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Conservation agroecology on organic rice farming through modified environmental model in sustainability

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Abstract

The purpose of this study is to conserve sustainability in organic rice agroecology to preserve the environment from pollutants. Organic farming is a cultivation system that focuses on environmental indicators and sustainability. This research was conducted at the organic rice centre in Penanggal Village, Lumajang District, East Java, Indonesia. The research stages comprised a community typology assessment of organic farming systems referring to SNI 6729:2016. Evaluation and monitoring of environmental quality such as water quality, environmental biological indicators, and agroecology components in agricultural areas. Water quality monitoring results in the upstream and midstream regions are well monitored. Water quality monitoring is inequality standard class III with the designation of irrigation and agricultural cultivation, the results that do not comply with the standard are located in the DO parameter 1.5 mg/L (upstream) and an average of 0.6 mg/L (middle). Indicators do not meet the standards in the BOD parameter (middle), namely 6.40 mg/L and 6.53 mg/L. The biological component in organic system waters has a high diversity index value of 2.007 (upstream) and 1.842 (middle). The indicator is characterized by the number of plankton and benthic species found in the flow of water sources.

Key words: Contaminant, monitoring, polutant, toxicology, water

Introduction

Sustainability is the key to all aspects of technological advancement for the future. Sustainability is not only seen from an economic perspective but also requires a balance between various elements ranging from the environment, regulations, human resources, and social aspects. The agro-industry is one of the accelerated efforts to fulfil human needs. The challenge faced is to increase high productivity based on environmental safety. The organic farming system is one of the implementations for sustainable agriculture. This system restricts synthetic materials from switching to organic materials and utilizing beneficial organisms (Atoloye et al. 2024, Dayet et al. 2024, Habte et al. 2024). Using organic materials and beneficial microorganisms has effectively influenced environmental conservation and soil fertility (Wang et al. 2024). Microorganisms in the soil, in addition to increasing fertility, the secondary metabolites produced can stimulate plant growth (Diwan et al. 2022, Shiade et al. 2024).

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Public awareness of the importance of health results in the need for residue-free agricultural products. Rice is one of the leading commodities in Indonesia that is cultivated organically. Previous research explains that the motivation to switch from conventional to organic systems is influenced by several factors, namely farmer income analysis and health (Hani et al. 2023). The impact of intensive agriculture with synthetic materials causes a decrease in water quality below quality standards. The water pollution index is influenced by human activities such as the massive use of artificial fertilizers and domestic. Indicators observed can be seen from the nitrate concentration and total coliform (Alfarisy et al. 2020, Hani et al. 2024). Several alternatives can be used to reduce the impact of pollution on water, namely using vegetable pesticides or biological agents (Habriantono et al. 2023, Hoesain et al. 2023, Guo et al. 2024).

Conservation is an action taken to restore environmental conditions to remain stable and minimize the risk of pollution. Conservation can be done preventively and curatively. Environmentally sound agricultural cultivation is regulated in SNI 6729:2016 regarding organic farming systems. Environmental recovery efforts based on components are divided into biotic and abiotic components and agroecosystem conditions. This research aims to conserve the environment from pollutants and promote sustainable conservation in organic rice agroecology.

Materials and methods

Materials

This research was conducted in March-September 2024 at an organic rice farming location in Penanggal Village, Candipuro District, East Java Province, Indonesia (Figure 1). The majority of farmers apply organic farming systems. The research site is located at coordinates 809'21” S 11300352” E. Sampling of water and biological components of the environment is located in the upstream and midstream areas (Figure 2). Materials used for plankton net, bucket, sieve, tweezers, raffia rope, sample bottle, plastic, permanent marker, microscope, object glass and cover glass, plankton, and benthic identification book.

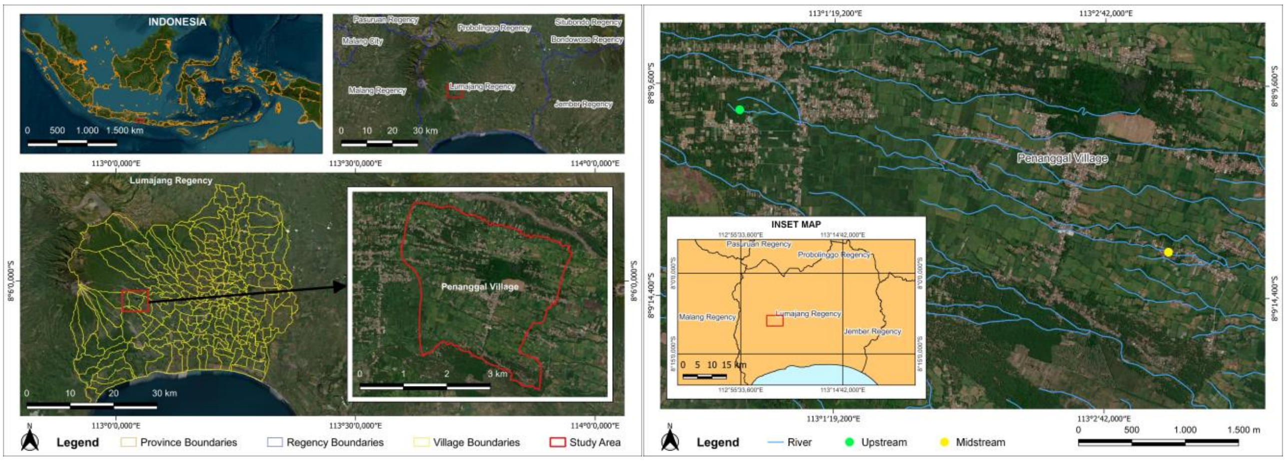

Figure 1. Study area and sampling location.

Methods

This stage is divided into two sessions: water sampling, biological component samples, agroecology observations, and a survey of farmer respondents. The hue of the environment and sampling points can be seen in (Figure 3). Water sampling was conducted in the upstream (water source) and middle (irrigation) areas. A water quality assessment was carried out at the Environmental Laboratory (Perum. Jasa Tirta 1). Each point has two types of samples, each bottle size of 1 L. The stages carried out are as follows:

1. Sampling of biological components

The method used is the direct method, and the placement of sampling points is based on purposive sampling. For plankton, community data such as the number of species, abundance (K), and relative abundance (KR%) can be analyzed. In contrast, the structure of plankton can be examined, namely the Diversity Index (H'), Index of Evenness I, and Index of Dominance I.

Figure 2. Environmental setting for biological indicator in organic farming area.

Abundance analysis aims to determine the distribution pattern of species that make up the environment. Abundance is one way to measure species diversity in a habitat. The formula for abundance analysis:

$$\text{Plankton abundance (Individual/Liter)} = (a \times c) / L \qquad (1)$$

Where: a = average number of plankton in 1 milli liter, c = sample volume (ml), and L = volume of filtered water (liter).

$$\text{Relative Abundance (KR\%)} = (\text{Individual Density/Total Density}) \times 100\% \qquad (2)$$

Plankton diversity was calculated with H' Shannon Wiener using the following formula, and the value was compared with the water quality scale according to the aquatic biota diversity index (Table 1).

$$H' = -\sum_{i=1}^{s} \frac{Ni}{N} \ln \frac{Ni}{N} \qquad (3)$$

Where: H'= Diversity Index (Shannon Wiener), ni = number of individuals or density value of a species, and N = number of individuals or density value of all species.

Table 1. Water quality scale according to plankton diversity index.

No.	Diversity Index (H') Plankton	Category	Scale
1	<0.3	Very Bad	1
2	0.3 – 0.7	Bad	2

3	0.7 – 1	Fairly Good	3
4	1 – 5	Good	4
5	>5	Very Good	5

Index of Uniformity I the composition of each individual of a species contained in a community. The more even the distribution of individuals between species, the more ecosystem balance will increase.

$$E = H' / H \max \quad (4)$$

Where: E = Uniformity Index, H'= Diversity Index, H max = ln (S), and S = All Species. Dominance Index shows the presence or absence of dominant macrozoobenthos organisms in the aquatic environment. The dominance index formula used is:

$$C = \sum pi \rightarrow pi = (ni/N)^2 \quad (5)$$

Where: C = Dominance Index, ni = Number of individuals to I, N = Total number of individuals of all species. The value of the dominance index I range from 0 to 1. If the value of C is close to 0, then there is a dominant individual, but if the value of C is close to one, then there is no dominant individual.

2. Tools and analysis

This research uses a Water Quality Combo Meter with AZ 86031 specifications, GPS (Global Positioning System), Camera, Stereo Microscope, Loop, and GIS tools. Data analysis using PAST 4.15 from Natural History Museum.

3. Survey

To identify farmer behavior in accordance with SNI 6729:2016, typology data is required using a questionnaire with data on the types of fertilizers, pesticides, organic and synthetic materials used, soil, water, and air management data, plant diversity ecosystems, management of plant nuisance organisms, infrastructure facilities, and selection of seeds and plant varieties. The respondents were 14 farmers spread across the upstream and midstream areas in organic rice farming.

4. Agroecology

Direct observation is the key to identifying the agro landscape. Identify plants other than the main crop and take notes on plants included in the conservation group, including annual, seasonal, and phytoremediation plants for pollution.

Result and discussion

Environmental biology indicators

Environmental quality cannot be separated from the role of biological components as actors in carrying out their roles as ecological processes and the relationship between biological components and the environment. Certain species have roles, functions, and indicators in determining environmental quality in terrestrial and aquatic ecosystems. Benthos is one of the organisms that reside in the waters and are located at the bottom of the attached sand (Grassle 2024). Plankton are aquatic biota organisms floating on the water's surface or moving with the flow of water currents (Zhang et al. 2023). Plankton and benthos are characteristic environmental bioindicators that signify ecosystem diversity and health. Several factors, such as extreme and anthropogenic environments in a particular region, influence these organisms' presence. Organisms such as benthos and plankton can be affected by climate and weather. Seasonality affects the presence of benthos and plankton as it relates to eutrophication and nitrification in ecological sustainability (Stevack et al. 2021, Shchapov and Ozersky 2024).

Indicators of environmental quality can be measured by assessing the biodiversity index in an ecosystem from the collected organisms. Figure 3 shows the curve of individual rarefaction, where the curve can show the expected number of species at a sample size based on the category of types and sample sizes based on the distribution of organisms. Based on the curve below, the number of species found at station B (centre) is higher than at station A (upstream). Some parts of individual rarefaction for diversity index categorized by taxa, biodiversity index based on Shannon exp, Simpson, and Shannon. The upstream area (A) comprises bamboo plants and water source centres. At the same time, the middle region (B) consists of organic water irrigation flow and some drainage to go into organic rice fields. Figure 4 shows that the abundance of species collected in the middle organic rice area is higher than in the upstream region. The relationship of species with the same type and number indicates a close kinship between species.

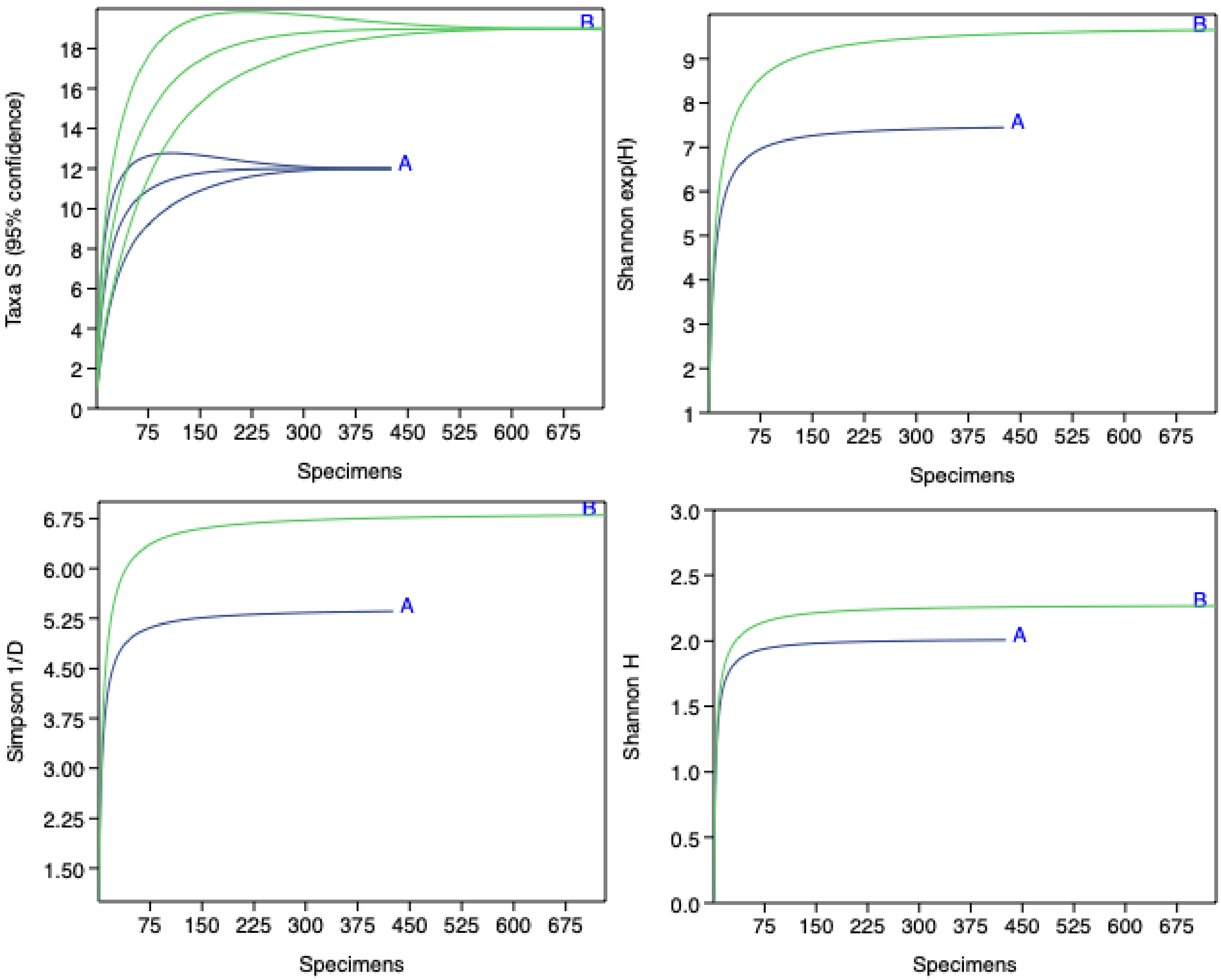

Figure 3. Individual Rarefaction for Index Diversity.

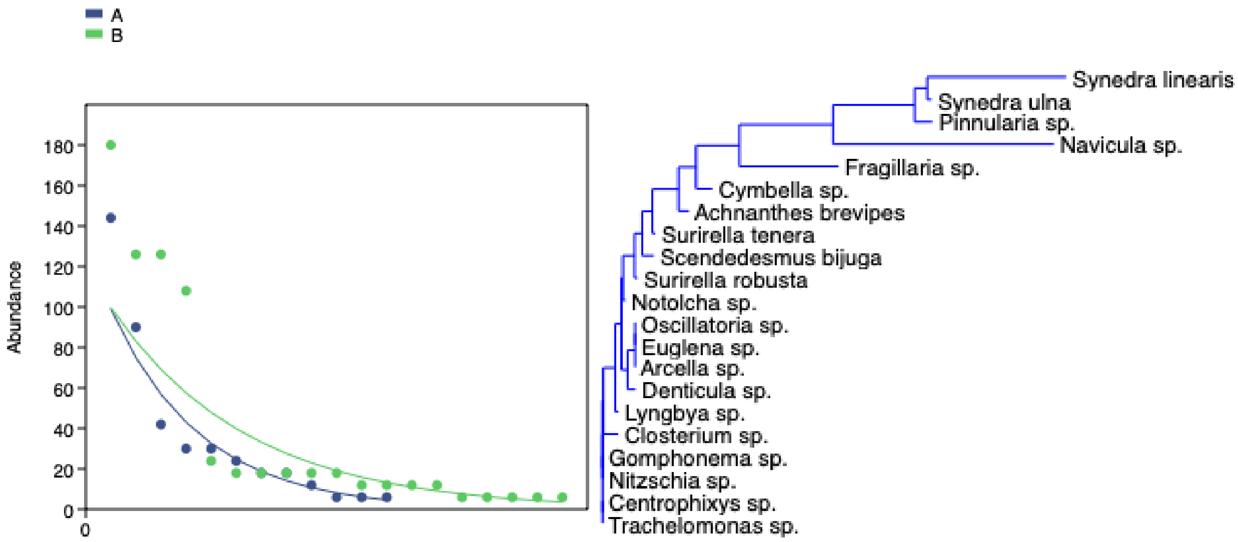

Figure 4. Abundance distribution model for species in habitat organic farming system.

Table 2. Composition of organisms in the environmental biological components of organic rice farming systems

Taxa/Group	**Station of Location**			
	Upstream area (A)		**Midstream area (B)**	
	Abundance	**Abundance Relative%**	**Abundance**	**Abundance Relative%**
A. Phytoplankton				
A.1 Bacillariophyceae				
Achnanthes brevipes	30	7.042	24	3.306
Cymbella sp.	42	9.859	12	1.653
Denticula sp.	6	1.408	18	2.479
Fragillaria sp.	90	21.127	0	0.000
Gomphonema sp.	0	0.000	6	0.826
Navicula sp.	144	33.803	108	14.876
Nitzschia sp.	0	0.000	6	0.826
Pinnularia sp.	6	1.408	126	17.355
Surirella robusta	12	2.817	12	1.653
Surirella tenera	18	4.225	18	2.479
Synedra linearis	30	7.042	180	24.793
Synedra ulna	24	5.634	126	17.355
A.2 Chlorophyceae				
Closterium sp.	0	0.000	6	0.826
Scendedesmus bijuga	18	4.225	0	0.000
A.3 Cyanophyceae				
Lyngbya sp.	0	0.000	12	1.653
Oscillatoria sp.	0	0.000	18	2.479
A.4 Euglenophyceae				
Euglena sp.	0	0.000	18	2.479
B. Zooplankton				
B.1 Protozoa				
Arcella sp.	0	0.000	18	2.479
Centrophixys sp.	0	0.000	6	0.826
Trachelomonas sp.	0	0.000	6	0.826
B.2 Rotifera				
Notolcha sp.	6	1.408	12	1.653
Total	426	100	726	100
Total Species	12		18	
Total Abundance (ind/l)	426		726	
Indeks Diversity (H'= - Σ pi ln pi)	2.007		1.842	
Indeks Equatability	0.807		0.637	

Table 3. Detail of parameter index diversity in organic rice farming system.

Diversity Indicates	A	B
Taxa_S	12	19
Individuals	426	732
Dominance_D	0.1848	0.1458
Simpson_1-D	0.8152	0.8542
Shannon_H	2.02	2.279
Evenness_e^H/S	0.6283	0.5143
Brillouin	1.947	2.211
Menhinick	0.5814	0.7023
Margalef	1.817	2.729
Equitability_J	0.813	0.7741
Fisher_alpha	2.295	3.565
Berger-Parker	0.338	0.2459
Chao-1	12	19
iChao-1	12	19
ACE	12	19
Squares	12	19

Note: A (Upstream area), B (Midstream area).

Plankton consists of phytoplankton and zooplankton. The lifespan of zooplankton is so short that zooplankton are very sensitive to changes in conditions in the water. Changes in the ecological structure of a water body (abundance, diversity, uniformity, and dominance) can indicate that the water body has changed conditions. Table 2 shows the diversity index in the organic rice farming system. Organisms such as plankton and benthos are part of the hydrobiology and environmental quality (Li et al. 2021, Rajaram et al. 2021, Shiganova et al. 2023). Plankton found in the Bamboo Forest water source amounted to 21 species belonging to the phytoplankton group (microflora), namely the Bacillariophyceae class (12 species), Chlorophyceae (2 species), Cyanophyceae (2 species), Euglenophyceae (1 species), and zooplankton (microfauna), namely there are two classes, Protozoa and Rotifera. The total abundance of plankton individuals in the Upper Bamboo Forest Water Source is 426 individuals per liter, and the Lower Bamboo Forest Water Source is 726 individuals per liter. Different environmental conditions may influence the striking difference in density between the upstream and midstream rivers. For example, the upstream river is an upstream water source that residents have yet to utilize, while the midstream has been used to irrigate rice fields and other plantations. Furthermore, in the upstream river, there is one species with the highest abundance, namely the Navicula species, while in the midstream river, the Synedra sp. In contrast to diversity analysis using PAST analysis, the Shannon index shows a biodiversity index in the excellent category (Table 3). The ecosystem of an area is influenced by activities and dominant constituent components that affect the survival relationship between species (Carrick and Forsythe 2020).

The plankton diversity index in the Upper Bamboo Forest Water Source is 2.007, and the Lower Bamboo Forest Water Source is 1.842. Based on the diversity index (H`), the stability of a community can be grouped into three categories, namely if H` > 3, then the water condition is said to be stable, if H` is between 1 <H'<3 then it is said that the waters are less stable, if H` is <1 then the waters are said to be unstable. The waters of the Bamboo Forest Source Water are less stable, but the species diversity is relatively high. The evenness index I range from 0.637-0.807. The smaller (closer to 0) the value of E, the smaller the uniformity of the population; on the other hand, if the value of E is more excellent (closer to 1), the greater the uniformity. So, the magnitude of the information I obtained in this study shows that each type of phytoplankton has an even level of individual abundance. Still, the value is different at each station.

Benthos are aquatic biota that live at the bottom of the water. These organisms are classified as low-level animals, so if pollution enters the waters, these benthic animals will be directly exposed (Pinheiro et al. 2020, Debnath et al. 2024). Macrozoobenthos found in this study were three species belonging to the Gastropoda class (Figure 5). Tarebia sp. is characterized by an oval-shaped and medium-sized shell with a sharp shell tip (Necker et al. 2023). The shell structure is uneven, with fine spots arranged horizontally. The shell is brownish. This species is found on mudstone along riverbanks. Tarebia is one type of snail that lives in freshwater. *Melanoides* sp. has the characteristics of an elongated shell with a slightly enlarged main thread, the main shell has a light brown colour, the surface of the shell is wavy, forming vertical lines, and has a pointed apex with wide and blunt siphon grooves commonly found in fresh waters (Peso et al. 2011, Bose et al. 2022).

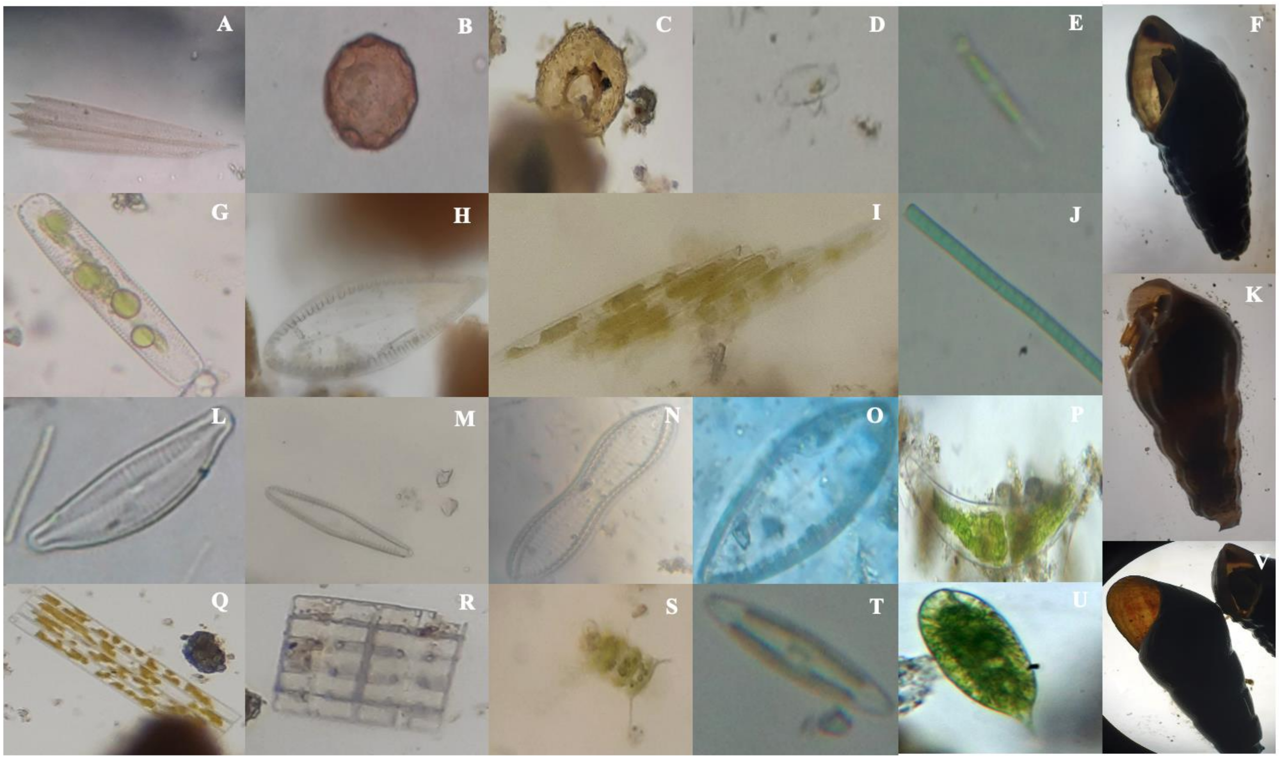

Figure 5. Overview composition of phytoplankton and benthos [Note: Zooplankton: **A** *Notholca* sp., **B** *Arcella* sp., **C** *Centrophyxis* sp., **D** *Trachelomonas* sp., Fitoplankton: **E** *Achnanthes* sp., **G** *Pinularia* sp., **H** *Surirella* sp., **I** *Nitzchia* sp., **J** *Lyngbia* sp., **L** *Cymbella* sp., **M** *Gomphonema* sp., **N** *Surirella linearis*, **O** *Surirella biserata*, **P** *Closterium* sp, **Q** *Fragillaria* sp., **R** *Denticula* sp., **S** *Scenedesmus bijuga*, **T** *Navicula* sp., **U** *Euglena* sp., Benthos: **F** *Sulcospira* sp., **K** *Tarebia* sp. and **V** *Melanoides* sp.].

Water quality in organic rice farming

Water is a vital requirement for plant growth. In organic farming systems, water is freed from pollutants that can pollute the environment. Polluted water will cause plants to experience poisoning, and residues will enter them. Therefore, filtering is needed to ensure that the water flowing in the organic farming system is free from fertilizer and pesticide residues. It is also possible that the water carries heavy metals. In the follow-up assessment for monitoring water quality at the organic farming site, it was observed to be good (Table 4). Unlike the previous year, the water quality on organic farms in 2023 was still below the class III quality standards in the parameters BOD, COD, and total coliform (Hani et al. 2024). The upstream part of the water can be categorized as good and feasible as a requirement for organic farming. It's just that the average DO parameter is 1.5 mg/L upstream. Do is rated low because the water flowing from the source is in the lowlands. So the water flow is smaller. The higher the DO value, the better the water quality value, depending on the area's topography (Zhong et al. 2021). In Table 4, water quality can be categorized as good based on class III quality standards regarding water designation for irrigation and crop cultivation. BOD in the central region amounted to 6.40 mg/L and 6.53 mg/L. The presence of high organic material causes a high BOD. Thus, increasing microbial activity causes the BOD value to increase (Arlyapov et al. 2022).

To maximize efforts to maintain water quality, filtering is made at each water entry point using phytoremediator plants (Figure 2). The filter functions when water flows on organic rice and the plant enters the vegetative phase. The filtering absorbs residues, pollutants, or heavy metals from entering the irrigated land (Hussein et al. 2022, Olayiwola et al. 2023). Several plants can be used: Common water hyacinth (Eichhornia crassipes) and Pistia stratiotes (Rizvi et al. 2024). Hyperaccumulator plants can absorb by optimizing the root system. The roots provide open space for phytoextraction (Calderon et al. 2021). Several conditions, such as the type of residue or heavy metal, the presence of beneficial microbes, and the environment, influence phytoremediation.

Table 4. Water quality in organic farming areas

Indicator	**Unit**	**Result (R1)**	**Result (R2)**	**Result (R1)**	**Result (R2)**	**Method**
		Upstream		**Midstream**		
Chemistry						
BOD	mg/L	4.36	5.77	*6.40	*6.53	SM APHA 23rd ED 5210 B. 2017
COD	mg/L	9.929	9.091	13.76	13.97	SNI 6989.2.2019
pH	-	6	5.65	5.54	5.55	Water Quality Meter AZ 86031
DO	mg/L	1.5*	1.5*	0.5*	0.7*	Water Quality Meter AZ 86031
PO4	mg/L	0.73	0.76	0.83	0.76	SNI 6989-31.2021
Nitrate	mg/L	2.691	2.798	0.47	0.47	QI/LKA/65
Nitrite	mg/L	<0.0022	<0.0022	<0.0022	<0.0022	SM APHA 23rd ED 4500 NO_2. 2017
Physics						
TSS	mg/L	10.1	10.2	10.3	10.4	SM APHA 23rd ED 2540 D. 2017
TDS	mg/L	70.7	70.1	129	127	Water Quality Meter AZ 86031
Temperature	^{0}C	20.3	20.4	22.3	23.0	Water Quality Meter AZ 86031
Biology						
Total Coliform	MPN/(100 mL)	170	210	240	220	QI/LKA/18

*Class III for irrigation and plantation based on Government Regulation of 82 Years 2001 (Pemerintah Republik Indonesia 2001).

Water quality determines the feasibility of organic cultivation. Based on the assessment results in the previous year, almost every sampling point was contaminated with *E. coli*, with an amount above 1000 MPN (Hani et al. 2024). Based on this data, the community uses water sources and irrigation areas for bathing and domestic activities. In the study, the recommendation was to refrain from carrying out activities that could increase the number of *E. coli* in the crop cultivation area. Based on Table 4, the amount of *E. coli* this year is less than last year. The researcher has recommended clearing the garbage from the irrigation area, which could increase the potential for pollution. Some of the parameters observed are based on the eligibility of the quality standard class for agricultural areas. Figure 6 explains the relationships and correlations presented in the heatmap. Based on the heatmap, colors and positive or negative values can be distinguished. Positive values illustrate that some parameters move in the same direction and show a relationship. Meanwhile, negative values indicate that the values on some parameters show the opposite. Whereas the values of 0 and 1 are that they have no relationship. There is likely a relationship between several parameters heading in the same direction. The relationship can be approached by influencing materials that impact other measurements.

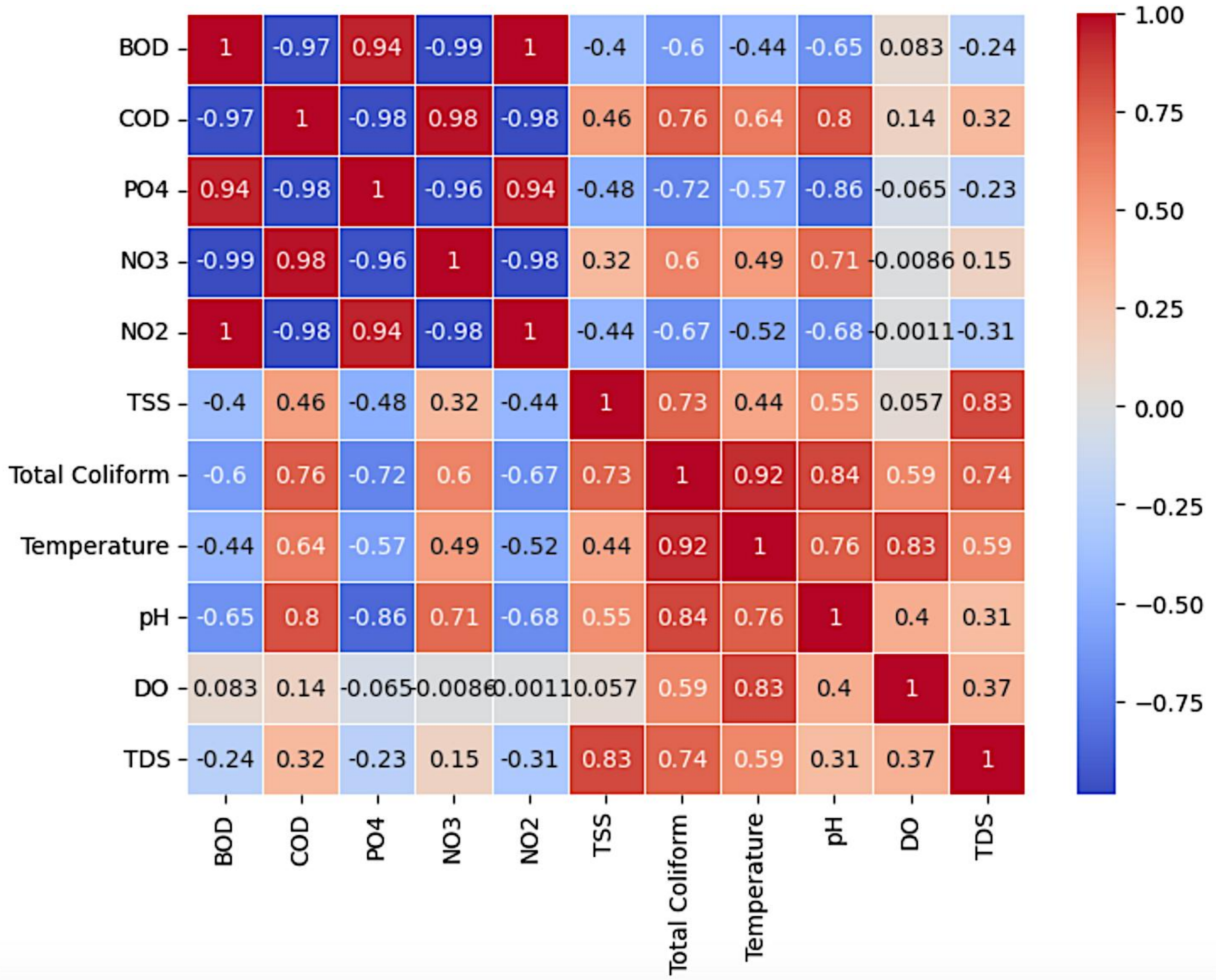

Figure 6. Heatmap of the water quality for antoher parameter.

Agroecology of organic rice farming

Agroecology are a unified relationship of biotic and abiotic components in one ecosystem. Agroecosystems are dominated by cultivated plants interacting with the elements around them. Based on SNI 6729: 2016 concerning organic farming systems in Indonesia. In addition to water and soil factors that are free of contaminated substances, it is recommended that there are air pollution absorption plants in organic rice agroecosystems. Figure 7 is a real visualization of the environmental conditions around organic rice plants. The upstream location has bamboo plants with water sources. Bamboo is a conservation plant because it has strong roots and can retain water (Thuy et al. 2021, Shang et al. 2024). *Cocos nucifera*, *Parkia speciosa*, and *Gliricidia sepium* plants are in the middle area between organic rice plots. Organic farming systems tend to use polyculture cropping systems. This system aims to reduce the level of disease and pest attacks in organic areas. This system can break the biological chain of pests and diseases (Rege and Lee 2023).

Agroecology in organic rice is very important to prevent pollution contamination. Pollution does not only occur in water and soil, it can be air pollution during the evaporation process and industrial activities that can pollute organic plants. Some plants can reduce pollutants in the air. Conservation crops can also break the wind during storms. Plants around organic rice, such as *Gliricidia sepium*, are used by farmers as animal feed. The manure obtained is used as organic fertilizer on crops.

Figure 7. Agroecology on organic rice farming system

Model of environmental sustainability

The key to organic farming is that it is free from contaminants caused by synthetic materials. Pollution generally occurs in the use of synthetic fertilizers and pesticides, domestic activities carried by water flow, and the use of genetic crops, as well as air pollution due to industrial activities. Therefore, to create a model for an organic farming system that includes environmental, social, and economic aspects, a model study is made by connecting the three without being left behind. Sustainable development is based on a holistic study of elements. So that the goals of food security and poverty are achieved. Organic farming stems from the awareness of the need for food and health to improve welfare (Epule 2019, Aïhounton and Henningsen 2024). A sustainable environmental engineering-based management model (Figure 8) has been developed based on preliminary and technical studies and site-specific environmental assessment and monitoring. The model examines the differences between organic and inorganic farming systems. From the cultivation input needs, agroecosystem performance, water sources, impacts and influences on all aspects, and conservation efforts.

Conservation can be done with preventive and curative technical approaches depending on restoring the part. Several conservation options can be implemented, such as the mass production of organic materials for organic pesticides and fertilizers. All needs and materials are based on local resources. Besides being safe for the environment, it is also economically valuable so that it can minimize expenses. In addition, preventive conservation can be done by increasing the insight and skills of farmers by conducting practices and demonstrations for organic farming for healthy living behavior, which will come.

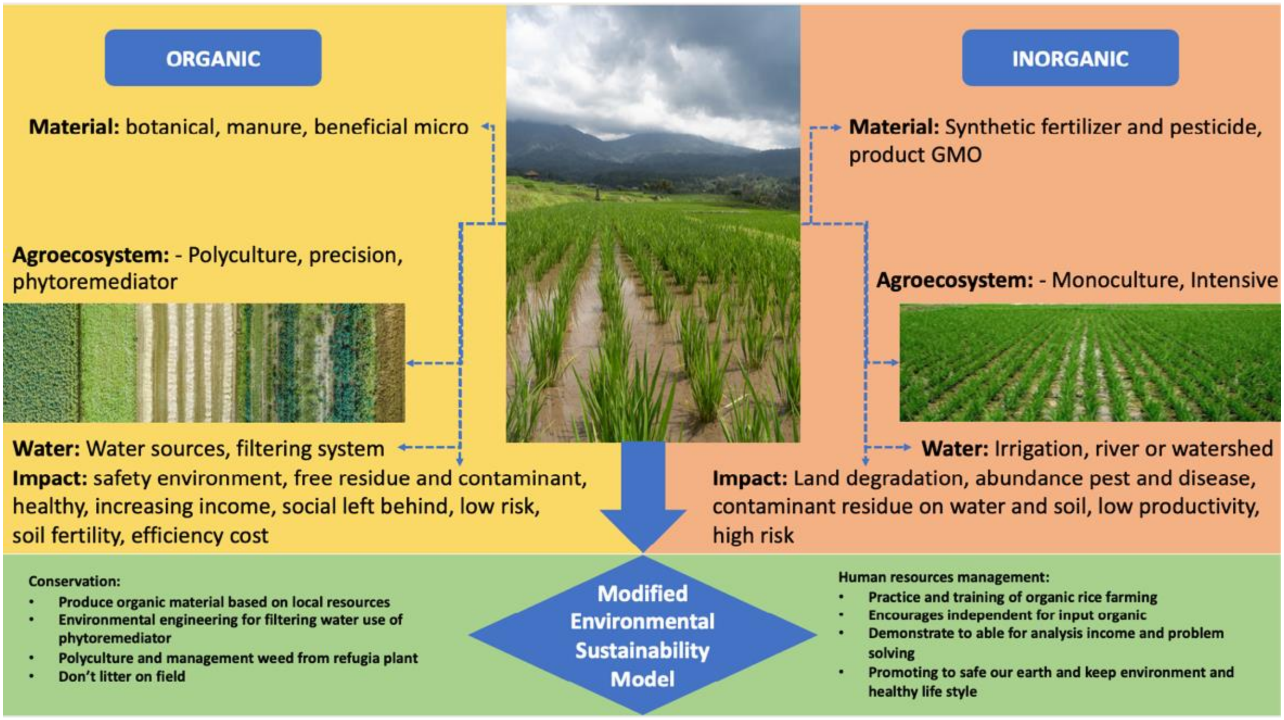

Figure 8. Ouput of modified environmental sustainabily model

Conclusion

This study examines conservation efforts in organic rice farming systems based on environmental quality assessment. Environmental quality indicators include biological components with several species from the plankton and benthic groups as bioindicators of the ecosystem. The diversity index assessment on organic rice farming is divided into upstream areas (A) with an index value of 2.007 and central areas (B) worth 1.842. The total abundance in the upstream area was 426 species, and 726 species in the middle area. Water quality analysis shows that water monitoring in organic rice areas is well monitored. Only a few indicators do not meet the standards of Government Regulation 82 of 2001 in class III water with irrigation functions for cultivated plants. The parameter in question is BOD, with a value of 6.40 mg/L and 6.53 mg/L in the central region. Agroecology around organic rice can be considered good because conservation plants and hyperaccumulators for air pollution exist. In addition, there are Gliricidia sepium plants between the rice fields as the main ingredient for making organic fertilizer.

In this conclusion, a sustainable environmental engineering model is obtained to improve and restore environmental health with a curative and preventive approach to environmental and human resources. The purpose of this model is to recommend maintaining environmental quality based on SNI 6729:2016 regarding organic farming systems.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Evita Soliha Hani – Conceptualization, Methodology, Writing, Review & Editing; Fariz Kustiawan Alfarisy – Methodology, Writing, Review & Editing, Supervision; Sigit Soeparjono – Writing, Review & Editing; Laily Ilman Widuri – Writing, Review & Editing; Wildan Muhlison – Writing, Review & Editing; Tri Wahyu Saputra – Writing, Review & Editing; Roni Yulianto – Writing, Review & Editing; Gusna Merina – Writing, Review & Editing; Farchan Mushaf Al Ramadhani and Jheng-Jie Jiang – Writing, Review & Editing.

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Data availability

All of the data that support the findings of this study are available in the main text.

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