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Research Article

Assessment of water quality in agricultural systems in Candipuro, Lumajang Regency, East Java, Indonesia

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Abstract

The current challenges of industrial agriculture focus on environmental safety. Water quality is an indicator of environmental sustainability. The cultivation system has an impact on water quality. The aim of this study is to assess the water quality of agricultural systems. Anthropogenically, agricultural activities have an impact on environmental aspects. Identification of agricultural systems is clustered into organic and non-organic agriculture. The agricultural system in Indonesia is regulated based on SNI 6729;2016. Water sampling was carried out at three points, including upstream, middle (irrigation), and downstream (river). Water sampling at each point was repeated three times. Assessment of the physical quality of water using the Combo Quality Meter. Water samples for chemical and biological analysis at the Environmental Laboratory, Perum. Jasa Tirta 1. Determination of water quality standards refers to Government Regulation No. 82 of 2001. In the upstream section, pollution can be seen in the biological oxygen demand (BOD) indicator, with an average of 15.03 mg L^{-1} for organic and conventional systems. The phosphate indicator averaged 1.96 mg L^{-1}. In the middle section (irrigation), the pollution indicators for BOD, phosphate, and total Coliform parameters were 6.76 mg L^{-1} for the organic system, 7.37 mg L^{-1} for the non-organic system, and 1,290 CFU mL^{-1}. In the downstream (river), pollution indicators consist of total suspended solids (TSS), BOD, chemical oxygen demand (COD), and total Coliform. Anthropogenic identification for clustering agricultural systems at the research location uses stratified disproportional sampling. The results of this research provide recommendations for water quality management for sustainable agricultural environmental management.

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Introduction

The agricultural system in Indonesia is currently moving towards a process called industrial agriculture. Patterns that are developing into a change to reach the world's food barn. Organic farming systems are part of the implementation of sustainable agriculture by prioritizing environmental safety (Gamage et al., 2023). In contrast to non-organic or conventional farming systems, namely cultivation activities that have been trusted from generation to generation by using dangerous synthetic materials, both fertilizers and pesticides. Anthropogenic is recognized that all activities can impact and damage the environment

(Azzellino et al., 2017; Higgs et al., 2023). The organic farming system in Indonesia started in the province of East Java. East Java is one of the highest producers of organic rice (Hani et al., 2023). Candipuro is an organic rice-producing village that has an organic certificate and implements an organic cultivation system based on SNI 6729:2016.

Organic farming is an agricultural system that uses natural materials for cultivation activities. The use of natural materials for fertilizers and pesticides can maintain biodiversity and environmental safety (Huang et al., 2020; Lengai et al., 2020; Ali et al., 2022; Deru et al., 2023). Organic farming does not only focus on production but also on food security and the environment. The use of natural materials and useful microorganisms has proven to be effective in increasing crop protection, so it has an impact on increasing agricultural production (Masnilah et al., 2021; Wagiyana et al., 2021; Habriantono et al., 2023a; Hoesain et al., 2023). Organic farming in Indonesia is regulated based on SNI 6720;2016, which regulates upstream to downstream activities by prioritizing environmental safety and health. Organic agricultural products are healthier and have a high selling value. Indonesia has independent institutions that assess the feasibility of organic farming activities, such as LeSOS, INOVICE, SUCOFINDO, BIOCert Indonesia, and PERSADA. The organic feasibility survey is assessed in terms of environmental components; both soil and water must be free from pollutant contaminants.

In contrast to organic farming systems, conventional farming or non-organic has been identified in the long run as causing environmental damage. Semi-organic is a period of transition from conventional to organic. Semi-organic still uses a combination of organic and systematic materials. The use of hazardous materials can cause pollution and hazards to health. The intensive use of synthetic pesticides and fertilizers is classified as anthropogenic so it has an impact on various sectors. Based on the results of research by (Alfarisy et al., 2020), the implementation of intensive farming in the upstream Bedadung watershed has an impact on pollution and a decrease in water quality. Water is a vital requirement for plant needs. Standardized organic farming water must be clean and free of contaminants. Environmental problems are part of social problems. (Alfarisy et al., 2020). Typology of conventional farmers tends to have middle to lower socioeconomic degrees and a low level of education.

Standardization of clean water quality standards in Indonesia has been regulated in Government Regulation Number 82 of 2001 regarding the classification of water quality standards based on their designation. Assessment of water quality is one of the considerations for whether organic farming is considered feasible or not. SNI 6729:2016 regarding organic farming systems that proper water is included in the category of clean and free of contaminants. Water will be clean if it is not polluted by harmful chemicals and garbage around the plant location. Based on the SNI, it is also recommended to use organic fertilizers for soil conservation. Organic fertilizers can be produced using agricultural waste or useful microorganisms. Biological agents are examples of microorganism products that can be an alternative to synthetic materials. The existence of biological agents is very important for biosafety and biosecurity (Chikowore et al., 2023; David and Lake, 2023). Biological agents are part of the conservation of soil and water and the presence of plant-disturbing organisms by using useful microorganisms and organic materials (Habriantono et al., 2023b; Prastiwi et al., 2023). Agricultural cultivation activities cannot be separated from organic matter, so they can be considered wisely to be developed to prevent the pollution of both water and soil. The purpose of this study was to assess the quality of water in organic and anthropogenic farming systems from human activities that cause environmental damage.

Materials and Methods

The research was conducted on organic and non-organic systems in Penanggal Village, Candipuro District, Lumajang Regency, East Java, Indonesia (Figure 1). The village is located at coordinate $8^0$9'21"S $113^0$0352"E. Penanggal Village has received an organic certificate since 2016. The organic area gets its water source from the upstream. The upstream part consists of a water source from the ground with bamboo trees around it. The agricultural system in Penanggal Village is divided into two, namely organic and conventional farming systems. The boundaries of the two agricultural systems are marked only by irrigation networks. The characteristics of an organic farming system based on SNI 6729: 2016 are that during the cultivation process, biophysical environmental components are free from pollutants. In contrast to non-organic farming, farmers are very massive in using pesticides and synthetic fertilizers.

Water sampling method

Samples were taken at several points, starting from the upstream (water source), middle (irrigation), and downstream (river) (Figure 2). Each point was taken with three repetitions to analyze the physical, chemical, and biological properties. Water sampling was carried out at a depth of ± 30 cm from the water surface. Previously, the researcher determined the sample plots to be taken. Ensure that the water sample taken is free of impurities in the form of leaves and twigs. The total volume taken was 1 L in the sample bottle, which was then closed tightly, and no air was entered. The collected water samples were then put in the freezer box. Sample bottles containing water were described as the date of collection, time, location, and point of collection. Water sampling was carried out in organic and non-organic farming areas.

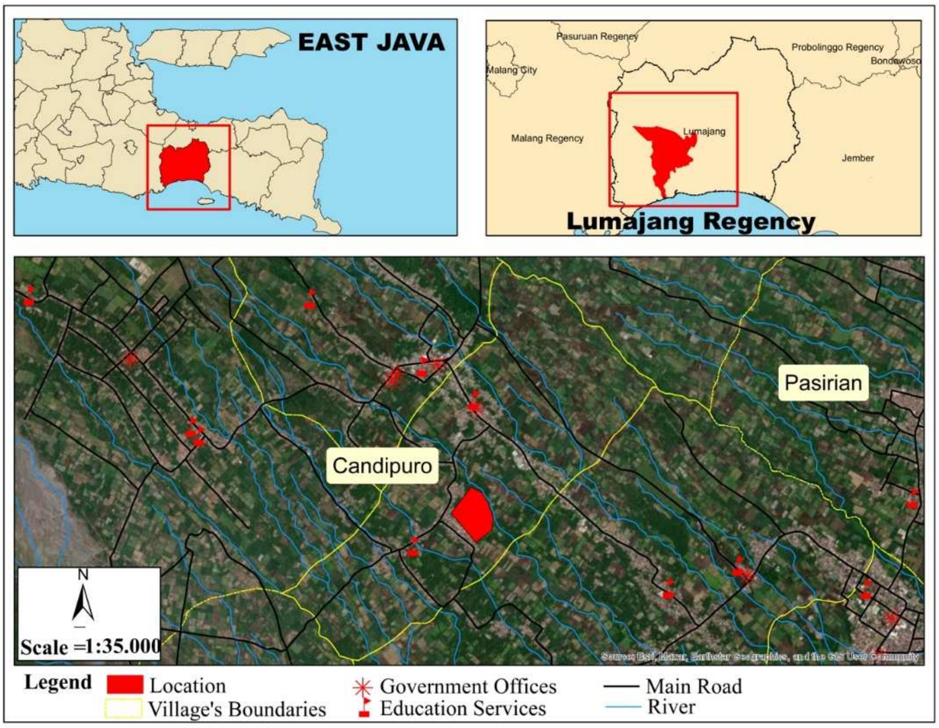


Figure 1. Location of the study.

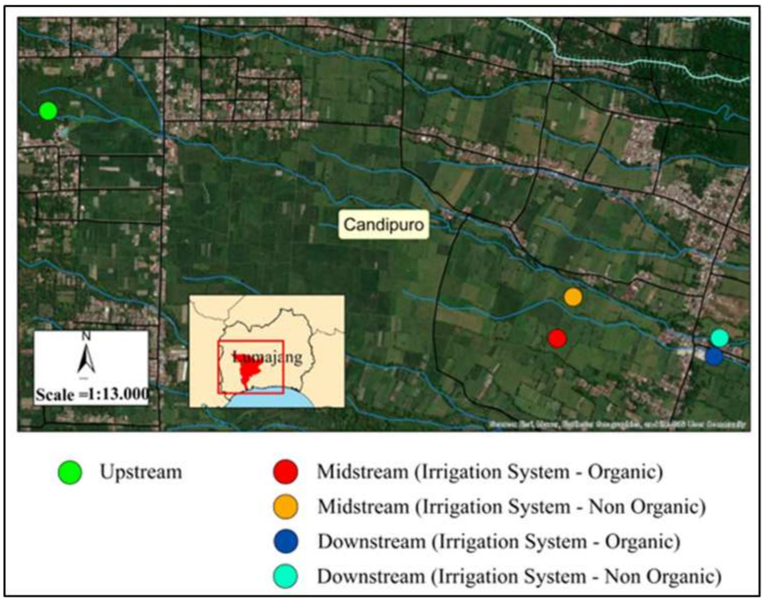


Figure 2. Water sampling points in research locations.

Water quality analysis

The water samples that have been collected are then analyzed in the laboratory. Testing of chemical and biological properties in collaboration with the Public Housing Accreditation Laboratory. Jasa Tirta 1 in Malang City, where maintenance has been carried out using a standardized method (Table 1). Physical observations such as temperature, pH, DO (dissolved oxygen), and TDS (total dissolved oxygen) were carried out using the Water Quality Mater version 8603 – Combo Water Quality Meter (Figure 3). Observation of other physical properties such as color, smell, and clarity. The material needed to support the testing of the tool is an aquadest solution. Aquades solution is used as a neutralizing or rinsing agent on the probe part of the tool to improve measurement accuracy. The procedure is carried out by spraying a solution of distilled water using a sprayer and rinsing it with a tissue. Then, dip the probe in the water to be measured. Standardization of water quality analysis aims to test whether the water being analyzed is by its designation. Regulations regarding water quality in Indonesia are regulated in Government Regulation Number 82 of 2011 regarding the classification and criteria for managing and controlling water quality. The parameters measured and the applicable standards can be seen in Table 2.

Figure 3. Combo quality meter for direct analysis.

Table 1. Water quality analysis method.

Parameter	Characterization	Unit	Analysis Method
Total Phospate (PO_4)	Chemical Organic	mg L^{-1}	SNI 6989-31:2021
BOD (Biological Oxygen Demand)	Chemical Organic	mg L^{-1}	APHA.5210 B1998
COD (Chemical Oxygen Demand)	Chemical Organic	mg L^{-1}	QI/LKA/19 (Sprectophotometry)
Nitrate (NO_3^-)	Chemical Organic	mg L^{-1}	QI/LKA/65
Nitrite (NO_2^-)	Chemical Organic	mg L^{-1}	APHA.4500-NO2B-2017
TSS (Total Suspended Solids)	Chemical Organic	mg L^{-1}	APHA2540D-2017
Total Coliform	Biological	CFU 100 mL^{-1}	Q1/LKA/18 (Double Tube)

Table 2. Criteria for water quality by class.

Parameter	Unit	Class				Information
		I	II	III	IV	
Physical						
Temperature	^{O}C	Deviation 3	Deviation 3	Deviation 3	Deviation 5	Deviation existing
Dissolved residue	mg L^{-1}	10^3	10^3	10^3	10^5	
Suspended residue	mg L^{-1}	50	50	400	400	Management for water conventional <500 mg L^{-1}
Color	-	-	-	-	-	
Smell	-	-	-	-	-	
Chemical						
pH		6-9	6-9	6-9	5-9	
BOD (Biological Oxygen Demand)	mg L^{-1}	2	3	6	12	
COD (Chemical Oxygen Demand)	mg L^{-1}	10	25	50	100	
DO (Dissolved Oxygen)	mg L^{-1}	6	4	3	0	
Total Phosphate	mg L^{-1}	0.2	0.2	1.0	5.0	
NO_3^-	mg L^{-1}	10	10	20	20	
NO_2^-	mg L^{-1}	0.06	0.06	0.06	(-)	
Microbiology						
Total coliform	cfu 100 mL^{-1}	10^3	$5x10^3$	10^3	10^3	

Remarks: Class I = focus on drinking water and domestic, Class II = focus on agriculture (irrigation) and fisheries, Class III = agriculture, plantation, irrigation, Class IV = tourism (Government Regulation No. 82 of 2001).

Mapping of biophysical components

The cultivation system cannot be separated from supporting elements such as rainfall, planting media, or soil type, as well as the level of elevation or slope. To map biophysical component indicators, researchers used ArcGIS Pro tools. Rainfall affects water availability and climate, while soil type describes land resources to support the optimal growth of cultivated plants.

Spatial analysis of water quality

Surfer is a 3-dimensional (3D) surface mapping program that generates contours (grid-based contouring and 3D surface plotting graphics program) by interpolating XYZ data. Making griding by selecting the kriging method with a linear variogram. This program maps the distribution of water quality based on the contours of the distribution of irregular points to become a pattern.

Anthropogenic studies

Knowing the typology of farmers in the research location requires a tool in the form of a questionnaire with a total of 30 respondents. The minimum sample limit is 30 respondents. The number of respondents was determined using stratified proportional sampling with organic, semi-organic, and conventional farmer strata. Disproportionate is used because the population numbers of the three agricultural systems are unknown. The determination of respondents used the accidental method. (Iliyasu and Etikan, 2021). This method is used to select respondents with different strata or levels. The deepened variation involves clustering organic, semi-organic, and conventional farming systems. Anthropogenic studies aim to identify the impact of a culture system on environmental indicators.

Results and Discussion

Water is a vital requirement for cultivation. Water can be used as an indicator of sustainability in an ecosystem. The organic farming system is a cultivation activity from upstream to downstream that is free from contaminants. Water is very easily contaminated with contaminants. Therefore, SNI 6729: 2016 concerning the Indonesian organic farming system stipulates that the water used for the cultivation process must be free from contaminants. In Indonesia, quality standards have been regulated in regulation PP 82 of 2001 concerning water quality management and water pollution control. The regulation stipulates that clusters I, II, III, and IV (Table 2) are standard values for water management. Water in agriculture is included in the class II category. These regulations exist to control the availability of clean water for food safety and the environment.

This study assesses the quality of water in organic and non-organic farming systems based on applicable quality standards. Water sampling starts from the upstream (water source), middle (irrigation), and downstream (river). Assessment of water quality becomes the basis for management recommendations to provide clean water for agricultural activities that is safe for plants and the environment. Table 3 presents the results of the water quality analysis of organic and conventional farming systems in Lumajang Regency. The organic farming system that is currently running at the research location has entered its 5th year with certification from LeSOS. The water used by the farmers comes from an underground water source which is located not far from the farmer's land.

In the upstream part, the BOD indicator still exceeds the quality standard. BOD is oxygen needed by a microorganism to degrade dissolved compounds. So, the high or low BOD value also depends on the amount of microorganism presence. BOD contains toxic compounds used by decomposing microorganisms to reduce them into simpler compounds (Sela et al., 2020; Bezsenyi et al., 2021). Chemical control based on research results can reduce BOD values such as PCP (Porous Concrete Pavements) and hydrogen peroxide (Faisal et al., 2020; Bezsenyi et al., 2021). However, the use of chemicals in the environmental field of agriculture is still not recommended. In controlled situations, it may still be possible, but application in the field still requires in-depth study. Based on the results of the analysis, the BOD values from the upstream, middle, and downstream sections are getting smaller but still do not meet quality standards. The value of water quality in the upstream is a source of water for organic and conventional farming activities.

Phosphate is one of the pollutant indicators in aquatic ecosystems. Phosphate (P) in water is divided into 3 groups, namely orthophosphate, polyphosphate, and organic phosphate. The movement of phosphate in the water is influenced by several factors, starting from fertilization activities, carried away by domestic waste, and disposal of sewage and food. One of the mobilizations of phosphate occurs by infiltration.

In Table 3 for the upstream, middle, and downstream sections, the phosphate indicator exceeds the quality standard. At the upstream location (water source), the phosphate value may be influenced by the surrounding activities. The source of water that emerges from the ground is a location in the middle of agricultural activities. The possibility is still carried away by agricultural activities upstream before the source. For Class II agriculture, the maximum recommended value is 0.2 mg L^{-1}. The presence of phosphates in the environment is an indicator of the presence of living things, such as biotic components in aquatic ecosystems. One method for assessing the mobilization and presence of phosphate is the use of UV-visible spectrophotometry (Oladeji et al., 2016). Downstream with a point Lat -8. 147999, Long 113.036091, COD in organic and non-organic farming systems exceeds quality standards.

Table 3. Water quality in organic and non-organic systems.

Location Point	Parameter	Organic Systems*			Non-organic Systems*		
		R1	R2	R3	R1	R2	R3
Physical							
Upstream (in)	Temperature	21.7	21.9	22	21.7	21.9	22
Years -8.138118	TDS	69.9	70	71	69.9	70	71
Long 113.014188	TSS	5	5.1	4.9	5	5.1	4.9
	Color	Clear	Clear	Clear	Clear	Clear	Clear
	Smell	-	-	-	-	-	-
Chemical							
	pH	6.45	6.5	5.29	6.5	6.40	6
	BOD	5.85*	20.73*	18.53*	5.85*	20.73*	18.53*
	COD	19.78	0.55	0.6	19.78	0.55	0.6
	Total Phosphates	0.65*	2.3*	2.95*	0.65*	2.3*	2.95*
	NO_3-	2.43	0.04	0.05	2.43	0.04	0.05
	NO_2-	0.05	6.5	5.29	0.05	6.5	5.29
	DO	0.2	0.3	0.3	0.3	0.3	0.2
Biological							
	Total Coliform	8	7	4	8	7	4
Physical							
Middle (irrigation)	Temperature	23.6	23	24.1	24.3	25	24.6
Years -8.147672	TDS	70.8	72	73.1	72.1	70	71.9
Long 113.035917	TSS	5.7	14.8	14.4	9.6	7.5	5.2
	Color	Clear	Clear	Clear	Clear	Clear	Clear
	Smell	-	-	-	-	-	-
Chemical							
	pH	7.43	7.4	7.3	7.4	7.1	7.0
	BOD	7.51*	7.3*	5.48*	6.55*	7.88*	7.68*
	COD	24.7	22.81	20.28	21.92	24.23	22.4
	Total Phosphates	0.43*	0.4*	0.4*	0.25*	0.26	0.21
	NO_3-	2.4	2.01	2.03	1.7	1.75	1.67
	NO_2-	0.04	0.04	0.04	0.05	0.48	0.05
	DO	0.4	0.3	0.4	0.9	1.2	1.5
Biological							
	Total Coliform	130	150	90	640	1290*	390
Physical							
Downstream (out)	Temperature	24.4	24.1	25	24.2	24.3	24.3
Years -8. 147999	TDS	73.9	80	72.1	70.2	90	95
Long 113.036091	TSS	96.4*	100.8*	90.2*	78.8*	73.4*	59.5*
	Color	cloudy	cloudy	cloudy	cloudy	cloudy	cloudy
	Smell	-	-	-	-	-	-
Chemical							
	pH	7.88	7.4	7.5	7.93	7.81	7.2
	BOD	9.01*	8.23*	9.01*	8.92*	9.16*	8.56*
	COD	35.29*	32.8*	33.34*	31.96*	30.65*	29.99*
	Total Phosphates	0.75*	0.43*	0.51*	0.52*	0.54*	0.47*
	NO_3-	2.64	2.5	2.64	2.7	2.68	2.8
	NO_2-	0.04	0.04	0.04	0.04	0.04	0.04
	DO	1.7	2.1	1.9	1.5	1.5	1.8
Biological							
	Total Coliform	1,500*	1,020*	1,100*	380	310	280

Note: * R = replicate.

The highest COD value among the samples collected was 35.29 mg L^{-1}. The maximum tolerated BOD limit is less than 25 mg $L^{-1.}$ The downstream section is the final part of all activities that cause the accumulation of pollutants to increase. The COD value is probably carried away by surfactant and detergent solutions carried around cultivated plants. The lower the COD value, the cleaner the water conditions, and the less pollutant substances are ensured. In waste handling, COD can be treated using silver nanoparticles to reduce COD levels in waste (Santos et al., 2022). Other methods can be used for water treatment using one-step electrochemical oxidation (Meng et al., 2023). Total coliform is a group of microorganisms in the form of bacteria, which is the basis for determining pollution in water or wastewater. The standard of clean water used in agricultural class (Class II) is a maximum of 5 x 10^3 CFU 100 mL^{-1}. Meanwhile, at the end, the BOD value reaches more than the standard set, namely a maximum of 1500 CFU 100 mL^{-1}. The BOD value in the conventional system is better than the organic farming system. This is because the downstream of the organic farming system is adjacent to the local community's domestic waste. Local people dispose of domestic waste in one of the irrigation canals. In this case, it causes a higher total coliform. Not only that but in Figure 4, it is clear that there are still piles of food waste and detergents that are wasted around the plants (irrigation). Some people still use the irrigation network for bathing and other domestic activities. The existence of coliform bacteria consists of several groups ranging from Citrobacter, Enterobacter, *Escherichia coli*, and Klebsiella. In general, this group of bacteria is a pathogen (Trmčić et al., 2016; Some et al., 2021; McMillan et al., 2023). In the organic farming system, there is an ICS (Internal Control System) division that functions as a safety and environmental control oversight. Organic certification bodies such as LeSOS cannot tolerate garbage around cultivated plants. ICS was formed from members of farmer groups. One of the efforts that can be made to reduce the BOD value in agricultural water is to ensure that no garbage or domestic waste is wasted into irrigation networks.

Figure 4. Spatial distribution of water quality on organic system.

Figures 5 and 6 map the values of several projected observation parameters using SURFER analysis tools. Surfer assists in a grid-based contouring and 3D surface plotting graphics program. In this study, Surfer helped map the projection of value streams for each analysis parameter based on the grid that was created. The grid components are made in XY to Z, with the XY composition being the coordinate points and Z being the values for each analysis parameter. The vertical column is the range of values that have been input into the SURFER system. The range of values at each interval will give a different color for easy reading. The range of values is increasingly varied depending on the amount of value collected. The pattern of the contours that is translated from Figure 5 is an illustration that each color has a different direction. Each line with a different color pattern represents the mobilization of parameter values in the vertical column. Studies in this research area are supported by biophysics that support the development of sustainable agriculture. At the research location, the soil type is dominated by eutric regosol. Lithosol soil types originate from igneous rocks and hard deposits due to weathering. Lithosol soils have very varied soil textures. Meanwhile, regosol soil has good porosity, consisting of fine sand components, but has a low fertility rate because it is prone to leaching. Based on Figure 7 section (b), the research location has different elevation levels. It is still very suitable for the suitability of rice cultivation plants. In part (c) is the amount of rainfall intensity with an average of 2,500-3,000 mm $year^{-1}$. The existence of water in the research location is very abundant and can suffice for the surrounding area.

The purpose of the anthropogenic study is to review human behavior related to cultivation activities and their impact on the environment. The results of the determination using stratified disproportionate sampling with the data collection obtained contained clustering of organic, semi-organic, and non-organic farming systems. This clustering was obtained based on the typology of farmers who each use synthetic fertilizers and pesticides, weeding treatment, handling of plant-disturbing organisms, and tillage. The cultivation system adopted by the community has a significant impact on water quality indicators. Intensive cultivation systems, such as the use of synthetic fertilizers and pesticides, have an impact on decreasing soil and water quality (Alfarisy et al., 2020; Singh et al., 2021; Ingrao et al., 2023; Yu et al., 2023). Based on studies in China, innovation, resource abundance, and the effects of climate change and green growth in agriculture and the relationship between components (Ren et al., 2023).

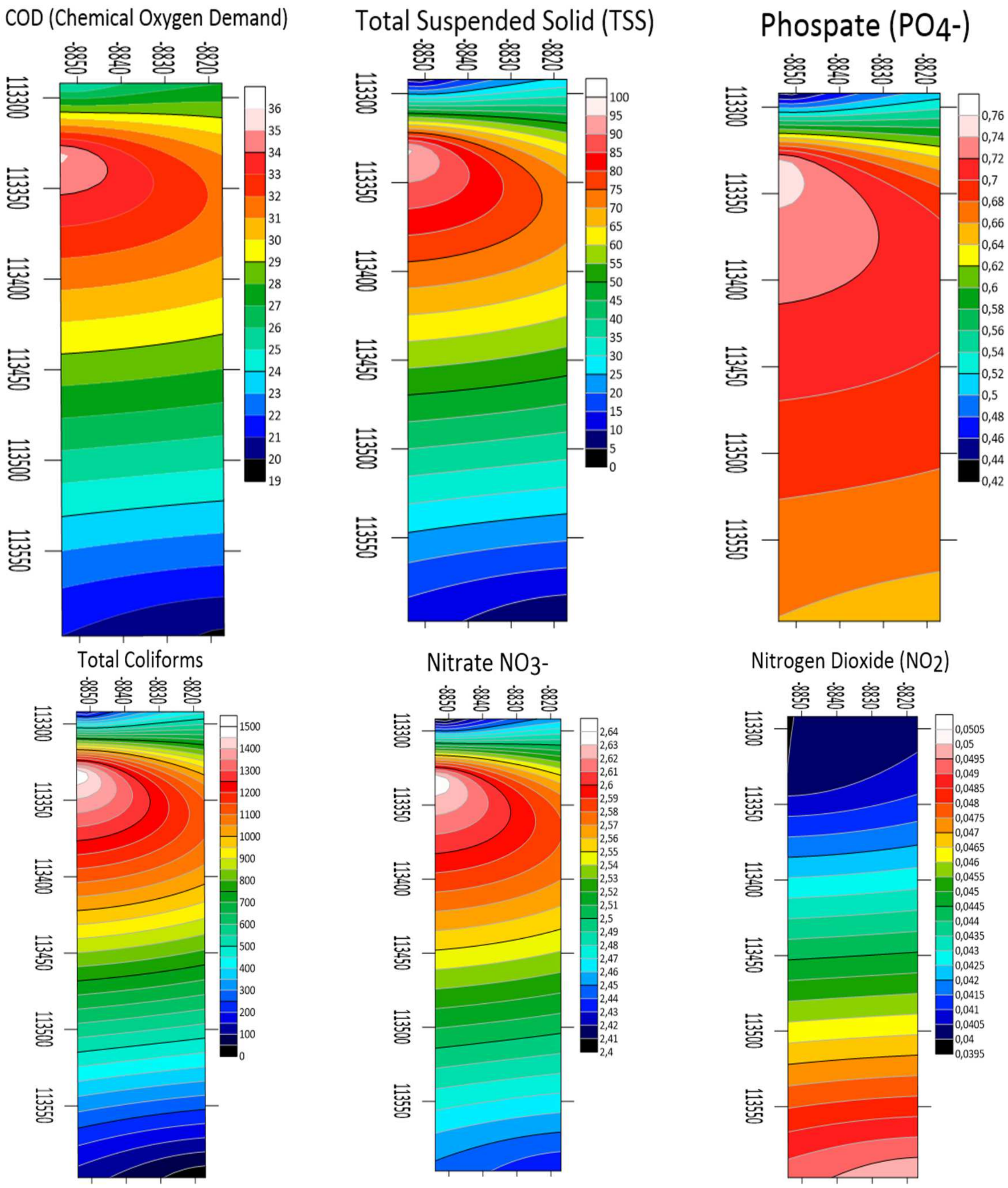


Figure 5. Spatial distribution of water quality on organic system.

Figure 8(a) explains that the impact of changes in water quality is influenced by a cultivation system based on a farmer's typology that is distributed 50% non-organic, 27% semi-organic, and 23% with an organic system. The composition of farmer clustering correlates with how farmers obtain rice. The phenomenon based on Figure 8(b) is very unique and may currently only occur in Indonesia. Farmers with non-organic systems obtain rice for consumption by buying rice that comes from organic cultivation.

However, these farmers are reluctant to cultivate organic crops. 40% of the total respondents chose to buy organic rice compared to non-organic cultivated rice.

Based on the information obtained, farmers assume that the use of synthetic fertilizers and pesticides can increase production. Meanwhile, the results of 100% organic and semi-organic cultivation have been consumed by themselves. The reason farmers practice organic cultivation, besides having a high selling value, also has a good impact on health. 100% of farmers in the area consume organic rice themselves, in contrast to the case in Thailand, where 63% of organic farmers market more through marketing (Methamontri et al., 2022). The reason farmers use an organic system is that 100% of farmers want to produce rice products that have a high price and want to maintain health by consuming organic rice that incomes from their own. On the other hand, they want to maintain the quality of soil and water.

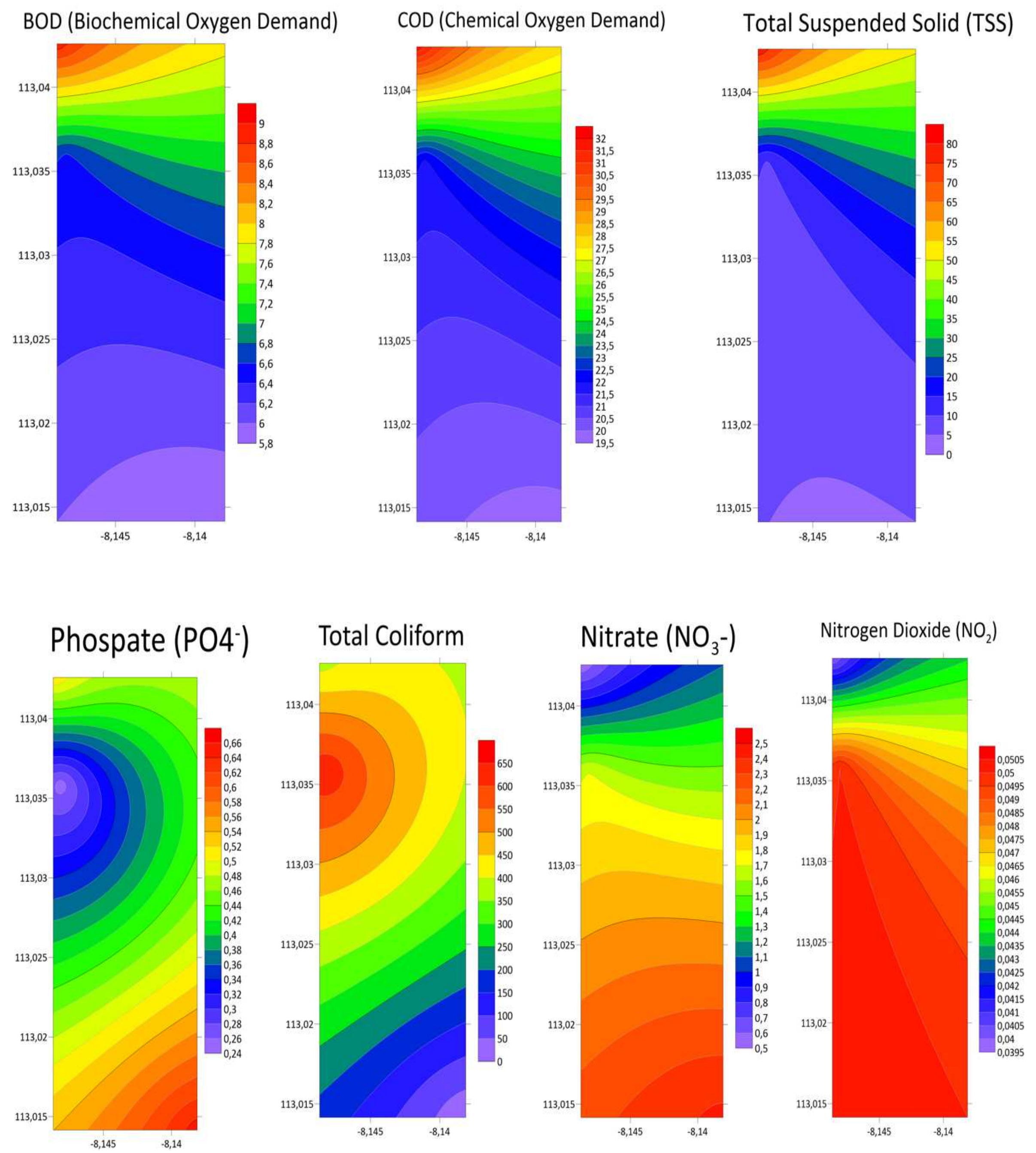


Figure 6. Spatial distribution of water quality on non-organic system.

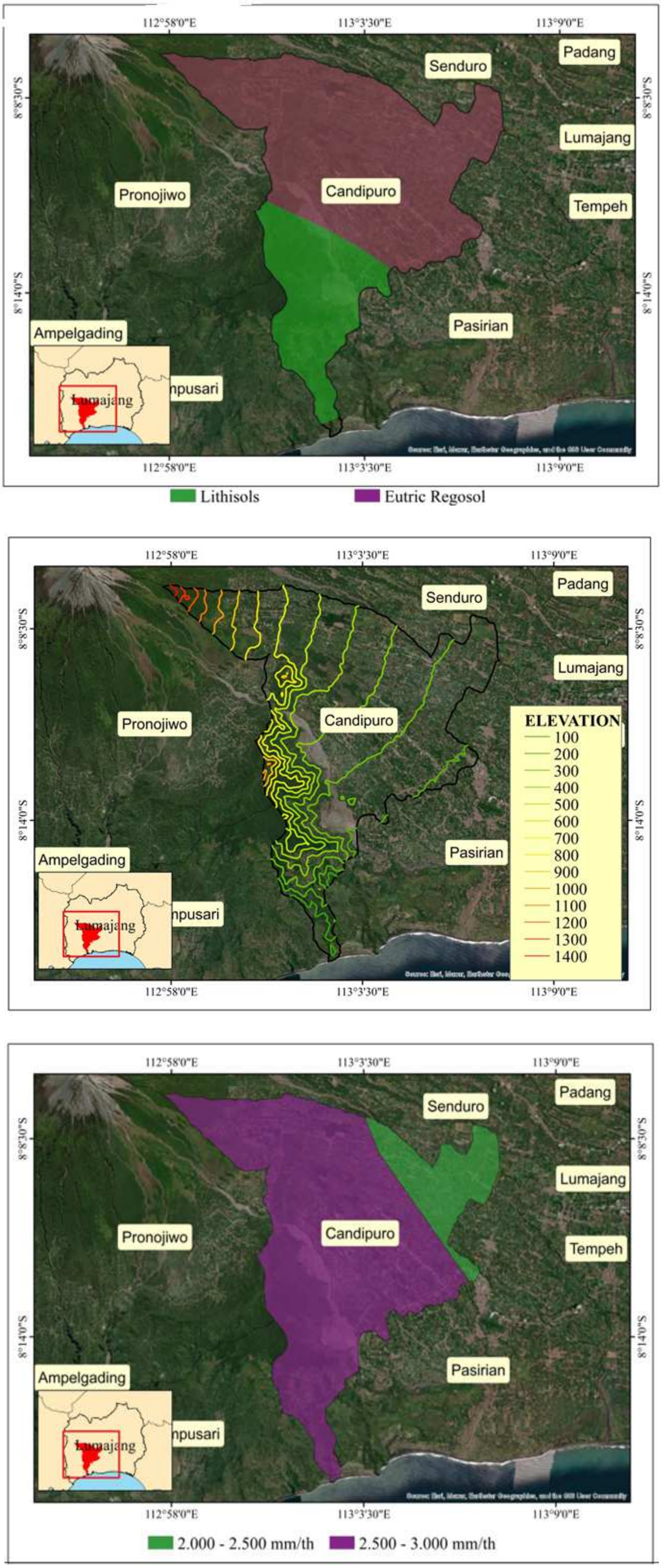
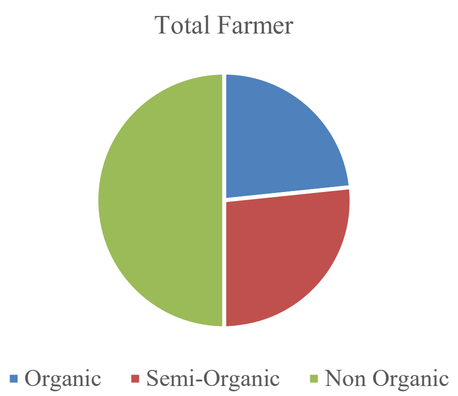
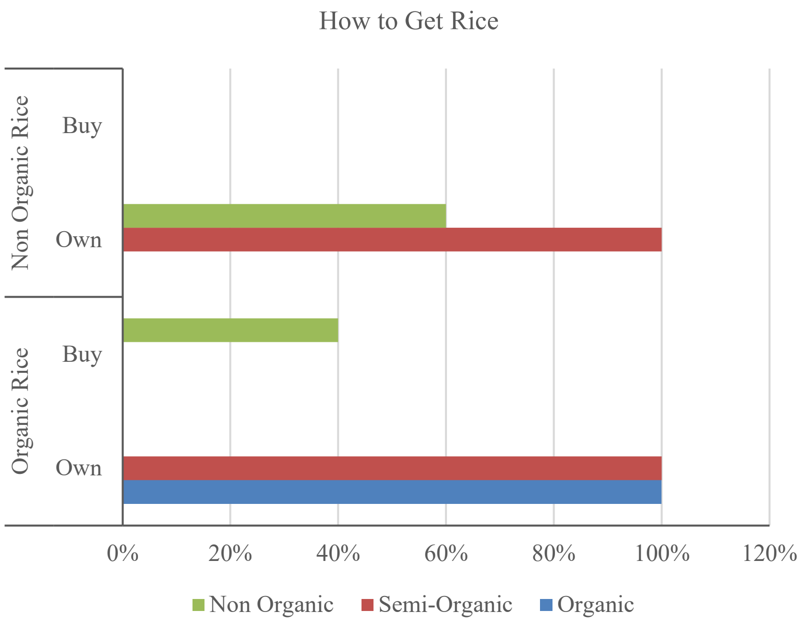


Figure 7. Biophysical mapping.



(a)



(b)

Figure 8. Responses of anthropogenic study.

Conclusion

Water quality is one of the environmental sustainability assessments in agriculture. Based on the rules of the organic certification agency, organic farming systems must be free from contaminants in both the soil and water. The principle of cultivation that must be carried out is that it is advisable to use natural ingredients to replace synthetic substances in cultivation. So that it does not have an impact on the sustainability of the aquatic ecosystem. Indicator parameters that still exceed quality standards include BOD, COD, TSS, total phosphate, and total coliform. Efforts are needed to control water quality to meet quality standards. Assessment of water quality in organic and non-organic systems is the basis for determining control recommendations to maintain ecosystem stability and implement the principles of sustainable agriculture. Anthropogenic control is needed to directly minimize the sewage and domestic waste that flows into irrigation networks. The results of clustering from organic, semi-organic, and non-organic can be used as an evaluation to identify cultivation systems so that they can maintain the stability of the rice ecosystem.

Acknowledgments

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