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Comparison of conventional and organic paddy cropping systems in South Sulawesi, Indonesia

Nurliani[1], Ida Rosada[1], Sitti Rahbiah[1], Sitti Nurani Sirajuddin[2,3], Abdel Razzaq M. Al-Tawaha[4], Abdel Rahman Mohammad Said Al-Tawaha[5]

[1] Agribusiness Study Program, Faculty of Agriculture, Universitas Muslim Indonesia
[2] Department of Socio Economics, Faculty of Animal Husbandry, Hasanuddin University, Indonesia
[3] Faculty of Animal Husbandry and Fisheries, Universitas Sulawesi Barat, Indonesia
[4] National Agricultural Research Center (NARC-Jordan), Amman, Jordan
[5] Department of Biological sciences, Al-Hussein bin Talal University, Maan, Jordan

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* *Corresponding Author*
Email address:
nurliani.karman@umi.ac.id

ABSTRACT

Rice is the food source for the community, including in the South Sulawesi area. Consequently, proper management is needed to support optimal production results. Several farmers are currently starting to develop organic farming systems due to the shortcomings of the conventional farming system such as the use of chemical inputs, land degradation, and decreased production. This study aims to compare the organic farming developed by farmers with conventional farming systems in terms of land ownership, input, soil quality, and productivity. This research used a simple random sampling method to collect land and production data from 130 farmers (90 conventional, 40 organic).In general, in South Sulawesi, the organic farming system is better than conventional farming systems. The inputs in the conventional are certified seeds, chemical fertilizers, and pesticides, which will affect costs and have an effect in the long term. Meanwhile, in an organic farming system, seed needs are met independently by farmers, using organic materials (manure, compost, bokashi) and biopesticides. Productivity also shows that the organic farming system increases production than conventional farming. In the future, farmers can start to develop an organic farming system by adding various organic ingredients to support their field performance.

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1. INTRODUCTION

Rice production in Indonesia is currently aimed at meeting its growing domestic demand. The average rice consumption per capita in Indonesia is notably high, reaching 81.23 kg per capita per year (BPS, 2024). To fulfill this demand, various policy programs have been implemented. However, the adoption of technology packages oriented toward synthetic chemical farming systems has led to the degradation of the soil's physical and chemical properties (Maro'ah et al., 2022). The lack of organic matter application in the soil has exacerbated the decline in the quality of paddy fields, particularly in terms of soil fertility (Ifadah et al., 2021). Farmers tend to overuse inorganic fertilizers, exceeding recommended doses, which, over time, contributes to the deterioration of soil quality in paddy fields (Zikria & Damayanti, 2019).

The use and management of land for economic growth purposes and food availability often seem to be in conflict with efforts to preserve natural resources, especially rice fields. In fact, land management for that purpose should be carried out without damaging the environment, or at least efforts must be made to balance these two components can approach ideal conditions. Consequently, the ideal field management application is economically feasible and ecologically sustainable (Indahyani & Maga, 2023). One effort that can be made is to support organic farming carried out by farmers on a massive scale. Organic farming systems have experienced rapid development in European and American countries. The rate of organic food sales in these countries has ranged from 20% to 25% per year over the last decade (Zulvera et al., 2014). Organic farming serves as an

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economically feasible and ecologically sustainable alternative by promoting cost-effective practices that conserve natural resources and maintain soil health.

Sukristiyonubowo et al. (2018) reported that in Indonesia, various practices of paddy farming remain closely related to green revolution technology, such as the combination of high external inputs (fertilizers and pesticides) and high-yielding varieties that are unsustainable in the long run and involve higher production costs. These issues have paved the way for farmers to adopt organic and semi-organic farming systems, where the latter combines elements of organic and conventional farming practices to balance ecological benefits and productivity (Sukristiyonubowo et al., 2018). The holistic organic agricultural production system considers long-term environmental sustainability and primarily aims to produce food in an environmentally friendly way (Seufert et al., 2012). Recent studies have shown that organic farming significantly improves soil properties and rice yields over time. For instance, research conducted in Central Java, Indonesia, found that soil organic carbon increased by 51.63% within ten years, leading to improved physical, chemical, and biological soil properties. This improvement is largely driven by increased soil total nitrogen, which directly contributes to higher rice yields (Syamsiyah et al., 2023). Additionally, research on Hazton's paddy farming method in Banyumas Regency, Indonesia, revealed that soil quality deteriorates despite the application of organic fertilizers, indicating that intensive paddy farming practices can significantly affect land sustainability and soil health (Supriyadi et al., 2022). Furthermore, studies on biochar, such as rice-husk biochar (RHB), have shown its potential in improving soil quality indices like soil organic carbon, aggregate stability, and nitrogen fertility in tropical soils, which in turn enhances crop growth and soil sustainability (Ebido et al., 2021). The important benefits of organics for the environment include biodiversity conservation, better soil quality, reduced evaporation, improved soil physical properties, enhanced water and air intake, compaction strategies, adaptation and reduction of greenhouse gas emissions, and improved energy efficiency (Reganold & Wachter, 2016; Seufert et al., 2012). Organic farming also increases social capital such as higher bargaining power, better access to credit and markets, opportunities to exchange knowledge and experience, reduced certification costs, and attractive contributions to policy institutions, increases employment opportunities in rural areas, and allows farmers to earn better education and health services due to higher incomes (UNEP-UNCTAD, 2008; van Elzakker & Eyhorn, 2010). Farmers who develop organic farming systems gain various economic benefits such as saving money by reducing input costs, selling by-products by entering the organic market with certified products, and selling at higher prices.

The urgency of this research lies in the need to provide empirical evidence supporting the benefits of organic farming systems over conventional methods in South Sulawesi. Given the high costs, declining yields, and environmental impact associated with conventional paddy farming practices, transitioning to organic farming offers a sustainable alternative. This study aims to demonstrate the improvements in soil quality, crop yields, and overall environmental sustainability achievable through organic farming, thereby encouraging farmers in South Sulawesi to adopt these methods for long-term economic and ecological benefits.

The appeal of organic farming, both to farmers and to the general public, is also fueled by awareness of the dangers posed by excessive residues; most consumers will choose food that is safe for their health. South Sulawesi is a province with an organic land area of 150 thousand hectares spread across all districts. The Ministry of Agriculture declared full support in 2019 for South Sulawesi as the largest producer or producer of organic rice in Indonesia (Ansar & Dirawan, 2023). In South Sulawesi, conventional rice fields are larger than organic ones. Various studies have shown the benefits of organic farming compared to conventional paddy fields. Therefore, it is necessary to provide evidence related to cultivation using organic and conventional farming systems to attract the interest of farmers in South Sulawesi so that they can switch to organic farming. This study aims to provide justification for the comparison of the development of organic and conventional farming systems in the South Sulawesi area. Several points are studied, namely, the use of inputs used for cultivation, soil fertility, and the rice yields produced.

2. MATERIAL AND METHODS

2.1. Place and Time of Research

This study was conducted from October 2022 to March 2023 in two rice production centers in South Sulawesi, namely, Bulukumba Regency (conventional rice farming) and Pucak Village, Maros Regency (organic rice development).

2.2. Coordinates and Land Characteristics

The position of Manjalling Village, Ujungloe District, Bulukumba Regency (Conventional Paddy) is located at coordinates 120°28'011"E and -5°51'633"S. The soil type is podsolic. The soil profile has a clay texture, with 58% clay, 18% silt, and 24% sand. Additionally, the position of Timpuseng Village (Pucak), Camba District, Maros Regency (Organic Paddy) is located at coordinates 119°80'339"E and -4°93'728"S. The soil type is regosol. The soil profile has a silty clay loam texture, with 65% clay, 21% silt, and 14% sand.

2.3. Methods

The research used a simple random method using land and production data from 130 farmers: 90 farmers using conventional farming system and 40 using organic farming system. Organic farmers implemented an organic farming system starting in 2017. Comparing farming systems used by farmers, various criteria, such as land area, inputs used, land quality, and land productivity, were explored. Information on land area and inputs used was obtained from interviews and discussions with farmers directly.

The research was conducted in three stages: (1) field research, (2) laboratory research, and (3) data analysis. In the field research stage, two steps were carried out: (1) Soil samples were collected from 10 locations in organic paddy fields, spread across predetermined soil map units.

Table 1. Distribution of land ownership of conventional and organic farmers

Category land area	Conventional (farmer)	Organic (farmer)
Narrow (<0.5 ha)	2 (2%)	24 (60%)
Medium (0.5–1.0 ha)	66 (73%)	16 (40%)
Area (>1.0 ha))	22 (25%)	0 (0%)
Total	90 (100%)	40 (100%)

At each location, composite soil samples were taken from 5 points, totaling approximately 1 kg, at a depth of 0–20 cm for physical and chemical soil property analysis. Soil sampling was conducted after the harvest season when the soil was dry or not waterlogged; (2) Primary data collection involved interviewing respondent farmers and agricultural extension workers (PPL) to gather socioeconomic data, such as farmer characteristics (age, education, family size, farming experience, land size), use of production inputs (seeds, organic fertilizers, and pesticides), rice production data, production costs, and income.

The land quality evaluation uses the land boundary approach method that divides land boundary levels and land suitability classes into five groups (Sys et al., 1991). The calculation of the land quality index uses the square index road method that is modified according to the criteria for land use requirements for irrigated rice crops (Sys et al., 1993; Wahyunto et al., 2016). Aside from that, in this research, soil fertility characteristics, such as cation exchange capacity, base saturation, pH H_2O, soil organic C content, and availability of nutrients N, P, and K, were also checked. Grain productivity values (production per hectare) were used to measure land productivity. Furthermore, to compare the differences in productivity between conventional and organic rice fields, the Independent t-test (Kim, 2015), a parametric statistical method, was used with the SPSS 22.0 program.

3. RESULTS

3.1. Land Area

The ownership status of conventional paddy fields is as a farmer-tenant with a land holding area in the range of 0.5–1.7 hectares, while organic paddy fields are around 0.1–1.0 hectares. The result was grouped into three criteria, namely, narrow land criteria (< 0.5 ha), medium criteria (0.5–1.0 ha), and large criteria (>1.0 ha) (Table 1). The average conventional farmer's land ownership is around 1 hectare, which means it is included in the medium category. Meanwhile, farmers with an organic farming system, on average, have a land area of 0.36 hectares, which is included in the narrow category. It shows that the land ownership of conventional farmers in South Sulawesi is larger than that of organic farmers.

3.2. Production Inputs

The use of inputs by farmers is based on cultivation needs. There are differences in land management carried out by conventional and organic farmers. In South Sulawesi, both conventional and organic farmers plant paddy twice a year. However, the planting pattern of conventional farmers is paddy-paddy-green beans, while that of organic farmers is paddy-paddy-fallow. The needs for rice cultivation include land, seeds, fertilizers, and pesticides. However, it will be different if the farmer uses an organic farming system.

Table 2. Use of rice seeds by farmers in South Sulawesi

Conventional farming system	Organic farming system
One hundred percent of farmers use varieties according to recommendations (commercial seeds)	The type used is the local type
There are variations in rotation	There is no variety of rotation
Just 66% of farmers use certified seeds	Seeds are produced by farmers independently
The number of seeds planted exceeds the number recommended	The number of seeds planted is lower than recommended

3.2.1. Seeds

There are differences in seed requirements between conventional and organic farmers in South Sulawesi (Table 2). The criteria for seeds used in conventional paddy fields include superior varieties with certificate and production potential of 5-8 tons ha^{-1}. However, the use of rice seeds in conventional rice fields is 32.88 kg ha^{-1}, while the recommended amount is 25-30 kg ha^{-1}. It is higher than recommended by agricultural extension workers. Meanwhile, the seeds used in organic rice fields come from local rice types developed by applying organic principles for at least one generation or two seasons. The use of rice seeds in organic rice fields is not engineered and not treated with chemicals. Aside from that, the average use of rice seeds in organic rice fields is 20 kg ha^{-1}, which is lower than recommended (25-30 kg ha^{-1}).

3.2.2. Fertilizer and pesticide

Aside from seeds, fertilizer is also one of the inputs that differentiates conventional and organic farming (Table 3). Conventional farmers used paddy fields twice, using single and compound fertilizers (urea and NPK). The composition of basic fertilizer given is 50% at plant aged 0–7 days after planting, and 50% supplementary fertilizer was given at plant aged 30–35 days after planting. All respondents did not use SP36 fertilizer, ZA fertilizer, and organic fertilizer/compost because they are often unavailable.

Table 3. Fertilizers and pesticides inputs on conventional rice fields

Fertilizers and pesticides	Average (ha^{-1})	Standard Deviation	Recommendation (ha^{-1})
Urea (kg)	194.53	40.82	250
SP36 (kg)	0.00	0.00	100
NPK (kg)	100.78	11.46	150
Organic (kg)	0.00	0.00	5000
Pesticide (L)	1.38	0.45	2

Table 4. Fertilizers and pesticides inputs on organic rice fields

Types of fertilizers and pesticides	Usage interval (ha^{-1})	Average usage (ha^{-1})	Standard Deviation
Manure (kg)	600–4,500	4,176.0	59.25
Compost (kg)	0–400	181.6	31.34
Bokashi fertilizer (kg)	200–2,000	1,717.8	24.71
Liquid fertilizer (Liters)	1–8	9.1	1.05
Biopesticides (Liters)	1–6	6.0	3.33

In contrast, farmers who have organic rice fields tend to use manure, compost, bokashi, and liquid organic fertilizer (Table 4). Aside from that, biopesticides are also used in order to prevent pest and disease attacks. The input needs of the organic rice farmers should be met independently of those of the conventional farmers. Consequently, the implementation of rice cultivation does not depend much on other parties in the future.

3.3. Land Quality

Table 5 shows the evaluation of various soil fertility variables between conventional rice fields in South Sulawesi. The values of all parameters, Cation exchange capacity (CEC), KB, pH, organic C, N, P, and K in organic fields are higher than those of conventional fields. Cation exchange capacity (CEC) in cmol(+) kg^{-1} is in the land suitability category S_1 (>16 cmol(+) kg^{-1}) for paddy.

3.4. Land Productivity

There is a statistically significant difference on the productivity of conventional and organic rice fields in South Sulawesi. The average productivity of conventional rice fields is lower than organic ones (5,536 kg ha^{-1} and 6,285 kg ha^{-1}, respectively) (Fig. 1).

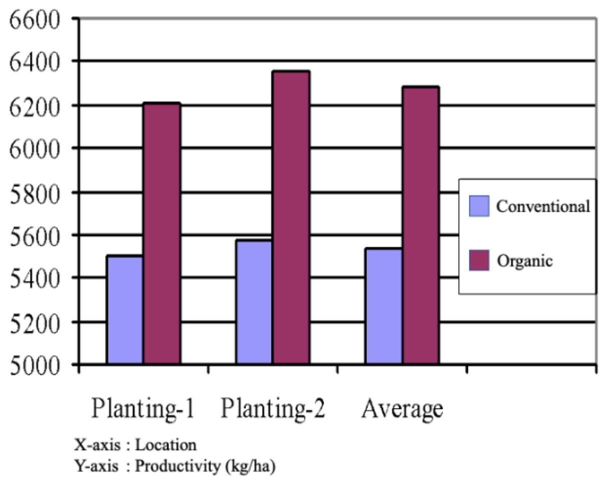

Figure 1. Comparison of Grain Productivity of Conventional and Organic Rice Fields

Table 5. Soil quality of conventional and organic rice fields

Category of soil fertility (Wahyunto et al., 2016)	Conventional	Standard deviation	Organic	Standard deviation
CEC:S_1 (>16 cmol kg^{-1})	19.24	0.81	23.24	1.24
KB: S_1 (>36%)	42.17	0.08	56.00	3.22
pHH_2O (pH 5.5–7.0)	6.5	0.19	6.5	0.28
<u>Organic C (%)</u> S_1 (>1.5%) S_2 (0.8–1.5%) S_3 (<0.8%)	1.05%	0.18	2.51%	0.21
<u>Nitrogen (N)</u> Low (0.1–0.2%) Medium (0.21–0.5%)	0.20%	0.07	0.44%	0.08
<u>Phosphor (P_2O_5)</u> Very low (<10 ppm P) Low (10–25 ppm P) Medium (26–45 ppm P) High (46–60 ppm P)	12.06	0.42	12.20	4.85
<u>Potassium (K_2O)</u> Very low (<10 mg 100 g^{-1}) Low (10–20 mg 100 g^{-1}) Medium (21–40 mg 100 g^{1}) High (41–60 mg 100 g^{-1})	40	2.06	42	1.10

Notes: KB = Soil organic matter content; S1 = Highly Suitable (Organic C > 1.5%); S2 = Moderately Suitable (Organic C 0.8–1.5%); S3 = Marginally Suitable (Organic C < 0.8%)

Table 6. Weighting of Rice Field Characteristics and Land Index Values

Rice Field	k/r	Nutrient Retention				Nutrient Availability			Land Index Value
		CEC	BS	pH	C-org	N	P	K	
Conventional	k	19.24	42.17	6.50	1.05	0.20	12.06	40	43.65
	r	90	90	100	72	85	62	100	
Organic	k	23.24	56.00	6.50	2.51	0.44	12.20	42	61.40
	r	95	100	100	100	100	63	100	

Notes: k = characteristic; r = rating; The land index value for conventional rice fields is 43.65, which falls into the S3 (marginally suitable) land suitability class; The land index value for organic rice fields is 61.40, which falls into the S2 (moderately suitable) land suitability class.

Table 7. Productivity Comparison: Conventional vs. Organic Rice Fields

Rice Field	Productivity (kg ha^{-1})	Standard Deviation	t-test	df	p-value (Sig. 2-tailed)	Mean Difference (Conventional – Organic)	95% Lower	95% CI Upper
Conventional	5.535	87.39	- 48.1	128	0.000	-746.000	- 776.6	- 715.3
Organic	6.285	63.47	- 54.2	100	0.000	-746.000	- 773.2	- 718.7

3.5. Land Quality Index

The calculation of the land quality index in this study used the Square Root Method Index (Sys et al., 1991), modified according to the land use criteria for irrigated paddy fields as specified by Sys et al. (1993). Soil fertility characteristics included in the evaluation are Cation Exchange Capacity, Base Saturation, pH H_2O, Organic C content, and the availability of nutrients N, P, and K (Table 6).

The comparison of productivity between conventional and organic rice fields, based on the results of the Independent Sample t-test, is presented in Table 7.

4. DISCUSSION

Based on the results of this study, organic paddy cropping systems have proven to be superior to conventional methods, as evidenced by significantly better soil quality and higher productivity in organic fields. The land quality index for organic rice fields reached an average value of 61.40, placing it in the S2 category (quite suitable), compared to 43.65 for conventional fields, which fell into the S3 category (marginally suitable). These differences are supported by improved soil chemical and physical properties in organic systems, such as higher organic carbon (C) and nitrogen (N) content, better pH balance, and greater availability of essential nutrients like phosphorus (P) and potassium (K). Additionally, organic farming practices enhance long-term soil fertility and stability, contributing to more sustainable and productive agricultural outcomes. The superiority of organic farming can be attributed to the consistent use of organic inputs, which enrich the soil with nutrients, improve its structure, and support a more balanced ecosystem, ultimately leading to increased rice yields and better overall soil health (Indriyati et al., 2024).

The organic paddy cropping systems in South Sulawesi have proven to be superior to conventional methods, particularly in improving soil quality and productivity. This is especially crucial given the current state of paddy fields in the region, which are characterized by low organic matter content (soil organic carbon levels below 2%), low cation exchange capacity (CEC) ranging from 3-15 cmolc kg^{-1}, and a soil pH of 6.92. These factors indicate a significant degradation in soil fertility, with limitations in phosphorus availability, organic matter, and CEC. As a result, the soil has become compacted and less responsive to fertilizers, leading to decreased crop productivity and increased farming costs (Budianto et al., 2021).

The application of organic fertilizers addresses these challenges by replenishing soil nutrients, enhancing soil structure, and improving the overall fertility of the land. Organic fertilizers provide multiple benefits, including the addition of organic matter to the soil, contributing essential nutrients such as nitrogen, phosphorus, and potassium, and enhancing the soil's physical, chemical, and biological properties. For instance, the combination of poultry manure with 100% N, P, and K fertilizers has been shown to yield 7,090 kg ha^{-1} of dry grain (Yuniarti et al., 2020). Furthermore, a combination of 25% NPK and 75% organic fertilizer has been recommended for achieving rice production of up to 8.05 tons ha^{-1} (Murnita & Taher, 2021). Additionally, research by Bachtiar et al. (2020) demonstrated that the application of organic fertilizers at a dose of 20 tons ha^{-1}, along with 300 kg N ha^{-1} of urea, significantly increased dry grain weight by 64.75%. The use of organic manure also enhances the availability of nutrients, particularly nitrogen, from the soil, which is crucial for rice growth. These findings underscore the importance of organic inputs in reversing soil degradation and enhancing the productivity of paddy fields in South Sulawesi, ultimately making organic farming systems more sustainable and beneficial than conventional practices.

Conventional farmers were not interested in using organic fertilizer. Due to the market conditions, obtaining fertilizer was difficult and required additional costs to procure. The SL-PTT (Integrated Crop Management Field School for Rice) technology component for paddy is the organic fertilizer provision of at least 500 kg ha^{-1} and straw return of at least 2 tons ha^{-1} (Supriadi et al., 2015). Chemical pesticides are also used in order to prevent pest and disease attacks in the field, although the average dose is lower than recommended.

The range of Cation exchange capacity (CEC) values in paddy fields is enough to support nutrient adsorption through fertilization. The optimal soil CEC value for irrigated and rainfed rice is in the range (>16 cmol kg^{-1} for S_1 and =16 cmol kg^{-1} for S_2). S1 and S2 represent land suitability classes, where S1 indicates land with no or only minor limitations, while S2 indicates land with moderate limitations (Wahyunto et al., 2016), and both fields already have high CEC even though organic has a higher value than conventional. In addition, the base saturation value expressed in units (%) at the research location is in the land suitability category S_1 (>35%) for rice plants. Base saturation conditions based on land suitability criteria for irrigated rice and rainfed rice are in the range (>36% for S_1; 20–35% for S_2; and <20% for S_3). The same condition can also be seen in the pH assessment, and the pH of both fields is sufficient to support plant growth because the field is in neutral condition (pH 5.5–7.0). The optimal pH value for rice plants ranges from 5.5 to 7.5 (Wahyunto et al., 2016).

Different results were shown by the organic C and nitrogen content. The organic C and nitrogen content of the organic fields is higher than that of the conventional fields. Organic C on organic and conventional land is 1.05% and 2.51%, respectively. The soil organic matter content in conventional rice fields is in the low category (<1.5%), including land suitability class S_2 for rice plant growth. This is probably due to the intensity of cultivation carried out throughout the year by conventional farmers. Meanwhile, organic rice fields are included in the high category (>1.5%) and included in class two (S_2) land suitability. Nitrogen is one of the main needs of plants. The nitrogen value of organic field reaches 0.44% (medium category), while that of conventional fields reaches around 0.20% (low category). The low nutrient status of N is due to the nature of N, which is very mobile, easy to evaporate (volatilize), and leaching. In general, farmers use urea fertilizer at quite high doses. Low soil nitrogen nutrient content correlated with organic material content. The availability of N in the soil is directly proportional to the availability of soil organic matter and limited water availability (Peku Jawang, 2021). N loss easily occurs in areas with high rainfall and in soils with low organic matter content. This condition shows that the land management system is not good, especially the application of fertilizer technology and not using organic materials. The limitations of nitrogen nutrients in rainfed paddy fields can be overcome by providing organic material sourced from harvest residues, combined with low doses of inorganic fertilizer (Benauli, 2021).

Phosphorus (P) availability in conventional and organic rice fields are 12.06 and 12.20 ppm, respectively. Both are in the low interval (10–25 ppm P). The availability of potassium (K) in conventional rice fields is 40 mg in the medium interval (21–40 mg 100 g^{-1}), and in organic rice fields, 42 mg is in the high category (41–60 mg 100 g^{-1}). These results show that rice fields managed with an organic farming system, using organic fertilizer and pesticides, show better macronutrient contents N, P, and K.

Overall, there are statistically significant differences in the results of the land quality index for conventional and organic rice fields. Numerically, the average index value for conventional rice fields is 43.65, with category S3 (according to marginal). Meanwhile, organic rice fields reached 61.40, including the S2 category (quite suitable). These data are presented in Table 6. Soil chemical–physical fertility in the organic field is superior to conventional vegetable farming systems, such as soil pH, organic C and N, total P and K, bulk density, particle density, soil porosity, permeability, bulk density, and dehydrogenase enzymes (Sukristiyonubowo et al., 2015; 2018). Similar results were reported in paddy farming that the chemical–physical soil fertility in organic land in Sambirejo District, Sragen Regency, was superior to semi-organic and conventional farming systems. Semi-organic was better than conventional farming systems in terms of soil pH, organic C and N, total P and K, bulk density, particle density, soil porosity, and permeability. Similar findings were observed in paddy biomass production.

There is a statistically significant difference in the productivity of conventional and organic rice fields in South Sulawesi, as indicated by the independent samples t-test result (p-value = 0.000 < α = 0.05), rejecting the null hypothesis (H_0) and supporting the alternative hypothesis (H_1). The detailed data can be found in Table 7. The superiority of production in organic farming systems is also supported by research results of Santoso et al. (2012), which state that organic farming systems can increase yields by 12% per hectare. Even organic farming systems can increase crop yields by 50–60% (Surekha et al., 2013). The productivity of organic farming in the beginning stages will decrease but will increase over time. Meanwhile, conventional farming productivity systems will tend to decrease in the long term due to the nutrient poverty caused by low organic matter content (Heryanto et al., 2016). This is influenced by soil fertility conditions that are increasingly stable because the inputs used are without chemicals.

The results of this study align with recent findings by Syamsiyah et al. (2023), who observed significant improvements in soil organic carbon and nitrogen levels in organic farming systems, leading to enhanced soil properties and higher rice yields. In contrast, Supriyadi et al. (2022) highlighted that intensive conventional practices, even with organic inputs, often deteriorate soil quality. Furthermore, the use of rice-husk biochar (RHB) has been shown by Ebido et al. (2021) to improve critical soil quality indices such as soil organic carbon and aggregate stability, which correlate with better crop growth and soil sustainability. These findings collectively emphasize the superior soil quality and productivity benefits of organic farming systems over conventional methods.

5. CONCLUSION

The organic farming system implemented by farmers in South Sulawesi is considered better than the conventional farming system based on the inputs used, the quality of the soil tested by looking at fertility parameters, and the grain yield obtained. In the future, the use of chemical inputs can be reduced and replaced with organic materials. Consequently, the farmers can slowly improve the field quality and switch to an organic farming system, which is more sustainable.

Declaration of Competing Interest

The authors declare that no competing financial or personal interests may appear to influence the work reported in this paper.

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