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RESEARCH ARTICLE

Evaluation of soil fertility index in organic, semi-organic, and conventional rice field management systems

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Abstract

Rice farming in Madiun Regency implements three different management systems, that is organic, semi-organic, and conventional. The different implementation of these rice field management systems impacts soil fertility index and rice productivity. This purpose of this research was to know the effect of rice field management systems on soil fertility index and rice productivity in the Madiun Regency. The research uses an explorative descriptive qualitative method with a survey approach. Soil samples were taken using a random sampling method and 3 types of soil management systems (conventional, semi-organic and organic), and rice production samples were taken using an estimation method. The research results show that the soil fertility index ranges from 0.78 to 0.82, which is high. The highest soil fertility index is in the semi-organic management system and the lowest is in the organic management. The management system of semi-organic gave a response to the highest rice production of 6.89 tons/ha. Management system of semi-organic is a better management for increasing and maintaining soil fertility and crop production than conventional or organic. Farming activities results show that organic management systems increase the highest income, increasing 115.58% and 53.30% in semi-organic compared to conventional. The rice field management system has the effect of increasing the worm population density with the highest in the organic system, namely 4.19 individuals m^{-2}. The *Pontoscolex* worm type dominates the three management systems. There is a correlation between organic matter content and earthworms.

Keywords: Inorganic fertilizer; Organic fertilizer; Rice field management systems; Rice productivity; Soil fertility index.

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1. Introduction

The rapidly growing green revolution has been able to transform Indonesian agricultural practices since the 1960s in meeting food needs. In Indonesia, it was marked by the implementation of an agricultural intensification program. Agricultural intensification, understood as increasing aggregate yield per unit of land, is an effective effort to increase agricultural production, while preserving land resources (Garcia, 2020). Implementation of agricultural intensification in Indonesia by implementing agrochemicals in the form of chemical fertilizers, pesticides, and the use of superior varieties. In the history of national rice production, rice productivity could be increased from 2.3 t/ha in 1960 to 4.54 t/ha in 2004. The increase in production was achieved mainly by the availability of new short-lived superior varieties, the use of chemical fertilizers (urea, TSP, KCl), use of pesticides together with the application of IPM principles (Integrated Pest Management), and improvement of irrigation networks (Makarim & Suhartatik, 2006).

The agricultural intensification carried out so far has caused many problems. The continuous use of chemical fertilizers and pesticides, although it has greatly increased national and global food production, has damaged agricultural land, reduced the quality of agricultural products, and increased environmental risks (Penuelas et al., 2023). Disproportionate use of agrochemicals can have an impact on soil productivity, pollute water resources and be dangerous for human health (Soni et al., 2022), have an impact on decreasing soil carbon in the top 0-30 cm layer (Fitria & Kurniawan, 2023).

Using fertilizers such as nitrogen, only around 50% of the N is applied effectively, while the rest is lost through various pathways to pollute the environment (Govindasamy et al., 2023). In addition, excessive use of chemical fertilizers, especially the addition of nitrogen, lowers soil pH and reduces the efficiency of fertilizer nutrient use (Liu et al., 2021). This is confirmed by Sharma & Chetani (2017) that the intensive use of conventional fertilizers in agriculture causes many health problems and environmental pollution. Agricultural systems have tended to exploit nutrients through intensive processing and unbalanced use of nutrients (Ravi Kumar et al., 2019), so that dependence on agrochemical inputs, or chemical fertilizers and pesticides, can affect soil quality and the efficiency of nutrient use (Iqbal et al., 2019).

Currently, many new agricultural practices have been developed, including organic farming, which is a sustainable agricultural approach with ecological principles (Soni et al., 2022). Agricultural development does not only focus on productivity but must also be sustainable as an answer to reducing environmental impacts (Rockström et al., 2017). The application of organic matter in the form of animal manure alongside conventional fertilizer not only helps to enrich the soil with organic matter but is also important for promoting soil health and soil quality (Swain et al., 2019). Some farmers support the need for chemical fertilizer with the addition of organic fertilizer that is environmentally friendly and cost-saving (Dikr & Belete, 2017).

Organic matter content is essential for soil fertility. Hoffland et al. (2020) state that one of the main roles of soil organic matter is in the soil ecosystem, where it serves as a source of plant nutrition, controlling the retention of macro and micronutrients. Organic matter content determines soil fertility levels. For rice crops >3% is good and <3% is considered too low (Ilagan et al., 2014). The use of organic fertilizer such as animal manure not only provides the soil with organic carbon but also supplies plant nutrients, as well as having the residual effect of providing nutrients to aid plant growth in the next planting season (Iqbal et al., 2019). It is reported that this residual effect provides benefits up to the third year after application (Koutev & Nenov 2016). The use of livestock waste from the mineralization process not only increases the availability of N but also increases the availability of P, K, Zn, and Cu nutrients (Hirzel et al., 2010). Suntoro et al., (2018) show in their research that the addition of animal manure increases corn yield. The comprehensive application of organic and conventional fertilizer is an effective way to increase the productivity of rice plants (Liu et al., 2021). Soil fertility maintenance is a fundamental principle of sustainable farming (Sapinas & Abbott, 2020). This kind of maintenance can be carried out by calculating the Soil Fertility Index (SFI). The soil fertility index is calculated based on the value and quality of each indicator of soil fertility. Soil fertility indicators are chosen from the characteristics that indicate the capacity of soil function (Mujiyo et al., 2020). Intensive management systems lead to a reduction in soil fertility. There is a need for the right kind of management to improve soil fertility. Soil fertility is one of the necessary conditions for increasing rice productivity. In general, organic production systems are associated with lower productivity per area unit than conventional systems, and the challenge is to overcome the problem of inadequate nutrient supply, which is one of the main causes of lower productivity.

Sustainable agricultural management systems can have an impact on the sustainability of the food system, because they can affect human health as well as animal welfare, food security and environmental sustainability (Mie et al., 2017). Organic farming can be a major pathway towards socio-economic and ecologically sustainable development, especially in developing countries. This can be achieved by using agronomic, biological and mechanical methods on agricultural land with no synthetic inputs outside of agriculture (Soni et al., 2022). Ma et al. (2023) in his research emphasized that organic fertilizer increases the nutrient content and biological indicators of the soil to a greater extent than chemical fertilizer alone; The effect of applying organic fertilizer on combined soil enzyme activity was also higher than applying chemical fertilizer alone.

The Indonesian government began promoting organic farming in 2001, with the launch of the 'Go Organic 2010 Program' (Schreer & Padmanabhan, 2020). Organic farming in Indonesia is currently developing very rapidly. Farmers' confidence in practicing organic farming still varies between semi-organic and full organic. Therefore, this research aims to evaluate the soil fertility index in organic, semi-organic and conventional Rice field management systems.

2. Methodology

Field survey

This research was conducted in Madiun Regency, East Java, Indonesia (Figure 1). The research uses an explorative descriptive method with a survey approach. Soil sampling used a stratified purposive sampling method (Soil Survey Staff, 2014), soil type was Vertisols (Soil Survey Staff, 2022), and 3 types of soil management systems (conventional, semi-organic, and an organic). A total of 24 soil samples and production samples were observed. These samples consisted of 6 sampling points from organic rice fields, 6 sampling points from semi-organic rice fields, and 12 sampling points from conventional rice fields. The soil samples were taken from a depth of 0-20 cm (Supriyadi et al., 2021) and the plant production samples were taken when the rice plants were 90-120 days after planting.

Soil analysis and field production

A chemical analysis was carried out in the Laboratory of Soil Chemistry in the Soil Science Study Program, in the Faculty of Agriculture, at Universitas Sebelas Maret, Indonesia. The soil parameters analyzed included moisture content (gravimetric method), pH H_2O (electrometric method), soil organic carbon (walkley and black method), total N (Kjeldahl method), total P (25% HCl extraction method), available K (ammonium acetate saturation method), cation exchange capacity (CEC) (ammonium acetate saturation method), and Ca, Na, Mg exchangeable (flamefotometry), and base saturation (BS) (ammonium acetate saturation method) (Eviati & Sulaeman, 2021). The plant production parameters included estimation of weight (the grain dry weight) and 1000 seed weight. The estimation method is caried out an area of 2.5 m x 2.5 m.

Data analysis

The determination of soil fertility index began with a Person Correlation Analysis to observe how close the relationships were between the variables tested. This was followed by a Principal Component Analysis (PCA) to find the data that would be used as the primary components. The data from the PCA with the highest scores and high correlation were chosen as the Minimum Data Set (MDS) to represent all the indicators of soil fertility. Calculation of the soil fertility index referred to Mukashema (2007): SFI : $(\frac{Sci}{N}) \times 10$

SFI: Soil Fertility Index; Sci: total Minimum Soil Fertility Index weights (= total score weight (cj) x appreciation value (pc)); N: total Minimum Soil Fertility Index (MSFI).

Table 1
Classification of Soil Fertility Index Class

Soil Fertility Index	Class
0-0.25	Very low
0.25-0.50	Low
0.50-0.75	Medium
0.75-0.90	High
0.90-1	Very high

Source: Bagherzadeh et al. (2018).

The SFI obtained was further analyzed using (ANOVA), followed by a Duncan's Multiple Range Test (DMRT). The ANOVA was used to examine the influence of rice field management on soil fertility index. The soil fertility index classification, based on Bagherzadeh et al. (2018) (Table 1).

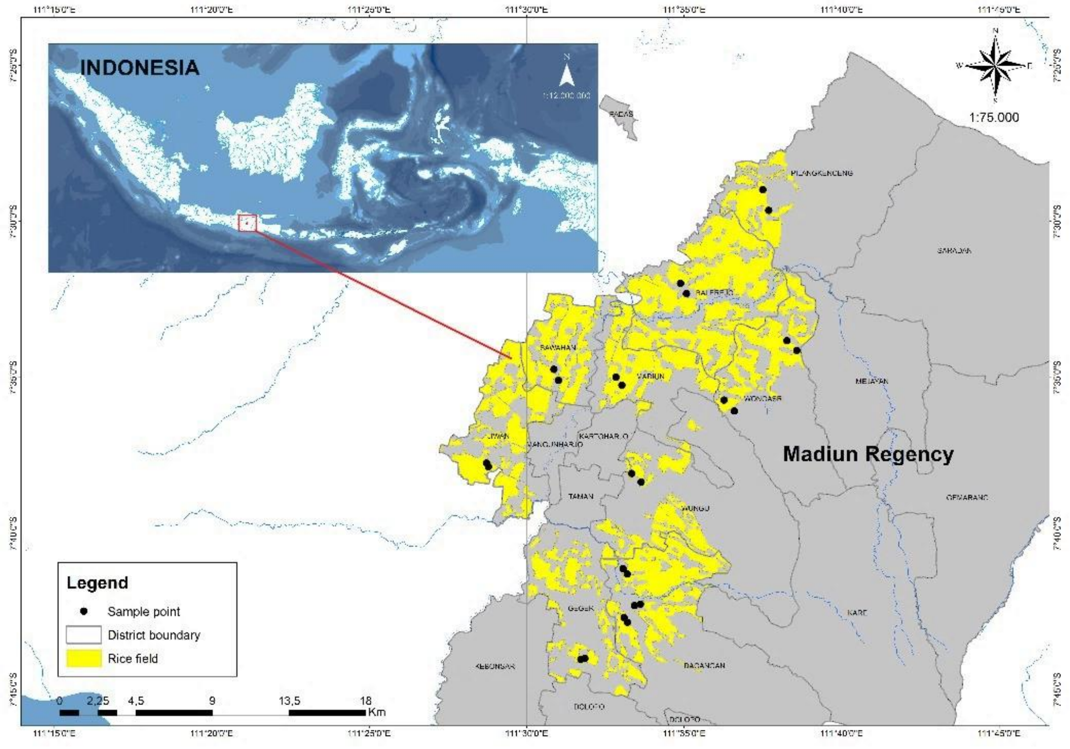

Figure 1. Map of sample collection points in Madiun Regency.

3. Results and discussion

Soil Properties

The soil in the research location includes Vertisols (Soil Survey Staff, 2022). This soil has vertic properties, neutral pH, moderate to high soil organic carbon, moderate to high total N, moderate to high total P, low available K, high CEC, medium to high base saturation and clay texture (Table 2). Based on the results of soil analysis, the research location is classified as high fertility. Parameters of soil pH, organic carbon, N, P, K, CEC, base saturation and texture are the basis for determining soil fertility (Nguemezi et al., 2020).

The soil pH values at the study sites ranged from 6.50-6.70 with the highest pH in organic management and the lowest in conventional management. According to research Tongka et al., (2019) Soil pH did not differ significantly between management systems due to the flooding process which increased the pH to near neutral. Paddy field management has a significant effect on soil organic carbon content. The highest soil organic carbon content was 2.99% in the organic management system and the lowest was 2.43% in conventional management. Organic management has the highest value of 2.99% and the lowest is conventional management of 2.43%. The level of organic matter is influenced by the amount of input of organic matter into the soil (Adekiya et al., 2021). Returning crop residues in the form of straw to the soil is one of the causes of increased soil organic carbon content (Chase & Singh, 2014). The low content of organic carbon in conventional management is caused by farmers in the research location continuously applying chemical fertilizers (Yang et al., 2016).

Table 2
Result of soil properties analysis

Soil Properties	Organic	Semi-organic	Conventional
pH	6.70^{a}	6.69^{a}	6.50^{a}
carbon organik (%)	2.99^{a}	2.86^{a}	2.43^{b}
total N (%)	0.47^{a}	0.47^{a}	0.25^{b}
total P (%)	37.9^{b}	46.1^{a}	39.8^{b}
available K (me 100 g^{-1})	0.85^{b}	1.32^{a}	1.13^{a}
CEC (me 100 g^{-1})	27.95^{ab}	29.37^{a}	26.7^{b}
Ca (me 100 g^{-1})	7.74^{b}	9.82^{a}	9.1^{ab}
Na (me 100 g^{-1})	0.89^{a}	0.95^{a}	1.06^{a}
Mg (me 100 g^{-1})	4.45^{c}	5.1^{a}	4.72^{b}
BS (%)	49.9^{b}	58.78^{a}	60.16^{a}

Explanation : CEC = Cation Exchange Capacity, BS = Base Saturation.

The total N content at the study site ranged from medium to high. Organic and semi-organic management has a total N content of 0.47% and conventional 0.25%. Other studies also explain that the application of organic fertilizers is very effective for increasing nitrogen in the soil and plant tissue (Supriyadi et al., 2019). The results of the total P analysis found significant differences between paddy field management systems. The highest total P value was found in semi-organic management with a value of 46.1% and the lowest was found in organic management with a value of 37.9%. Burning straw residue causes a decrease in the P content in the soil by 34%-59% (Pakpahan et al., 2019). Available K in the soil also showed significant differences between paddy fields management. The highest content was found in semi-organic management with a value of 1.32 me 100 g^{-1} and the lowest in organic management with a value of 0.85 me 100 g^{-1}. Giving a combination of 1 dose of organic fertilizer with ¾ dose of inorganic fertilizer has been shown to significantly increase the growth of caisim and can affect the availability of potassium in the soil (Mulyani et al., 2017).

Analysis of Cation Exchange Capacity (CEC) showed significant differences between rice fields management. The highest CEC was found in semi-organic management of 29.37 me 100 g^{-1} and the lowest in conventional management of 26.7 me 100 g^{-1}. The addition of organic matter causes an increase in the CEC value because cations can be retained by negatively charged ions on the soil surface (Tomašić et al., 2013). The increase in CEC generally increases the base saturation (Bande et al., 2016). But in the results of the analysis above, the high CEC is not followed by base saturation. This is in accordance with the statement Sufardi et al. (2017) that the calculated CEC is not the effective CEC, but the potential CEC. This shows that the CEC in tropical soils does not always reflect the amount of cations absorbed by the soil, but only as the CEC formed from variable charges and does not reflect the actual adsorption of cations on the colloidal surface. Base saturation values ranged from 60.16% - 49.9% with the highest in conventional management and the lowest in organic management.

Earthworm population

Earthworms are a very important soil biological parameter. The presence of earthworms on agricultural land will maintain a sustainable cycle of nutrient availability (Gamasika et al., 2017). The research results showed that between all management systems, the highest earthworm population density was in organic management, 4.19 individuals m^{-2} with several earthworms of 26.7 and the lowest in conventional management, namely 1.72 individuals m^{-2}, with a number of 10.75 (Figure 2).

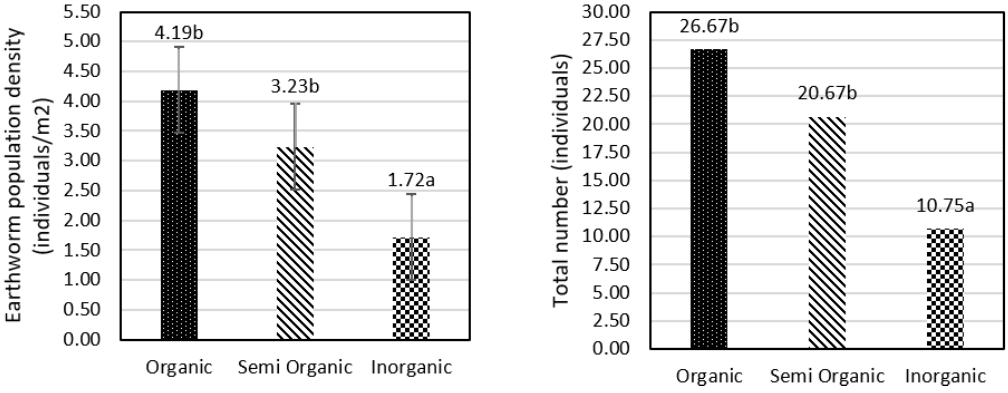

Figure 2. Effect of management system on population density and number of earthworms.

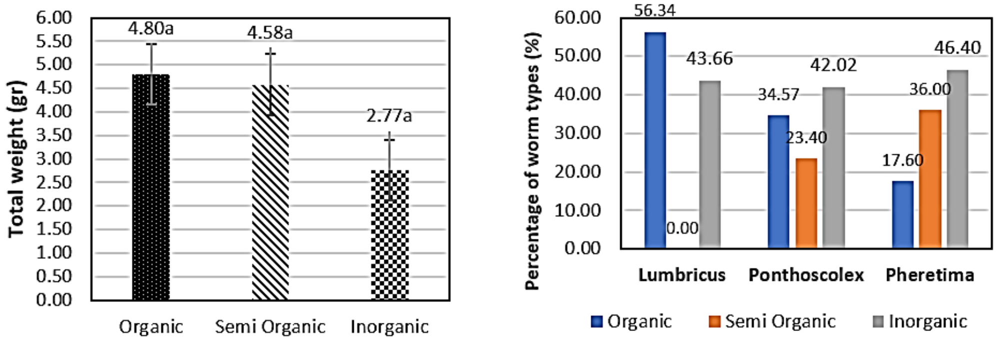

Figure 3. Population of Worm Types in Various Rice Field Management Systems.

Earthworms are indicators of the health of soil agroecosystems and can also be known as a determining tool for soil improvement and nutrient cycles. This is related to the accumulation of organic matter in the soil which causes soil fertility (Chaulagain et al., 2017). It was proven that there was a positive correlation between soil organic matter content and earthworm population density (r = 0.512*). The response to changes in the soil environment, whether changes in cultivation systems including physical and chemical changes, will affect the population density of microbes and earthworms is one indicator of population density (Dewi et al., 2022). In the organic management system, organic waste is transformed by earthworm activity through the digestive tract into organic fertilizer. The resulting organic manure is rich in microbes, regulates plant growth and enables plant health. The population of earthworm types in each land management system is different.

The results show that there are three types of earthworms, namely *Lumbricus sp*., *Pontoscolex sp*., and *Pheretima* sp (Figure 3). The types of earthworms are dominated by the Pontoscolex type which has a high population and is found in all management systems. Pheretima sp worms is an epianetic type of earthworm that lives in the surface layer of the soil and eats litter to help soil fertility (Darmawan et al., 2023). The highest *Lumbricus* sp earthworms were found in organic management (56.34%). Dulaurent et al. (2020) showed that *Lumbricus* earthworms increase the concentration of N, P, K and Ca in barley (*Hordeum vulgare L.*), can increase the efficiency of organic fertilizer and support the importance of developing sustainable agricultural practices. Earthworms are a good predictor of ensuring sustainable agriculture. Earthworms in the soil are very important biological organisms that maintain the recycling of nutrients in the soil and increase soil fertility. Therefore, the existence of earthworms needs to be maintained by providing soil organic matter.

Soil Fertility Index

The calculation of soil fertility index in this research uses the Minitab 19 application and IBM SPSS Statistics 25. The soil fertility index calculations began with the Pearson Correlation Analysis to find how close the relationships were between the variables tested. The Principal Component Analysis (PCA) produced data referred to as the Principal Components, which were used to determine the value of the Minimum Data Set (MDS). The MDS is the smallest data set that is able to represent all the existing data, which in this case was the soil fertility parameters (Mukashema, 2007).

Table 3
Correlation of Fertility Indicators and Worm Populations in Madiun Regency

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1														
2	0.156	1													
3	0.026	-.516**	1												
4	-0.158	0.071	0.385	1											
5	-0.028	-0.330	.558**	0.346	1										
6	0.237	0.295	-0.116	0.211	0.173	1									
7	-0.110	0.087	.414*	0.184	0.304	0.274	1								
8	0.088	-0.099	0.144	-0.284	-0.187	-0.016	0.218	1							
9	0.077	-0.140	.579**	.643**	.472*	0.365	0.285	0.111	1						
10	-0.203	-0.195	.597**	0.105	0.295	-0.389	.736**	0.366	0.219	1					
11	-0.172	.512*	-.544**	0.152	-0.284	0.193	-0.076	-0.047	-0.123	-0.252	1				
12	0.095	0.040	-0.015	0.165	0.061	0.217	0.176	-0.028	0.159	0.022	0.105	1			
13	-0.030	0.399	-0.305	0.211	-0.098	0.051	-0.256	-0.034	0.045	-0.230	.509*	0.141	1		
14	0.156	1.000**	-.518**	0.069	-0.331	0.295	0.085	-0.098	-0.141	-0.197	.511*	0.038	0.397	1	
15	-0.172	.512*	-.544**	0.152	-0.284	0.193	-0.076	-0.047	-0.123	-0.252	1.000*	.105	.509*	.511*	1

Remarks: (*): significant correlation at <0.05 level, and (**): very significant correlation at <0.01 level. 1=pH, 2=Organic carbon, 3=Total N, 4=Total P, 5= available K, 6=Cation Exchange Capacity, 7=Ca, 8=Na, 9=Mg, 10=Base Saturation, 11=Population density of worms, 12=Average length of worms, 13=Total weight of worms, 14=Organic matter, 15=Total number of worms

The MDS was determined by selecting the PCs with an eigenvalue >1, and for each PC, the value was sought with the highest correlation in Table 3. The results of the PCA can be seen in Table 4.

Table 4
Result from Principal Component Analysis (PCA)

Eigenvalue	3.2043	1.9401	1.4767	11908
Proportion	0.32	0.194	0.148	0.119
Cumulative	0.32	0.514	0.662	0.781
		Eigenvectors		
Variable	PC1	PC2	PC3	PC4
pH	-0.068	-0.209	0.274	-0.644
Organic-C	-0.213	-0.31	0.424	0.414*
Total-N	0.488*	0.108	-0.114	-0.222
Total-P	0.306*	-0.387	-0.209	0.281
Available-K	0.391*	-0.152	-0.233	-0.104
CEC	0.042	-0.561	0.324*	-0.089
Ca	0.365*	0.043	0.459	0.32
Na	0.087	0.312	0.518*	-0.299
Mg	0.41*	-0.32	0.014	-0.162
BS	0.394	0.4*	0.223	0.22

Explanation : CEC = Cation Exchange Capacity, BS = Base Saturation, * = Minimum Data Set (MDS)

Based on the results of the PCA, 4 PCs were obtained, where the parameters with the highest correlation were 9 of the 10 existing parameters. The parameters chosen as the MDS represented 78.1% of all the existing data. PC1 represented 32% with the indicators Total N, Total P, Available K, Ca, and Mg. PC2 represented 19.4% with the indicator base saturation. PC3 represented 14.8% with the indicators CEC andNa. PC4 represented 11.9% with the indicator Organic C, from all the data used in determining the soil fertility index.

The soil fertility index calculations in this research show that the SFI (Table 4) was in the high classification range for all three rice field management systems. The highest SFI was found in the semi-organic management system, with a value of 0.82. The conventional and organic management systems had lower SFI values than the semi-organic management systems, 0.80 and 0.78, respectively. Figure 4 shows the distribution of the soil fertility index in Madiun Regency.

Table 4 shows that the SFI values at the research location were all in the high classification range, varying from 0.78 to 0.82. The highest SFI was found in semi-organic management, with a value of 0.82 (high) and the lowest was in organic management, with a value of 0.78 (high). Semi-organic rice field management had a higher SFI value than the other management systems because applying chemical and organic fertilizer is more effective in increasing soil fertility. Chemical fertilizer supplies nutrients directly, especially N, P, and K, and increases nutrient availability more rapidly. In contrast, organic fertilizer increases nutrient binding capacity so that the chemical fertilizer applied will be withheld to become available for plant growth. This combined fertilization influences the accumulation of C and N in the soil through the components of soil organic C and N. However, the response of fertilization to the accumulation of C and N in the soil varies because the different saturation levels and initial C and N levels in the soil can limit the capacity of C and N absorption in the soil (Yang et al., 2016). This is in line with the research of (Kai et al., 2020) which shows that a higher application of organic fertilizer increases bacterial biomass and activates the circulation of N and P, compared with chemical fertilizer. The soil's microorganisms utilize carbon as a source of nutrition, which is supplied in abundance by organic fertilizer, so a lack of microorganisms correlates to the long-term use of fertilizer. This is in accordance with research from Iqbal et al. (2019), that organic fertilizers in combination with inorganic fertilizers is a better approach to increasing and maintaining soil fertility and crop production than just the application of inorganic or organic fertilizers. Ma et al. (2023) emphasize that the main issues in soil performance are related to variations in total N, organic matter, and available potassium or available phosphorus content.

The role of organic carbon is very important in maintaining the quality of soil fertility (Alam et al., 2024). Maintenance of adequate stocks of organic carbon in agricultural soils is essential for providing nutrients, for improving soil structure, maintaining microbial activity, and guarding against pathogens (Scotti et al., 2015). One of the important roles of soil organic carbon is related to CEC. Around 20 - 70% of soil exchange capacity is generally sourced from humus colloids (example: Molisols), so there is a correlation between organic matter and soil CEC (Stevenson, 1994). With a high CEC, it causes the ability to retain K, NH_4, Ca and Mg nutrients in the soil, so that these cations are retained in the soil.

Conventional rice field management also showed a higher SFI value than organic management because most farmers use intensive inorganic fertilizer. This means that the nutrient content in conventional management is sufficient and not easily depleted because the solubility properties of chemical fertilizer are relatively slow. According to (Dharmayanti et al., 2013) chemical fertilizer can increase nutrient content and has slow solubility, so its availability remains high until harvest time. An increase in the application of inorganic fertilizer leads to more productive land (Hailu and Mezegebo, 2021). An increase in the status of soil fertility in the inorganic management system is also related to the farmers' long-standing habit of using chemical fertilizer as the primary way of supplying nutrition to the rice field soil. Farmers who are more experienced will be more inclined to adopt the practice of inorganic fertilizer (Hailu & Mezegebo, 2021). Chemical fertilizers (inorganic) will supply nutrients, especially Nitrogen, Phosphorus and Potassium directly and will increase the availability of nutrients quickly and the role of organic fertilizers will increase the binding capacity of nutrients, so that the added chemical fertilizers will be retained and available for plants. This is consistent with the highest CEC found in semi-organic management of 29.37 me/100 gr and the lowest in conventional management of 26.7 me/100 gr (Table 2). The addition of organic matter causes an increase in the CEC value because cations can be retained by negatively charged ions on the soil surface.

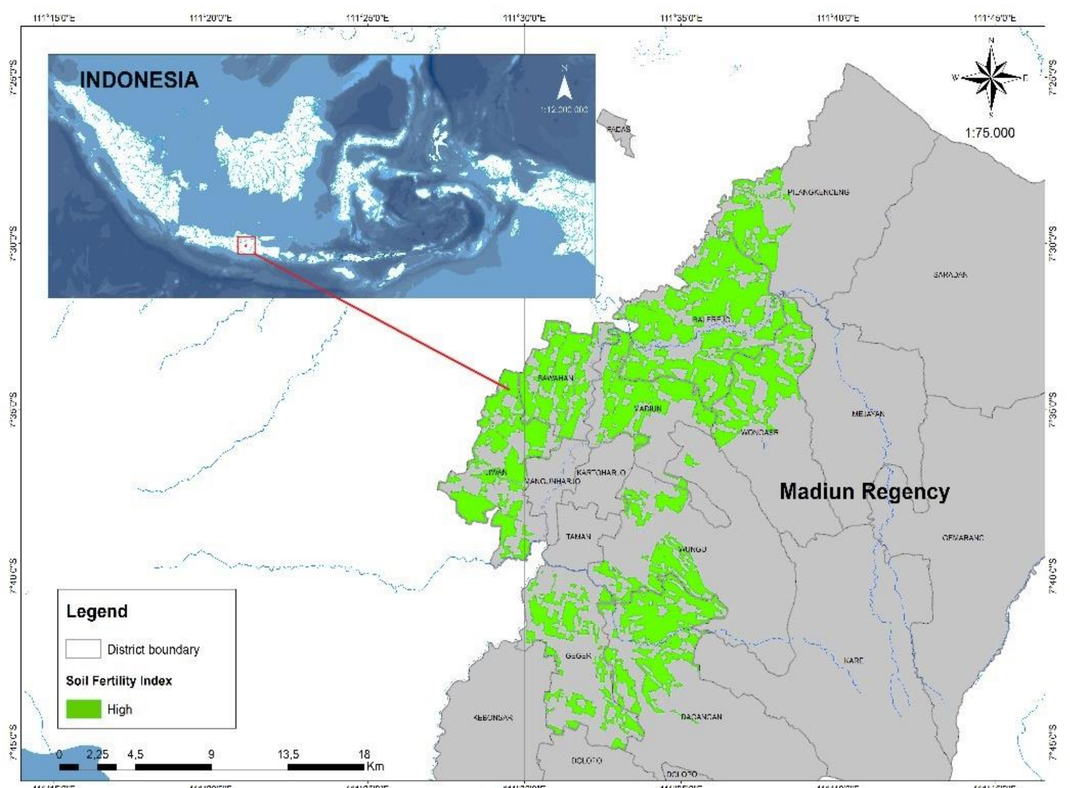

Figure 4. Map of Soil Fertility Index in Madiun Regency.

On the other hand, organic management showed a lower soil fertility index value than semi-organic and conventional management. This is because of the factor of changing from intensive use of chemical fertilizer to the use of organic fertilizer. Soil that has been supplied with chemical fertilizer for a long time will experience an imbalance when a change is made to organic fertilizer, which will cause the soil's nutrient content to be less than optimal. According to Heryanto et al. (2016) a transition from conventional management to organic management requires at least 3 planting periods to achieve optimal productivity. Siwanto et al. (2015) stated that only applying organic fertilizers without chemical fertilizers caused the availability of available nutrients to be lower. This is because in the release of nutrients it takes time for nutrient mineralization, so there is a need for synchronization of fertilizer application, when tilling the soil. The role of organic matter in the availability of nutrients in the soil is inseparable from the mineralization process, which is the final stage of the process of decomposing organic matter. In the mineralization process, plant nutrient minerals will be completely released (N, P, K, Ca, Mg, S, and micronutrients) in uncertain and relatively small amounts. Nutrients N, P and S are relatively more nutrients to be released and can be used by plants (Suntoro, 2003).

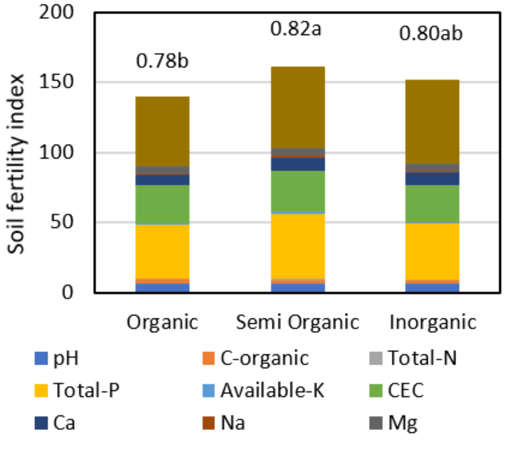

Figure 5. Influence of rice field management systems on soil fertility index.

The analysis results show a significant difference between semi-organic and organic management but no significant difference with conventional management. This corresponds to the research of (Murnita & Taher, 2021) which shows that the application of a combination of organic and chemical fertilizer is significantly different from the application of organic fertilizer. When combined with chemical fertilizer, there is a significant increase in soil fertility status (Figure 5). The long-term use of chemical fertilizer makes the soil more dependent on the supply of chemical fertilizer. However, other factors such as water and other macro and micro elements can also limit plant growth, and limitations due to these factors can be reduced with the application of organic fertilizer, which provides various nutrition and can significantly increase the soil water retention capacity (Tadesse et al., 2013). However, it should be considered, the application of organic fertilizers such as manure not only provides soil organic carbon, but also has a residual effect on the availability of soil nutrients which are important for plant growth and development in the following season (Iqbal et al., 2019).

Rice Productivity

The rice productivity calculated in this research includes 1000 seed weight (g), rice production (t/ha), and farmer's income (IDR). The results of rice productivity in Table 4 include the results of rice productivity in organic, semi-organic, and conventional management systems. The 1000 seed weight in organic, semi-organic, and conventional management ranges between 23.51 g and 25.49 g (Table 5). Semi-organic management produced the highest 1000 seed weight, at 25.49 g, while the organic management system produced the lowest 1000 seed weight, at 23.51 g. Rice weight in this research was the weight of the rice after undergoing the drying process to reach a dry condition. The highest rice production was obtained in the semi-organic management system, at 6.89 tons/ha, and the lowest was in organic management, at 6.17 t/ha. The farmers' income from rice crop yield was found to be opposite to the results of 1000 seed weight (g) and rice production (t/ha). This is because of the different selling prices of rice in the three rice field management systems. The selling price of dry rice in organic management was around 10.000 IDR/kg, while in semi-organic management, the price was 6.500 IDR/Kg. In conventional management, the price was 4.500 IDR/kg. These different selling prices meant that farmers using the organic management system achieved the highest income, at 61.709.333 IDR, while those using the conventional management system had the lowest income, at 28.625.400 IDR.

Table 5
Soil fertility index result

Rice Field Management	SFI	SFI Class
Organic	0.78	High
Semi-Organic	0.82	High
Conventional	0.80	High

Explanation : SFI= Soil Fertility Index

Table 6
Rice productivity

Rice Field Management	1000 seed (gram)	Production rice (t ha^{-1})	Farmer's Income (IDR)
Organic	23.51	6.17	61.709.333
Semi-Organic	25.49	6.89	44.777.200
Conventional	24.98	6.36	28.625.400

The calculation of rice productivity in this research refers to the results of 1000 seed weight (g), rice production (t/ha), and farmer's income (IDR/Rupiah/Rp). Table 5 shows that the 1000 seed weight in organic cultivation was 23.51 g. In semi-organic management, the result was 25.49 g; in conventional management, the result was 24.98 g. Thus, semi-organic management produced the highest 1000 seed weight, at 25.49 g, while the organic cultivation system produced the lowest 1000 seed weight, at 23.51 g. Applying a combination of organic and chemical fertilizer affects the availability of nutrients that are needed by the plant, which can lead to an increase in crop yield. According to Widiatmika et al. (2017) sufficient availability of nutrients in rice field land will promote good rice growth in the vegetative and generative processes. An increase in 1000 seed weight will occur with the application of chemical fertilizer together with organic fertilizer (Mahmud et al., 2016). Sugiono & Saputro (2016) add that a high 1000 seed weight indicates the presence of greater biomass.

Table 5 shows the level of rice production per hectare in the different types of rice management shows varying results. The highest rice production was found in semi-organic management, with a weight of 6.89 tons/ha, and the lowest was in organic management, with a weight of 6.17 t/ha. Semi-organic has been found to yield better production than using organic fertilizer alone. Chemical fertilizer is important in improving farmers' livelihood by increasing land productivity (Hailu & Mezegebo, 2021). A combination of chemical and organic fertilizer (semi-organic) results in an increase of 0.12 quintals/ha compared with the use of organic fertilizer in sesame cultivation (Hailu & Mezegebo, 2021). In the organic system, a reduction in yield of 20-50% has been reported compared with the conventional system, with the supply of N as the main limiting factor for productivity in the organic system (Bergstrand, 2022). The results of the DMRT on the influence of rice cultivation systems on dry rice yield production in this research show no significant difference. Applying 50% inorganic fertilizer replaced by the same level of organic N fertilizer produced a consistent yield but no significant increase (Agegnehu et al., 2014). Semi-organic management boosted the level of rice production because the plants could achieve optimal absorption of nutrients in the soil. This corresponds to the research of Ngantung et al. (2018) which finds that the application of urea, SP-36, and compost can increase plant quality, both in terms of plant weight and height. A different point of view is presented by Kresnatita et al. (2013) who state that the combination of organic and inorganic fertilizer can increase corn production. Therefore, the implementation of semi-organic management is highly recommended for farmers if their orientation is towards high production levels.

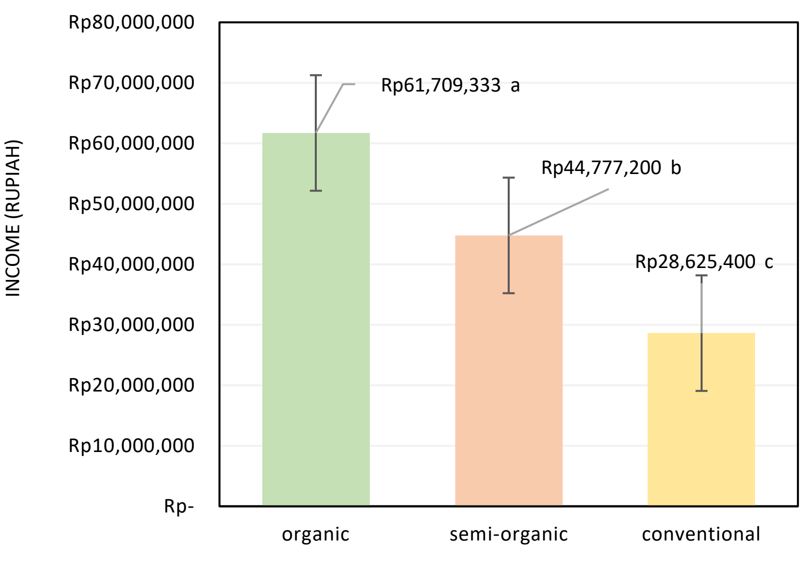

Figure 6. Influence of rice field management systems on income from rice production (Rupiah).

A high level of rice production does not necessarily correspond to a high level of income. The price of dry rice is significantly different per kilogram in organic, semi-organic, and conventional management. Based on information from local farmers, the price of dry organic rice was reported to be around IDR.10,000/kg, while semi-organic rice was IDR.6,500/kg, and conventional rice was IDR.4,500/kg. These price differences meant that income per hectare for each rice management type differed significantly (Figure 6). The highest income per hectare was obtained in organic management, with a total of 61.709.333 IDR, and the lowest income was in conventional management, with a total of 28.625.400 IDR. This shows that a high production level per hectare does not necessarily mean a high farmer income. In this research, organic management resulted in the highest income compared with semi-organic and conventional management. According to Wihastuti et al. (2017) the R/C ratio in organic farming is 1.97 IDR, a value that is highly profitable for a farming enterprise. Semi-organic management resulted in a higher rice production than organic and conventional management, but the highest profit was obtained in organic management.

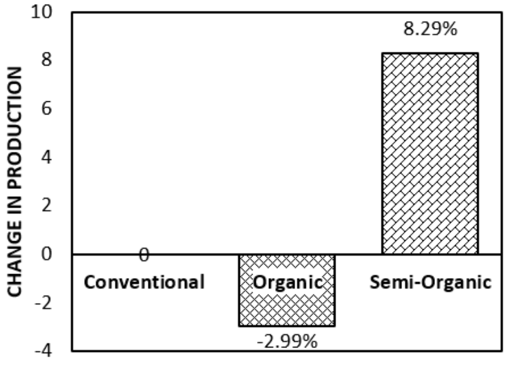

Figure 7. Change in production yield of organic and semi-organic rice compared with conventional production.

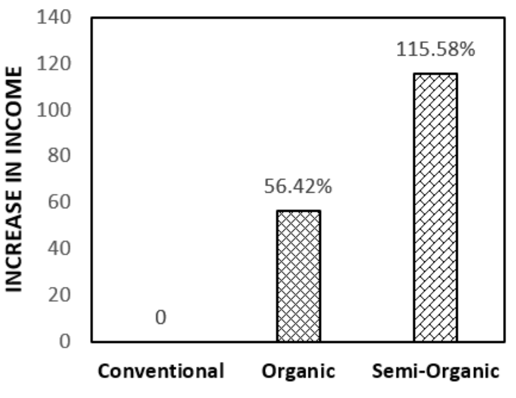

Figure 8. Increase in income from organic and semi-organic rice production compared with conventional production.

Figure 7 shows the change in organic and semi-organic rice production yield compared with conventional production. In semi-organic management, it can be seen that there is an increase of 8.29% compared with conventional production, while organic production shows a decrease of 2.99% compared with conventional management. This indicates that in the Madiun Regency, the semi-organic management system can increase rice production yield compared with conventional production. Treatment that combines half a dose of inorganic fertilizer and half a dose of organic fertilizer produces high and consistent results compared with a full dose of inorganic or organic fertilizer (Werede et al., 2018). From the point of view of rice production, the quantity of organic rice production is still unable to match the quantity of rice produced through conventional management. Based on the results of the farming activities analysis, it shows that the income level of farmers in organic management systems is higher than semi-organic and conventional management systems (Figure 8). Organic management can increase income by 115.58% compared with conventional management. Semi-organic management also increases income by 53.30% compared with conventional management. This is due to the increase in the price of organic rice which is higher than the price of semi-organic and conventional rice, besides that the costs incurred by farmers are lower. Organic farming can be used as a solution for sustainable farming. In addition, implementing organic farming is more beneficial as it can suppress production costs and offers a higher profit than semi-organic and conventional farming.

4. Conclusions

Soil fertility index ranged from 0.78 to 0.82 with high criteria. The highest score is found in the semi-organic management system and the lowest is in the organic management system. Semi-organic management systems show higher Soil Fertility Index results than other managements because the application of a combination of chemical and organic fertilizers is more effective in increasing soil fertility. The semi-organic management system responded to the highest rice production, namely 6.89 tons/ha. Semi-organic management systems are a better alternative for increasing and maintaining soil fertility and crop production than conventional and organic management systems. The results of the analysis of farming activities, the organic farming management system shows the highest increase in income of 115.58% and 53.30%

for semi-organic compared to conventional systems. The organic rice field management system has the effect of increasing the population density of worms as the key to sustainable agriculture. The types of earthworms found were dominated by *Pontoscolex* sp., besides *Lumbricus* sp., and *Pheretima* sp. There is a correlation between organic matter content and earthworms.

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