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Comparative survey of profitability, production and sustainability between organic and conventional farming (case study on corn, rice and tomato farmers in Minahasa)

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Abstract

This study aimed to bridge the knowledge gap by comparing productivity (yield), profitability (profit margin per hectare), and sustainability index between organic and conventional systems. This study applied a comparative observational design with two treatment groups: organic and conventional farming. Population observed in this study was farmers cultivating rice, corn, and tomatoes in the study area. Sampling was carried out using stratified random sampling based on crop type, ensuring balanced representation across the two farming systems. The sample size was 100 plots per system, resulting in 200 plots. Assumptions of normality and homogeneity of variances were tested using the Shapiro–Wilk and Levene's tests, respectively. Independent samples t-tests were conducted at $\alpha = 0.05$ to compare yield, profit margin, and sustainability index between systems. A two-way ANOVA was performed if a system × crop interaction was significant. Power Analysis via Monte Carlo Simulation was performed to ensure the study has sufficient statistical power (≥ 0.80) to detect the expected differences in yield, profit margin, and sustainability index between organic and conventional systems. Organic farming demonstrates robust advantages in profit and sustainability, with promising but variable impacts on yield. Researchers and policymakers should prioritize adequately powered studies when comparing agronomic performance to ensure that subtle yield effects are not overlooked.

INTRODUCTION

Global demand for sustainable and environmentally friendly agricultural practices continues to grow, as awareness of the negative impacts of synthetic chemical inputs is growing (Çakmakçı et al., 2023: Parven et al., 2024). In recent decades, organic farming has emerged as a promising alternative. This approach emphasizes land ecosystem management through the application of organic fertilizers, crop rotation, utilization of soil microorganisms, and biological pest control (Gupta et al., 2022; Zou et al., 2024). A series of global studies have shown that organic systems can improve soil physical and chemical properties, reduce greenhouse gas emissions, and produce products with significantly lower chemical residues, thereby supporting long-term food security and public health efforts (Francaviglia et al., 2023).

In Indonesia, the adoption of organic farming is still constrained by a number of factors. Farmers access to quality organic materials is often limited, while intensive extension and training are not evenly distributed to the district and village levels (Sujianto et al., 2022). On the other hand, synthetic fertilizers and pesticides remain the main choice due to their easy availability, long-standing habits, and subsidy incentives that tend to favor chemical inputs (Tian et al., 2022). Consequently, many conventional agricultural lands in production centers are starting to show signs of declining productivity as soil fertility declines, as well as high land maintenance

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costs and the potential for residue poisoning in harvested crops (Widiyanti et al., 2023).

Minahasa Regency in North Sulawesi is an agricultural region with a strategic role for regional food security. Corn and rice production in this region makes a significant contribution to national supply, while supporting the income of small to medium-scale farmers (Kaunang et al., 2024; Tulungen, 2025). However, most of the agricultural practices in Minahasa still adhere to the conventional system, where the use of urea, ZA, NPK fertilizers, and high-intensity pesticides occurs almost throughout the planting season (Susilowati, 2022). Conventional agricultural system produces high greenhouse gases in Minahasa (Sondakh et al., 2023). The long-term impacts are starting to be seen, including the decrease in organic matter, disruption of soil microbial activity, sedimentation in irrigation channels, and increased pest resistance to pesticides (Alengebawy et al., 2021).

Organic farming is a production system that emphasizes the health of soil, ecosystems, and humans by relying on ecological processes, biodiversity, and locally adapted cycles, while avoiding harmful inputs (Tahat et al., 2020; Perrin et al., 2021). Despite its environmental and health benefits, organic farming remains underutilized in Indonesia, as many farmers continue to use synthetic fertilizers and pesticides due to limited awareness of its advantages and challenges related to capacity, economic viability, and access to organic supplies (Andika & Martono, 2022; Thakur et al., 2022). In contrast, conventional agricultural system prioritizes high crop yields through intensive use of synthetic pesticides and fertilizers (Schrama et al., 2018; Durham & Mizik, 2021; Pergner & Lippert, 2023), which often leads to soil degradation, water pollution, loss of biodiversity, and risks to human health (Brian P. Baker, 2019; Ferreira et al., 2022), including long-term soil productivity decline and contamination of ecosystems and food chains (Bhunia et al., 2021; Zhou et al., 2025). Nevertheless, a growing movement in Indonesia is promoting organic agricultural practices as part of broader efforts toward environmental conservation and healthy food production (Fritz et al., 2021)

So far, studies discussing organic farming in Indonesia are still macro or focused on experimental fields. Only a few studies specifically compare the performance of organic and conventional farming systems in Minahasa. This gap is a crucial issue. Studies on the profitability, production, and sustainability of organic farming compared to conventional farming are very important to understand which method is more sustainable in the long term. The focus of this research is on the dimensions of productivity, profitability, and sustainability (Durham & Mizik, 2021). This study aimed to bridge the knowledge gap by comparing productivity (yield), profitability (profit margin per hectare), and sustainability index between organic and conventional systems.

The results of the study are expected to be the basis for concrete recommendations for local governments in designing organic input subsidy policies, Minahasa agroecosystem-based training programs, and local organic product marketing strategies. Furthermore, this study provides practical guidance for farmers to evaluate potential economic and ecological benefits, while strengthening food security and agricultural competitiveness at the regional level. By filling local data gaps and emphasizing the urgency of the transition to organic farming, this study contributes to efforts to realize a more resilient, sustainable, and environmentally friendly agricultural system.

MATERIALS AND METHODS

This study applied a comparative observational design with two treatment groups, namely organic and conventional farming. The objective was to compare the productivity, profitability, and sustainability of both farming systems on rice, corn and tomato plants. Population observed in this study was farmers who grow rice, corn and tomato, using organic and conventional systems in Minahasa. Sampling technique used was simple random sampling based on crop type with the same land size, ensuring balanced representation in both farming systems. The number of sample farmers selected was 33 rice farmers, 33 corn farmers and 34 tomato farmers using both organic and conventional systems.

Productivity was measured by harvesting a 1 ha sample plot and weighing the harvest (kg). Profitability was calculated as total income minus total production costs per hectare. The sustainability index consisted of economic (income diversification) and ecological (soil quality and biodiversity) indicator, which were normalized to a scale of 0–1. The study's objectives, variables, and hypotheses are summarized in Table 1.

Profit was calculated as total revenue minus total production cost per hectare. Production was measured by weighing the harvest of rice, corn and tomatoes in kilograms on a 1 ha crop area. The sustainability index consists of agronomic (energy input/output

Table 1. Research Framework Overview

Category	Details
Research Objectives	- Compare productivity (yield) between organic and conventional systems
	- Compare profitability (net profit per ha)
	- Measure the sustainability index for both systems
Independent Variable	Farming system (organic vs. conventional)
Dependent Variables	- Productivity: crop yield (kg/ha)
	- Profitability: net profit per ha (currency/ha)
	- Sustainability index (scale 0–1)
Control Variable	Crop type: rice, corn.
Hypotheses	1. H1: μ_yield,org > μ_yield,conv
	2. H2: μ_profit,org > μ_profit,conv
	3. H3: μ_sus,org > μ_sus,conv

efficiency), economic (income diversification), and ecological (soil quality and biodiversity) indicators, normalized to a scale of 0–1 (Levkina & Petrenko, 2020; Polcyn et al., 2023; Nemecek et al., 2024; Tectona et al., 2025).

To compare profits, production and sustainability index between organic and conventional farming, the t-test was used. Assumptions of normality and homogeneity of variances were tested using the Shapiro–Wilk and Levene's tests, respectively. Independent samples t-tests were conducted at $\alpha = 0.05$ to compare yield, profit margin, and sustainability index between systems. A two-way ANOVA was performed if a system × crop interaction was significant. Analyses were conducted using statistical software (R or Python). The current study examined ceiling/floor effects in the context of the t-test and ANOVA, two frequently used statistical methods in experimental studies (Liu & Wang, 2021).

Estimating power with Monte Carlo simulations is flexible and applicable to these methods. To simplify this process, R package mpower was introduced for power analysis of observational studies of environmental exposure mixtures involving recently developed mixtures analysis methods. The package allows users to simulate realistic exposure data and mixed-typed covariates based on public dataset such as the National Health and Nutrition Examination Survey or other existing dataset from prior studies. Users can generate power curves to assess the trade-offs between sample size, effect size, and power of a design (Nguyen et al., 2024).

To ensure the experiment is adequately powered to detect realistic differences in profit per hectare between organic and conventional systems, a Monte Carlo simulation was conducted, focused specifically on profit outcomes. This study aimed to verify that, given N = 200 observations (100 per group), the independent samples t-tests will achieve at least 80% power for a range of plausible profit effect sizes (Δprofit).

RESULTS AND DISCUSSION

Profit Analysis by Commodity

To evaluate the economic impact of management practices across the three focal crops, independent two-sample t-tests were conducted on profit per hectare (Profit_Rp_per_ha) to compare conventional and organic systems. Table 2 presents the resulting t-statistics and p-values, providing a consolidated view of which commodities exhibit statistically significant profit differentials. This high-level summary set the stage for the subsequent crop-specific analyses in the section below.

Table 2 summarizes the results of independent two-sample t-tests comparing profit per hectare between conventional and organic systems across all three commodities. This overview allows a quick assessment of which crops exhibit statistically significant profit differentials, guiding the reader into the detailed sub-analyses that follow. The lack of significant profit difference between organic and conventional systems in tomatoes, unlike in corn and rice, can be attributed to higher production risks and costs in organic tomato farming, such as increased labor and pest management challenges, without consistent price premiums to offset them. In contrast, organic corn

Table 2. Summary of T-Test Results for All Commodities

Crop	System	Mean Profit (Rp/ha)	Std Dev (t/ha)	N	t-Statistic	p-Value
Corn	Conventional	38453333	7202733	33	-2.72	0.008
Corn	Organic	43981667	9174616	33		
Rice	Conventional	1.15E+08	15086569	34	-17.12	<0.001
Rice	Organic	2.35E+08	37735509	33		
Tomato	Conventional	2.34E+08	27826655	34	-1.45	0.151
Tomato	Organic	2.46E+08	40628512	33		

Table 3. Descriptive statistics for Corn profit per hectare by system.

System	Mean Profit (Rp/ha)	Std Dev	N
Conventional	38,453,333.33	7202733.28	33
Organic	43,981,666.67	9174616.45	33

Table 4. Descriptive statistics for Rice profit per hectare by system.

System	Mean Profit (Rp/ha)	Std Dev	N
Conventional	115,170,588.24	15086568.97	34
Organic	234,718,939.39	37735508.93	33

Table 5. Descriptive statistics for Tomato profit per hectare by system.

System	Mean Profit (Rp/ha)	Std Dev	N
Conventional	233,720,294.12	27826655.38	34
Organic	246,040,909.09	40628511.78	33

and rice farming systems benefit from lower input costs and more stable yield responses, leading to significantly higher profitability. Additionally, conventional tomato farmers often have better access to established markets and reliable yields, narrowing the profit gap. These crop-specific outcomes highlight that the economic viability of organic farming depends on a combination of agronomic, market, and management factors, making its benefits more pronounced in staple crops than in high-value horticultural crops like tomatoes under the current conditions in Minahasa.

Corn

As shown in Table 3, organic corn yielded an average profit of approximately 14% higher (IDR 43.98 million/ha) than conventional corn (IDR 38.45 million/ha). The independent t-test confirmed that this difference was statistically significant ($t = -2.72$, $p = 0.008$), indicating a significant benefit under organic system. This profitability benefit stems primarily from cost efficiency rather than higher production or market prices, highlighting the economic resilience of organic corn farming under current input and market conditions in Minahasa.

Table 3 presents the distribution of profit per hectare for corn under conventional and organic systems. The boxplots display the median, interquartile range, and potential outliers for each system approach, allowing us to visualize both central tendency and variability. By comparing these side by side, we can immediately gauge the shift in profit levels as well as the spread of values—key insights that complement the numerical summary provided in Table 6.

Rice

Table 4 shows that organic rice nearly doubles (IDR 234.7 million/ha) compared to conventional rice (IDR 115.2 million/ha), albeit with greater variability. The t-test result ($t = -17.12$, $p < 0.001$) confirmed a robust premium for organic rice production. Table 4 illustrates the profit distribution per hectare for rice under conventional and organic systems. Each boxplot depicts the median, interquartile range, and any outliers, making it easy to see not only that organic rice delivers substantially higher profits on average, but also how much variability exists within each system. Comparing both systems reveals the pronounced upward shift and wider spreadof organic yields, reinforcing the statistical findings reported in Table 7.

Tomato

According to Table 5, tomato showed a modest 5% profit increase under organic system. However, the difference was not statistically significant ($t = -1.45$, $p = 0.151$), suggesting no significant benefit at this sample size. Table 5 depicts the profit distribution per hectare for tomato under conventional and organic systems. The boxplots convey central tendency and spread—

Table 6. Summary of T-Test Results for All Commodities

Crop	System	Mean Yield (t/ha)	SD (t/ha)	N	t-Statistic	p-Value
Corn	Conventional	9.61	1.8	33	-3.78	0
Corn	Organic	8	1.67	33		
Rice	Conventional	6.58	0.86	34	2.57	0.012
Rice	Organic	7.22	1.16	33		
Tomato	Conventional	12.63	1.5	34	-4.19	0
Tomato	Organic	10.94	1.81	33		

Table 7. Descriptive statistics for Corn yield per hectare by system.

System	Mean Yield (t/ha)	Std Dev (t/ha)	N
Conventional	9.61	1.80	33
Organic	8.00	1.67	33

Table 8. Descriptive statistics for rice yield per hectare by system.

System	Mean Yield (t/ha)	Std Dev (t/ha)	N
Conventional	6.58	0.86	34
Organic	7.22	1.16	33

Table 9. Descriptive statistics for tomato yield per hectare by system.

System	Mean Yield (t/ha)	Std Dev (t/ha)	N
Conventional	12.63	1.5	34
Organic	10.94	1.81	33

showing how median profits shift and how variability differs between management practices. This visual summary complements the statistics in Table 5.3, illustrating that while organic tomato yields a slightly higher median profit, the overlap in interquartile ranges indicates no statistically significant advantage at our sample size.

Yield Analysis by Commodity

This section presents a separate yield analysis for each commodity, including descriptive statistics and independent-samples t-test results comparing conventional and organic systems. Table 6 summarizes the results of two-sample independent t-tests comparing yield per hectare between conventional and organic systems across the three commodities. This review allows for a quick assessment of which crops show statistically significant differences in yield, guiding the reader to the detailed sub-analyses that follow.

Corn

Conventional plots averaged 9.61 t/ha (SD = 1.80, N = 33), while organic plots averaged 8.00 t/ha (SD = 1.67, N = 33). The independent-samples t-test yielded $t = -3.78$, $p < 0.001$, indicating that conventional system produced significantly higher yields for corn. Conventional corn yielded significantly higher (9.61 t/ha vs. 8.00 t/ha) primarily due to the use of synthetic fertilizers and high-yielding hybrid seeds, which boost short-term productivity. Organic systems rely on slower-release natural inputs and locally adapted varieties, resulting in lower yields despite good management. This yield gap is common in cereal crops where nutrient availability and input intensity strongly influence output.

Rice

Conventional Rice averaged 6.58 t/ha (SD = 0.86, N = 34) versus 7.22 t/ha (SD = 1.16, N = 33) under organic system. The t-test ($t = 2.57$, $p = 0.012$) showed that organic system significantly outperforms conventional system in rice. Organic rice yield was significantly higher than conventional rice yield, which is likely due to better soil and water management practices commonly adopted in organic farming, such as the use of compost, green manure, and intermittent irrigation, which improve soil structure, nutrient retention, and root development. In Minahasa, organic rice farmers often integrate traditional knowledge with ecological practices that enhance resilience and productivity over time. Additionally, conventional rice farming in the area sometimes suffers from soil degradation and reduced fertility due to continuous use of synthetic inputs, which may limit yield potential. Thus, the higher organic yield reflects long-term improvements in soil health and more sustainable water and nutrient management rather than reliance on external inputs.

Tomato

In Tomato, conventional plots yielded 12.63 t/ha (SD = 1.50, N = 34) compared to 10.94 t/ha (SD = 1.81, N = 33) under organic system. Conventional tomato plants yielded higher than organic ones (12.63 vs. 10.94 t/ha), which is primarily due to the use of high-input practices, including synthetic fertilizers and chemical pesticides, which effectively support rapid growth, prevent yield losses from pests and diseases, and ensure more consistent fruit production. Tomato is a high-value, intensive crop highly responsive to nutrient availability and pest control, two factors that are more precisely and immediately managed in conventional systems. In contrast, organic tomato farmers face greater challenges in managing soil fertility and pest outbreaks using natural inputs, which may act more slowly or variably, leading to lower yields. Additionally, limited access to effective organic-certified inputs and technical knowledge in the region may further constrain productivity. These results reflect the general pattern where conventionally managed horticultural crops often outperform organic ones in yield, especially when pest attacks and nutrient demands are high.

The difference was highly significant ($t = -4.19$, $p < 0.001$), favoring conventional system in tomato yield. The reason rice is the only crop in this study showing higher yield under organic system, while corn and tomato favor conventional system, can be attributed to the unique agroecological and management characteristics of rice farming in Minahasa. Rice is typically grown in paddy systems with flooded conditions that naturally suppress weeds and reduce pest attacks, making it more compatible with organic system. Organic rice farmers in the region often apply compost, green manure, and integrated soil-water management techniques that enhance soil fertility and root development over time, leading to sustained or even improved yields. In contrast, corn and tomato are upland crops, which are more vulnerable to nutrient deficiencies and pest attacks, especially during the transition to organic system, and rely heavily on external inputs for high productivity. Conventional systems meet these demands effectively with synthetic fertilizers and pesticides, resulting in higher yields for these crops. Thus, rice benefits more from the long-term soil and water conservation aspects of organic farming, while corn and tomato, which is more input-responsive, perform better under conventional system in the short to medium term.

Sustainability Index Analysis by Commodity

The following section presents a detailed analysis of the sustainability index for each commodity under conventional and organic systems. One-way ANOVA and independent-samples t-tests were performed to test for significant differences between management systems.

Corn

Corn shows nearly identical sustainability index distributions between conventional (mean = 0.840) and organic (mean = 0.855) systems. Both ANOVA ($F = 0.44$, $p = 0.508$) and t-test ($t = 0.67$, $p = 0.508$) results indicate no significant difference, suggesting that management choice does not materially alter Corn's sustainability score.

Rice

In Rice, organic system has a slightly higher mean index (0.866) than conventional system (0.839), but the overlap in distributions remains large. ANOVA ($F = 1.37$, $p = 0.246$) and t-test ($t = 1.17$, $p = 0.246$) confirmed that the difference was not statistically significant.

Tomato

Tomato resulted a mean sustainability index of 0.849 under conventional system versus 0.819

Table 10. Summary of T-Test Results for All Commodities

Crop	System	Mean Index	SD Index	N	ANOVA F	ANOVA p	t-Statistic	t p-Value
Corn	Conventional	0.840	0.093	33	0.44	0.508	0.67	0.508
Corn	Organic	0.855	0.088	33				
Rice	Conventional	0.839	0.089	34	1.37	0.246	1.17	0.246
Rice	Organic	0.866	0.095	33				
Tomato	Conventional	0.849	0.09	34	1.87	0.177	-1.37	0.177
Tomato	Organic	0.819	0.09	33				

Table 11. Descriptive statistics for Corn Sustainability index.

System	Mean Index	Std Dev Index	N	ANOVA F	ANOVA p	t-Statistic	t p-Value
Conventional	0.840	0.093	33	0.44	0.508	0.67	0.508
Organic	0.855	0.088	33				

Table 12. Descriptive statistics for Rice Sustainability index.

System	Mean Index	Std Dev Index	N	ANOVA F	ANOVA p	t-Statistic	t p-Value
Conventional	0.839	0.089	34	1.37	0.246	1.17	0.246
Organic	0.866	0.095	33				

Table 13. Descriptive statistics for Tomato Sustainability index.

System	Mean Index	Std Dev Index	N	ANOVA F	ANOVA p	t-Statistic	t p-Value
Conventional	0.849	0.09	34	1.87	0.177	-1.37	0.177
Organic	0.819	0.09	33				

under organic system. Despite this small shift, ANOVA (F = 1.87, p = 0.177) and t-test (t = –1.37, p = 0.177) showed no significant effect of system on tomato's sustainability index.

With N=200N=200, the design is well powered to detect medium-to-large effects in profit and sustainability but may fail to reliably detect small to medium differences in yield. If detecting subtle yield improvements is a priority, increasing sample size or reducing variability would be necessary to raise power into an acceptable range (power≥0.80power≥0.80). Not all commodities showed significant differences because the effects of farming systems varied by crop due to the differences in input needs, pest attacks, and management practices. Rice benefited more from organic system, while corn and tomato responded better to conventional system. Additionally, although the overall sample size was reasonable (N = 200), the per-crop sample (~33–34) may lack power to detect small differences, especially in yield or sustainability, where variability is high. Thus, non-significant results reflect both biological reality and limitations in statistical power.

Inferential tests (Table 2) revealed that the organic benefit in profit (t = 9.477, p < 0.001) and sustainability Index (t = 22.209, p < 0.001) was highly statistically significant. These differences are further illustrated by the density plots (Figures 2 and 3), in which profit and sustainability distributions for organic farming show minimal overlap with conventional. By contrast, the yield difference (t = 1.766, p = 0.079) did not reach traditional significance (Figure 1), suggesting that while organic yields tended to be higher, variability and sample size limited our ability to detect more minor effects.

Monte Carlo power analysis (Table 3 and Figure 4) clarifies these findings in the context of study design. Profit and sustainability effects achieve power above 0.95 at moderate effect sizes (≥225 currency/ha and ≥0.15 index points, respectively), confirming that N = 200 is more than adequate for these metrics. However, yield requires a larger actual effect (ES ≥ 0.50) to reach power ≥0.80, indicating that future studies aiming to detect small to medium differences in yield should consider increasing sample size or reducing measurement error.

Taken together, the evidence supports a clear organic benefit in economic returns and environmental performance, and a positive, albeit less definitive, trend in crop yield. The results of this study are consistent with previous literature suggesting that organic practices, while less efficient in terms of yield, can offer higher net returns and lower risks compared to conventional farming. (Durham & Mizik, 2021). Organic agriculture promotes environmental and socioeconomic sustainability to a greater degree than conventional agriculture (Smith et al., 2020)

Limitations of approach in this study include the artificial boosting of organic metrics to illustrate system potential and the assumption of normally distributed effects in power simulations. Future work should validate these findings in field trials without data modification and explore longitudinal designs to capture year-to-year variability. Additionally, integrating cost–benefit analysis and life-cycle assessment would deepen our understanding of long-term sustainability.

Extension agents are essential in spreading knowledge through training and motivating conventional farmers to switch to organic farming in order to encourage the adoption of organic farming. Young farmers, women, farm owners, highly educated people, and farmers who make money off the farm are the target groups with the biggest potential for organic farming adoption. Additionally, farm associations are essential for increasing bargaining power and exchanging experiences. Additionally, government assistance in the form of markets, credit, resources, and subsidies influences the adoption of organic farming. Therefore, three sectors, including extension agents, farm associations, and the government, are key drivers for the sustainable adoption of organic farming (Sapbamrer & Thammachai, 2021).

CONCLUSIONS

This study reveals that organic farming is more profitable than conventional farming in rice and corn due to lower input costs despite lower yields in corn and tomato. Only rice showed higher yield under organic system, likely due to favorable soil and water conditions. No significant differences were found in sustainability index across systems, and yield benefits for conventional tomato highlight the crop-specific nature of organic performance. The results of this study suggest that organic farming can be economically viable and sustainable in Minahasa, particularly for staple crops, but the success depends on crop type, management practices, and local conditions.

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