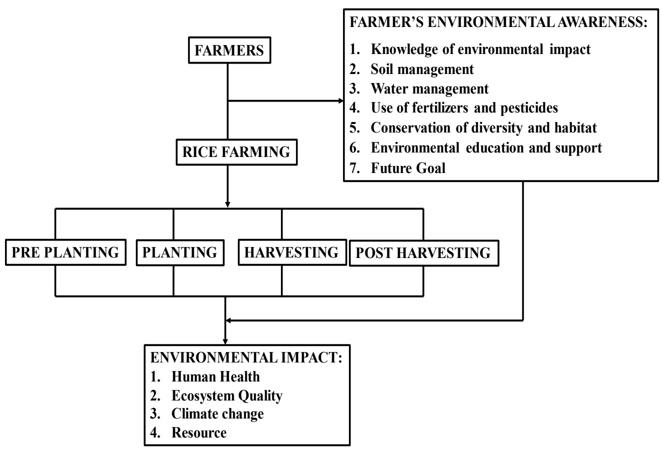

Figure 1. Environmental impact flowchart

The environmental awareness analysis will include seven indicator variables, each measured using a single question on a 5-point scale ranging from "1-strongly disagree" to "5-strongly agree." The seven indicators of environmental awareness are (Figure 1):

1) Knowledge of environmental impacts, to assess farmers' understanding of the environmental impacts of various farming activities and other activities.
2) Soil management, to determine farmers' responses regarding soil management practices in farming.
3) Water management, to evaluate farmers' responses concerning water management in agricultural activities.
4) Use of fertilizers and pesticides, to gauge farmers' responses about the use of chemical fertilizers and pesticides in farming.
5) Conservation of biodiversity and habitats, to assess farmers' awareness of preserving biodiversity and habitats.
6) Environmental education and support, to evaluate farmers' responses regarding the role of education quality and government support in environmental conservation.
7) Future goals, to understand farmers' long-term objectives for maintaining environmental sustainability.

For the environmental impact analysis, data were collected regarding the inputs used from pre-planting to post-harvest activities conducted by the farmers. The focus of the environmental impact analysis includes human health, ecosystem quality, climate change, and resource use.

2.3 Analytical technique

This research employs a descriptive quantitative method which can better picturing the findings. Life Cycle Assessment (LCA) was used as approach to know the environmental impacts of rice farming. And SimaPro using the IMPACT 2002+method, the quantity of inputs in farming activities were analyzed. For the environmental awareness analysis, Rank Spearman was used to analyzed the correlation between the seven indicators of environmental awareness and farmer characteristics, which include age, land area, education level, and farmer income.

3. RESULTS AND DISCUSSION

3.1 Farmers' characteristics

The socioeconomic characteristics of farmers provide background information on the social and economic conditions of irrigated rice farmers and rain-fed rice farmers, potentially influencing their awareness of environmental impacts [27]. These characteristics include age, education level, income, and land area.

Based on Table 2, the age distribution of rain-fed rice farmers shows that the largest group, 47%, is aged between 50-60 years. This age group falls within the productive age range for rice farming, with sufficient physical capability to manage farming activities. This observation is consistent with Shalli et al. [28], who noted that age influences physical ability and farm management skills.

Regarding the education level of rain-fed rice farmers, the majority, 59%, have completed elementary school (SD). This low level of education indicates a lower quality of human resources for improving farm performance. This aligns with Guo et al. [29] and Ruhyana et al. [30], who found that education level impacts the ability to enhance performance for economic improvement.

Table 2. Rain-fed farmers characteristics

Age	Freq.	Percent.	Income	Freq.	Percent.
28-38	2	2.00	≤3,500,000	30	30.00
39-49	30	30.00	3,500,001-7,500,000	44	44.00
50-60	47	47.00	7,500,001-11,500,000	12	12.00
61-71	18	18.00	11,500,001-15,500,000	9	9.00
72-82	3	3.00	15,500,001≤	5	5.00
	100	100.00		100	100.00
Education	**Freq.**	**Percent.**	**Land Size (m^2)**	**Freq.**	**Percent.**
No School	1	1.00	300-4,240	18	18.00
Elementary School	59	59.00	4,241-8,181	40	40.00
Primary School	29	29.00	8,182-12,122	25	25.00
High School	10	10.00	12,123-16,063	12	12.00
Diploma/University	1	1.00	16,064-20,004	5	5.00
	100	100.00		100	100.00

Table 3. Irrigated famers characteristics

Age	Freq.	Percent	Income	Freq.	Percent
34-43	9	6.00	≤3,500,000	68	45.33
44-51	27	18.00	3,500,001-7,500,000	52	34.67
52-59	45	30.00	7,500,001-11,500,000	9	6.00
60-67	47	31.33	11,500,001-15,500,000	7	4.67
68-76	22	14.67	15,500,001≤	14	9.33
	150	**100.00**		**150**	**100.00**
Education	**Freq.**	**Percent**	**Land Size (m^2)**	**Freq.**	**Percent**
No School	9	6.00	300-4,240	105	70.00
Elementary School	38	25.33	4,241-8,181	30	20.00
Primary School	40	26.67	8,182-12,122	8	5.33
High School	49	32.67	12,123-16,063	6	4.00
Diploma/University	14	9.33	16,064-20,004	1	0.67
	150	**100.00**		**150**	**100.00**

In terms of income, 44% of rain-fed rice farmers earn between IDR 3,500,000 and IDR 7,500,000. The income level is relatively low, influenced by land area and farming practices on the farmers' land. The most common land area owned by rain-fed rice farmers is between 4,241-8,181m^2, accounting for 40%, while the largest land area is 16,064-20,004m^2, representing 5%. Rain-fed rice farmers generally have larger land areas compared to those in Giritirto Village, Purwosari District, where the average land area is 2,500m^2. In Indonesia, the average land ownership among farmers is quite small, typically less than 1,000m^2 [31].

Table 3 presents the characteristics of irrigated rice farmers, revealing that the majority, 47%, are aged between 60-67 years, indicating an older demographic. While increasing age enhances farming experience and skills, it can lead to decreased performance and productivity [32].

The education level of irrigated rice farmers is predominantly high school, with 49 farmers holding this level of education. This is advantageous as higher education levels facilitate the absorption of new knowledge and technological advancements in any sector, particularly agriculture [33]. The relatively high education level indicates a strong awareness of formal education and the availability of adequate educational facilities.

Income for irrigated rice farmers is mostly below IDR 3,500,000, attributed to relatively low rice production yields, resulting in lower income levels. Regarding land area, 70% of irrigated rice farmers own between 250-4,240m^2. The relatively small land areas influence lower production yields and, consequently, lower farmer incomes. Efforts to intensify farming through the use of high-quality seeds or agricultural machinery are undertaken, but limited land and resources result in less than optimal outcomes [34].

3.2 Farmers environmental awareness

3.2.1 Environmental awareness

Farmer awareness of environmental issues is a crucial component in efforts to achieve agricultural sustainability. Environmental awareness indicators can reveal the level of farmers' awareness and serve as a reference for environmental conservation efforts in the agricultural sector. According to Table 4, the indicators-ranging from knowledge of environmental impacts, soil management, water management, fertilizer and pesticide use, biodiversity and habitat conservation, environmental education and support, to future goals-have respective scores of 4.55, 4.03, 3.72, 4.51, 4.53, 4.28, and 4.49. All indicators are categorized as good, with an overall average score of 4.30, which also falls within the good category.

The same results were obtained in the assessment of indicators among irrigation farmers, with consecutive scores of 4.09, 4.10, 4.23, 4.20, 4.30, 4.23, 4.22 indicating a rating of "Good" (Table 5). This indicates that environmental awareness among both rainfed and irrigated rice farmers falls within the "Good" category. Such good environmental awareness serves as a foundation that farmers can use to enhance their commitment to reducing chemical inputs or activities that have potential environmental disturbances in their farming practices [35].

Table 4. Rain-fed farmers' environmental awareness

Indicator	Score	Category
Knowledge of environmental impacts	4.55	Good
Soil management	4.03	Good
Water management	3.72	Good
Use of fertilizers and pesticides	4.51	Good
Conservation of biodiversity and habitats	4.53	Good
Education and environmental support	4.28	Good
Future Goal	4.49	Good
Total	**4.30**	**Good**

Table 5. Irrigated farmers' environmental awareness

Indicator	Score	Category
Knowledge of environmental impacts	4.09	Good
Soil management	4.10	Good
Water management	4.23	Good
Use of fertilizers and pesticides	4.20	Good
Conservation of biodiversity and habitats	4.30	Good
Education and environmental support	4.23	Good
Future Goal	4.22	Good
Total	**4.20**	**Good**

Table 6. Factors that have correlation for rain-fed farmers

	Age	Edu.	Income	Land
Knowledge of environmental impact	.213	-.019	-.097	.166
	.137	.894	.339	.249
Soil management	.287*	.129	-.003	-.008
	.043	.371	.980	.954
Water management	-.077	-073	.083	-.060
	.596	.616	.414	.678
Use of fertilizers and pesticides	.325*	.013	.091	-.097
	.021	.929	.528	.503
Conservation of diversity and habitat	.327*	-.206	-.008	-.025
	.021	.151	.935	.862
Environmental education and support	.293*	.045	.126	-.035
	.039	.755	.211	.812
Future Goal	.220	.104	.105	.091
	.126	.473	.297	.529

3.2.2 Correlated factors

The correlation analysis using the Rank Spearman method between farmer characteristics and environmental awareness indicators was conducted to determine relationships among all variables and ascertain correlation coefficients for these relationships. According to Tables 6 and 7, the results indicate that farmer Age significantly correlates with the Soil Management Indicator, with a correlation coefficient of 0.287 and a significance level of 5%. Based on field conditions, rice farmers in Girikarto Village predominantly use organic fertilizers over chemical fertilizers, and they infrequently conduct soil testing on their land.

Furthermore, Age shows a significant correlation at the 5% significance level with the Biodiversity and Habitat Conservation Indicator, with a correlation coefficient of 0.325. Age also correlates significantly at the 5% level with the Pesticide and Fertilizer Use Indicator, with a correlation coefficient of 0.327. Another correlation involving Age is observed with the Environmental Education and Support Indicator. Age and environmental education/support indicators exhibit a significant relationship at the 5% significance level, with a correlation coefficient of 0.293.

In Table 6, the results show that Land Area characteristics exhibit inverse correlations at a 5% significance level with the indicators Knowledge of environmental impacts, Soil management, Water management, Fertilizer and pesticide use, and Environmental education and support, with respective correlation coefficients of 0.196, 0.172, 0.167, 0.193, and 0.179. Additionally, Land Area demonstrates an inverse correlation at a 1% significance level with a coefficient of 0.226. This indicates that as land area increases, the level of awareness regarding environmental indicators decreases.

In addition to Land Area, Age and Income are also correlated. Age correlates positively with the Soil management and Future goals indicators at a 5% significance level, with coefficients of 0.172 and 0.189, respectively. Income, on the other hand, correlates positively with the Future goals indicator at a 5% significance level with a coefficient of 0.177.

3.3 Environmental impact

3.3.1 Network

The network is used to understand the relationships between agricultural activities that impact the environment. Red lines indicate the influence on environmental impacts, where thicker red lines indicate greater influence. Based on Figure 2, it is found that the input contributing significantly to the environmental impact of rain-fed rice farming is fertilizer (N), with 24.3 Pt, indicated by thick red arrows.

In Figure 3, red lines are used to depict environmental impact influences. The input material most affecting environmental impact is Urea, used for land processing, planting, and pesticides. According to the diagram, Urea as an input material shows high and thick red lines, indicating that its use in irrigated rice farming significantly affects the environmental impact of rice farming.

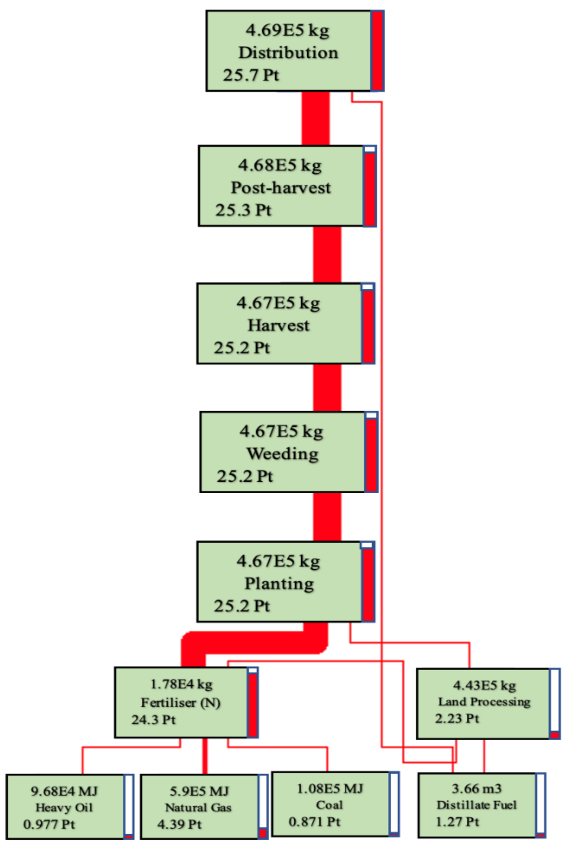

Figure 2. Network for rain-fed rice

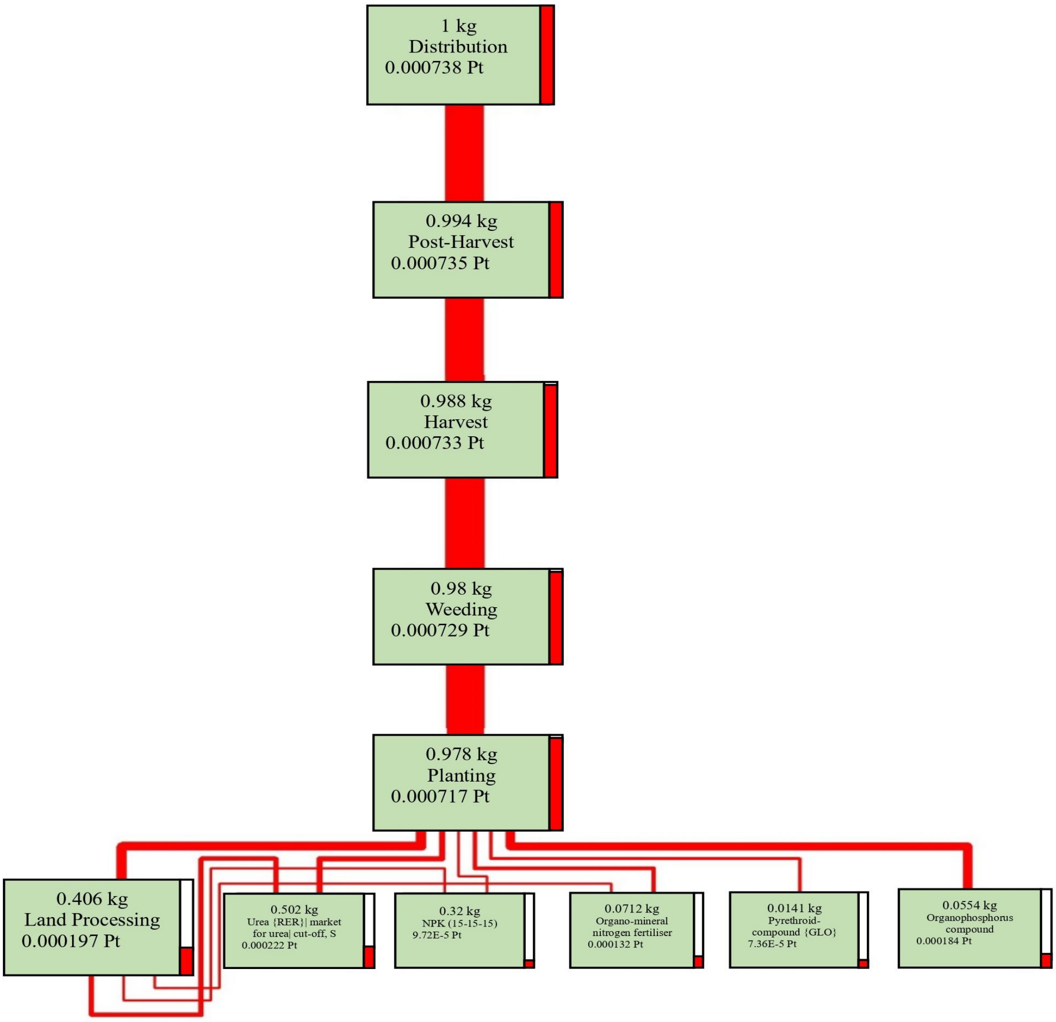

Figure 3. Network for irrigated rice

Table 7. Factors that have correlation for irrigated farmers

	Age	Edu.	Income	Land Size
Knowledge of environmental impact	.027	.153	.057	-.196*
	.747	.062	.486	.016
Soil management	.172*	.020	.123	-.172*
	.035	.812	.135	.035
Water management	.089	.039	.070	-.167*
	.280	.632	.394	.042
Use of fertilizers and pesticides	.082	.0.72	.049	-.193*
	.316	.384	.554	.503
Conservation of diversity and habitat	.113	.004	-.018	-.226**
	.17	.963	.825	.006
Environmental education and support	.130	.027	.139	-.179*
	.113	.746	.089	.028
Future Goal	.189*	.021	.177*	-.114
	.021	.801	.030	.163

3.3.2 Characterization

The data obtained after inputting agricultural inputs resulted in characterization data, yielding 15 impact categories (Tables 8 and 9). These categories are used to detail each impact in respective units to understand their specific effects.

3.3.3 Damage assessment

The damage assessment stage is used to evaluate the impacts of damage based on their impact categories. This stage aims to categorize several indicators from the characterization stage into 4 scopes of damage categories.

In Table 10, the first impact category from rain-fed farming, human health, is found to have an overall impact total of 0.0512, with the highest value observed in the Post-Harvest process at 0.0508 DALY (Disability-Adjusted Life Years). One DALY represents one year of healthy life lost. According to Table 11, the impact from irrigated farming on human health totals 0.0519, indicating that the impact on human health is not greater than that of rain-fed land.

Next, in the ecosystem quality category, it is noted from the table that the highest value is associated with "Post-Harvest". This is because the post-harvest phase involves activities from land processing to post-harvesting, thus involving more complex inputs such as chemical fertilizers, pesticides, and fuel use in agricultural activities, resulting in an ecosystem quality impact of 3.73×10^3 PDFm²yr (Potentially Disappeared Fraction per square meter per year). Table 10 shows that on irrigated land, the impact amounts to 8.69×10^3 PDFm²yr. Therefore, based on calculations, rain-fed farming has the potential to impact species or ecosystems over an area of 3,740 m² per year, whereas irrigation affects ecosystem quality over an area of 8,690m².

Moving on to the climate change category, Table 10 reveals that the impact generated from climate change due to rain-fed farming amounts to 1.12×10^5kg CO_2eq (carbon dioxide equivalent), whereas irrigation yields 6.28×10^4kg CO_2eq. Rain-fed rice farming thus potentially contributes 112,000kg CO_2eq to climate change, while irrigated rice contributes 62,800kg CO_2eq. Previous research [36] showed that organic Hom Mali rice farming in Thailand produced 2.88kg CO_2eq per kg of rice. If Thailand's annual organic Hom Mali rice harvest totals 17 million tons, the climate change impact amounts to 4.896×10^{10}kg CO_2eq.

In the resources category, rain-fed rice farming has a total surplus of 1.06×10^6 MJ surplus, while irrigated rice production results in a surplus impact of 1.33×10^4 MJ surplus. This indicates the amount of energy required for extracting natural resources, with rain-fed and irrigated fields requiring 1,060,000 MJ surplus and 1,330,000 MJ surplus respectively.

Table 8. Characterization for rain-fed rice

Impact Category	Unit	Total	Distribution	Post-Harvest	Gasoline FAL	Destillate Fuel Oil (DFO) FAL
Carcinogens	kg C_2H_3Cl eq	42.4	0	42.3	0.00538	0.0184
Non-carcinogens	kg C_2H_3Cl eq	220	0	219	0.0764	0.263
Resp. Inorganics	kg $PM_{2.5}$ eq	72	0	71.5	0.106	0362
Ionizing radiation	Bq C-14 eq	0	0	0	0	0
Ozone layer depletion	kg CFC-11 eq	6.79E-6	0	4.7E-6	4.66E7	1.62E-6
Resp. organics	Kg C_2H_4 eq	21,9	0	17.3	1.04	356
Aquatic ecotoxicity	kg TEG water	3.3E3	0	2.43E3	196	678
Terrestrial ecotoxicity	kg TEG soil	1.78E3	0	1.58E3	42.2	149
Terrestrial acid/nutri	kg SO_2 eq	3.58E3	0	3.57E3	2.48	8.51
Land occupation	m²org.arable	0	0	0	0	0
Aquatic acidification	kg SO_2 eq	577	0	573	1.08	3.72
Aquatic eutrophication	kg PO_4 P-lim	0.0111	0	0.00768	0.000769	0.00265
Global warming	kg CO_2 eq	1.12E5	0	1.11E5	90.7	312
Non-renewable energy	MJ primary	1.06E6	0	1.01E6	1.19E4	4.09E4
Mineral extraction	MJ surplus	0	0	0	0	0

Table 9. Characterization for irrigated rice

Impact Category	Unit	Total	Distribution	Post-Harvest	Gasoline FAL	Destillate Fuel Oil (DFO) FAL
Carcinogens	kg C_2H_3Cl eq	573	0	573	0.0493	0.197
Non-carcinogens	kg C_2H_3Cl eq	1.82E3	0	1.77E3	10	40
Respiratory inorganics	kg $PM_{2.5}$ eq	64.2	0	64.1	0.0302	0.121
Ionizing radiation	Bq C-14 eq	4.42E5	0	4.42E5	0	0
Ozone layer depletion	kg CFC-11 eq	0.0106	0	0.0106	5.86E9	2.34E8
Respiratory organics	kg C_2H_4 eq	57.3	0	57	0.0573	0.229
Aquatic ecotoxicity	kg TEG water	3.34E6	0	3.01E6	6.68E4	2.67E5
Terrestrial ecotoxicity	kg TEG soil	7.22E5	0	7.22E5	7.38	29.5
Terrestrial acid/nutri	kg SO_2 eq	1.37E3	0	1.37E3	0.879	3.51
Land occupation	m²org.arable	1.27E3	0	1.27E3	0	0
Aquatic acidification	kg SO_2 eq	399	0	397	0.279	1.12
Aquatic eutrophication	kg PO_4 P-lim	84.4	0	84.4	0.00122	0.00488
Global warming	kg CO_2 eq	6.28E4	0	6.27E4	18.1	72.3
Non-renewable energy	MJ primary	1.33E6	0	1.32E6	2.12E3	8.45E3
Mineral Extraction	MJ surplus	2.96E3	0	2.96E3	0	0

Table 10. Damage assessment rain-fed rice

Damage Category	Unit	Total	Distrib.	Post-Harvest	Gasoline FAL	Destillate Fuel Oil (DFO) FAL
Human Health	DALY	0.0512	0	0.0508	7.63E-5	0.000262
Ecosystem Quality	PDF*m²yr	3.74E3	0	3.73E3	2.92	10.1
Climate Change	kg CO_2eq	1.12E5	0	1.11E5	90.7	312
Resources	MJ surplus	1.06E6	0	1.01E6	1.19E4	4.09E4

Table 11. Damage assessment for irrigated

Damage Category	Unit	Total	Distrib.	Post-Harvest	Gasoline FAL	Destillate Fuel Oil (DFO) FAL
Human Health	DALY	0.0519	0	0.0516	4.95E5	0.000198
Ecosystem Quality	PDF*m²yr	8.69E3	0	8.67E3	4.32	17.3
Climate Change	kg CO_2eq	6.28E4	0	6.27E3	18.1	72.3
Resources	MJ surplus	1.33E6	0	1.32E6	2.12E3	8.45E3

Table 12. Normalization for rain-fed rice

Damage Category	Total	Distrib.	Gasoline FAL	Destillate Fuel Oil (DFO) FAL	Post-Harvest
Human Health	7.21	0	0.0108	0,037	7.17
Ecosystem Quality	0.273	0	0.000213	0.000735	0.272
Climate Change	11.3	0	0.00916	0.0315	11.2
Resources	6.97	0	0.0784	0.269	6.62

Table 13. Normalization for irrigated rice

Damage Category	Total	Distrib.	Gasoline FAL	Destillate Fuel Oil (DFO) FAL	Post-Harvest
Human Health	7.32	0	0.00698	0.0279	7.28
Ecosystem Quality	0.634	0	0.000316	0.00126	0.633
Climate Change	6.34	0	0.00183	0.0073	6.33
Resources	8.75	0	0.0139	0.0556	8.68

Table 14. Weighting for rain-fed rice

Damage Category	Unit	Total	Distrib.	Gasoline FAL	Destillate Fuel Oil (DFO) FAL	Post-Harvest
Total	Pt	25.7	0	0.0985	0.338	25.3
Human Health	Pt	7.21	0	0.0108	0.037	7.17
Ecosystem Quality	Pt	0.273	0	0.000213	0.000735	0.272
Climate Change	Pt	11.3	0	0.00916	0.0315	11.2
Resources	Pt	6.97	0	0.0784	0.269	6.62

Table 15. Weighting for irrigated rice

Damage Category	Unit	Total	Distrib.	Gasoline FAL	Destillate Fuel Oil (DFO) FAL	Post-Harvest
Total	Pt	23	0	0.0231	22.9	22.9
Human Health	Pt	7.32	0	0.00698	7.28	7.28
Ecosystem Quality	Pt	0.634	0	0.000316	0.633	0.633
Climate Change	Pt	6.34	0	0.00183	6.33	6.33
Resources	Pt	8.75	0	0.0139	8.68	8.68

3.3.4 Normalization

Normalization is a stage aimed at standardizing unit measures across all damage categories. This standardization occurs after the damage assessment process and serves to facilitate analysis among environmental impact categories. The results obtained during the normalization stage do not have specific units because this stage involves aligning the unit measures generated from the damage assessment stage (Tables 12 and 13).

3.3.5 Weighting

The weighting stage is where all assessed impacts are simplified and compared on a standardized scale to reflect their relative importance. According to Table 14, the total environmental damage score for rainfed rice farming is 25.7 Pt, whereas Table 15 shows that the total damage score for irrigated rice farming is 23 Pt. In the climate change category, rainfed rice farming has a score of 11.3 Pt, whereas irrigated rice farming has a lower score compared to rainfed rice farming, at 6.34 Pt. The unit of measurement in this stage is Points (Pt), where 1 Pt represents one-thousandth of the annual environmental burden per average European resident [8].

3.3.6 Interpretation

The use of chemical fertilizers (Urea, NPK, KCL) impacts the environmental footprint of both rainfed and irrigated rice farming activities. Additionally, the use of diesel and gasoline in tractors during land preparation and harvesting machines during crop harvesting, as well as in the transportation of harvested produce using motorized vehicles such as motorcycles, trucks, and cars, contribute to this impact. Efforts to reduce the environmental impact of rainfed rice farming can include decreasing the use of chemical fertilizers and increasing the application of organic fertilizers. Furthermore, the use of fossil fuel-powered machinery increases environmental impact through carbon dioxide emissions, which can contribute to greenhouse gas potential if emitted excessively. These impacts can be mitigated through training in the production of organic fertilizers from agricultural waste residues, thereby facilitating the conversion of waste into reusable resources.

Although the result of LCA analysis show different between irrigated and rainfed rice farming, but the same thing is both have environmental impacts. Therefore, the awareness of not only farmers, but also the other stakeholders, need to be raised in order to the sustainable agriculture can be achieved. Based on research by Triyono et al. [16], sustainable agriculture must consider not only the economic side, but also the ecological and social side. Three aspects of sustainable agriculture can be achieved through collaboration among stakeholders where the first step can be the awareness regarding the environmental impact of rice farming [37, 38].

4. CONCLUSION

Overall agricultural development is often assessed based on production levels, while the environmental impacts also need attention. Farmers' awareness of environmental impacts has become a shared concern, shifting focus not only towards increasing production but also towards mitigating the environmental impacts of agricultural activities. Age, income, and land area are correlated with farmers' awareness of the environmental impacts of their rice farming practices. Farmers aged over 50 years appear to have greater awareness of the environmental impacts of their rice farming activities. The environmental impact of irrigated rice farming, which is 23 Pt, is lower than rainfed rice farming, which is 25.7 Pt, mainly due to rainfed systems using larger quantities of organic fertilizers, resulting in higher environmental impact calculations. In the context of climate change, irrigated rice farming also shows lower impacts compared to rainfed rice farming, with values of 6.34 Pt and 11.3 Pt, respectively. Field observations indeed indicate considerable activities in rainfed rice farming, potentially contributing to climate change impacts. Awareness of agricultural impacts on the environment can influence reductions in activities that pose environmental risks. Support from governments, private sectors, and other stakeholders is crucial to enhancing awareness of the environmental impacts of rice farming practices, thereby mitigating these impacts.

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