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Jane M. Tecson
Faculty of the College of Engineering and Industrial Technology, Agusan del Sur State College of Agriculture and Technology

Julie O. Lucnod
Faculty of the College of Engineering and Industrial Technology, Agusan del Sur State College of Agriculture and Technology

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Jane M. Tecson[1], Julie O. Lucnod[1]
[1]Faculty of the College of Engineering and Industrial Technology, Agusan del Sur State College of Agriculture and Technology.
Corresponding author email: jtecson@asscat.edu.ph

Abstract: *The study was conducted to analyze cost and examine the energy inputs of organic and inorganic rice production in Agusan del Sur. A structured Questionnaire was utilized to gather relevant data from rice farmers through face-to-face interviews. The sample farms were chosen through a stratified sampling method. Results revealed that energy inputs in inorganic rice production were eight times higher than that of organic farming due to the heavy use of inorganic fertilizer, which reached a total of 21,864.5 MJ/ha. Results also showed that the Energy efficiency and profitability in organic rice farming were higher than that of inorganic rice farming as indicated by their Output/Input Ratio (OIR)and Benefit-cost ratio, suggesting that inorganic farming has a lesser return than organic rice production. Moreover, fertilizer application in inorganic farms within the study area is significantly higher due to the heavy application of inorganic fertilizer.*

Keywords: organic rice production, inorganic rice production, energy inputs, economic analysis

1. INTRODUCTION

Rice is considered a staple food in the Philippines and one of the world's most essential crops. Its production in the Philippines remained more than 20 million tonnes in 2023, with an average yield of 4.17 metric tonnes per hectare [1] versus the average global rice production rate of 4.66 metric tonnes per hectare [2]. Therefore, immediate action is necessary to address the issue of low yield. According to Demircan [3], Effective energy use is essential as it leads to significant financial savings, conserves fossil resources, and minimizes environmental damage [4], thereby ensuring the sustainability of agricultural production.

There are three primary sources of power available for rice production in the Philippines: human labor, animals, and mechanical. This power usage usually depends on farm size, cultural practices, soil conditions, and land topography. The combined rice harvester is also becoming popular in many areas, making harvesting operations easier and faster. Adopting modern technologies such as high yielding rice varieties, hybrids, appropriate machinery, and more fertilizers has generally enhanced farm productivity. The use of machinery made farm operations easier, with fewer grain losses and shorter operations time. Such technologies have made up for the energy shortage in rice production, ensuring the timeliness of operation and increasing farmers' productivity.

Adequate crop production requires sufficient energy in the proper form and time. Optimizing agricultural output involves assessing the efficiency of various methods and techniques. With the rising global population, effective energy planning is crucial. Identifying input elements is necessary to recommend the most efficient control methods. Numerous studies have analyzed energy and economic aspects to determine the energy efficiency of different crop production practices in developed countries [5] [6] [7] [8]. However, only a limited number of studies have been published on comparing energy and economic analysis of organic and inorganic rice production in the Philippines. Thus, this study was undertaken to identify the direct and indirect energy consumption of each field operation in organic and inorganic rice production in Agusan del Sur. Organic and inorganic rice production's energy efficiency and profitability were also evaluated. The results of this study can assist farmers, resource managers, and policymakers in creating alternative practices and energy-efficient plans, aiming to conserve non-renewable energy inputs while maintaining production levels and avoiding economic burdens on farmers.

2. METHODOLOGY

2.1 Study Area

The study took place in Agusan del Sur, Philippines. This region experiences a Type II climate, characterized by a pronounced wet season with no dry periods. The heaviest rainfall typically occurs from December to January, with an average monthly rainfall of 355 millimeters (14.0 inches). The average temperature in the area is 27.15°C.

2.2 Research Design

At the outset, after consulting authorities in the Department of Agriculture, two groups of farmers engaged in rice production with different farming practices were interviewed using a structured questionnaire. The sample size was determined using Cochran's equation for a large population, given below, with a 90% confidence level and a 7 % margin of error:

$$n_0 = \frac{Z^2 * p * (1-p)}{e^2}$$

Where:

- Z is the Z-value for the desired confidence level (for 90%, Z=1.645
- p is the estimated proportion of the population (0.5 was used for maximum sample size)
- e is the desired margin of error (7%)

To reduce estimate error, samples were selected using random stratified sampling. The two-stage sampling design included farmers from various barangays in proportion to the number of organic and inorganic rice growers. Furthermore, the Provincial Office of the Department of Agriculture provided information on the number of organic and inorganic rice growers in Agusan del Sur. Table 1 shows the sample size allocation for the two farming practices.

Table 1. Sample Size Allocation

Farmer classification	Sample Size
Organic Farmer	72
Inorganic Farmer	199
Total	**271**

The farmers were asked according to the required data needed to analyze the total cost and energy input and output in rice production. All data were arranged and tabulated based on actual Farmer's practices, including land preparation procedures, crop establishment, fertilizer and pesticide application, harvesting, threshing, and hauling operation. For each Farm operation, information about the energy inputs was collected and categorized into two: Direct Energy inputs like fuel, human and animal power, and Indirect Energy inputs like machinery/tools, seedlings, fertilizer, and pesticides.

The system boundary of the study considered field operations from land preparation to hauling paddy yield to the nearest road accessible by vehicles because farmers in Agusan del Sur tend to sell their produce at fresh weight right after harvesting and threshing.

2.3 Direct Energy Computation

Each agricultural input has its energy value, the amount of energy required to produce that specific component. These energy inputs include food/feed, machinery, and more. The energy coefficient is defined as the energy equivalent of these sources, accounting for all forms of energy used in their production [9]. Energy coefficient analysis was based on energy equivalents available in the literature [7]. The energy values referenced in this paper represent the ratio of dietary energy derived from agricultural output to the fossil energy expended to produce it. Direct energy refers to the energy used per hectare derived from fuel and human and animal labor, which are used to operate the machinery and do other field operations like land preparation, planting, harvesting, and many others.

Direct Energy from fuel was computed using the formula [10] :

$$ED = h \times AFU \times PEU \times RU$$

Where:

ED is the Specific direct energy use (fuel) for field operation (MJ/ha)

H is the specific working hour per run (hr/ha)

AFU is the average fuel used per working hour (L/hr)

PEU is the specific energy value per liter of fuel (MJ/L).

RU is the runs number of applications in the considered field operation

The labor rate for various crop production operations in the study area was determined for each stage. The labor energy input (MJ/ha) at each production stage was calculated using the following equation:

$$LE = \frac{n \times t \times LEf}{A}$$

Where:

LE is the labor energy (MJ/ha)

n is the number of laborers

t is the number of operating time (hr)

LEf is the Labor energy factor (MJ/hr)

A is the operating area (ha)

2.4 Indirect Energy Computation

The energy contribution of machinery for each field operation was calculated using the equation below:

$$EID = \frac{TW \times CED \times h \times RU}{UL}$$

Where:

EID is the Specific indirect energy for machinery (MJ/ha)

TW is the total weight of the specific machine, kg

CED is the cumulative energy demand for machinery (MJ/kg)

UL is the wear-out life of the machinery (hr)

H is the specific working hours per run (hr/ha)

RU is the number of applications in the considered field operation.

The indirect energy per unit area for other production inputs such as fertilizer, pesticides, and seed was expressed as:

$$\boldsymbol{EID = Rate \times EFm}$$

Where:

EID is the indirect energy input (MJ/ha)

Rate is the application rate of input,(kg/ha or L/ha))

EFm is the energy Factor of materials used (MJ/kg or MJ/L)

Table 2 displays the energy equivalence of inputs and output in rice production. In this study, an equivalent energy demand value of 62.7 MJ/kg was utilized to quantify the embodied energy in a piece of equipment [11] [12] [13].

The energy associated with the production of fuel used was 56.31 MJ/L for diesel and petrol fuels [11] [12] [13]. The human and animal energy needed for any operation or practice depends on the number of laborers required and was assessed at 1.96 MJ/hr per unit of labor input and 10.12 MJ/hr [7] [12] [14], respectively.

The typical energy expenditures involved in producing the active ingredients for complete fertilizer, nitrogen, Potassium, and organic fertilizer are 80.79 MJ/kg [14], 66.14 MJ/kg, 11.15 MJ/kg [14] [16], and 0.3 MJ/kg, respectively [3] [5,] [7] [8] [12], which embodied the energy requirement to produce and transport commercial fertilizers. The average energy required to make the active ingredients of molluscicides/pesticides, herbicides, insecticides, and Organic Herbal Nutrient (OHN) were reported as 97 MJ/kg, 255 MJ/kg, 185 MJ/kg [17], and 0.3 MJ/kg respectively. [3,5,7,8,12], respectively. Moreover, the average energy coefficients for rice seedlings and paddy rice used were 16.74 MJ/kg [18] and 15 MJ/kg [19].

Table 2. Energy Equivalent of inputs and output in rice production

Particulars		Energy Equivalent
A. Inputs		
1	Human/Animal Labor	1.96 MJ/hr
2	Machinery/Tools	62.7 MJ/kg
3	Diesel Fuel	56.31 MJ/L
4	Seeds	16.74 MJ/kg
5	Fertilizer	
	a. Complete Fertilizer	80.79 MJ/kg
	b. Nitrogen	66.14 MJ/kg
	c. Potassium	11.15 MJ/kg
	d. Vermicast	0.3 MJ/kg
	e. Vermitea	0.3 MJ/kg
6	Pest Control	
	a. Molluscide/ Pesticide	97 MJ/kg
	b. Herbicide	255 MJ/kg
	c. Insecticide	185 MJ/kg
	d. Organic Herbal Nutrient (OHN)	0.3 MJ/kg
B. Output		
1	Rice Grains	15 MJ/kg

2.5 Energy Efficiency and Economic Analysis

Fundamental data regarding energy inputs and rice yields were inputted into Excel spreadsheets. Calculations were performed using the energy equivalents from Table 1 to determine the energy ratio (energy use efficiency), energy productivity, and specific energy [3].

$$\text{Grain use effeciency} = \frac{\text{Energy Output (MJ/ha)}}{\text{Energy Input (MJ/ha)}}$$

$$\text{Energy productivity} = \frac{\text{Grain yield (kg/ha)}}{\text{Energy Input (MJ/ha)}}$$

$$\text{Specific Energy} = \frac{\text{Energy Input (MJ/ha)}}{\text{Grain yield (kg/ha)}}$$

$$\text{Net Energy} = \text{Energy Output} - \text{Energy input}$$

In the final phase of the study, a cost analysis was conducted comparing organic and inorganic rice production. The net return was determined by subtracting the total production costs from the gross return per hectare of rice. Additionally, the benefit-cost ratio was computed by dividing the gross return by the total production costs per hectare [3] [7] [8].

$$\text{Net Return} = \text{Gross return} - \text{total cost of production}$$

$$\text{Benefit} - \text{Cost ratio} = \frac{\text{Gross return}}{\text{Total Production cost}}$$

3. RESULTS AND DISCUSSION

3.1 Energy Inputs Based on Field Operation

The operational energy inputs in the organic and inorganic rice production for each field operation were computed and presented in Figure 1 and Figure 2, respectively.

With a mean of 1,266.65 MJ/ha, or 34.74% of the total energy input, land preparation had the highest energy input among the six primary field operations in organic rice production, as shown in Figure 1. The threshing operation came in second with a mean of 1,164.54 MJ/ha, or 31.94% of the total energy input in the production.

The remaining energy was consumed in crop establishment, crop care and maintenance, harvesting, and hauling with an average value of 569.84 MJ/ha (15.63%), 336.07 MJ/ha (9.22%), 289.35 MJ/ha (7.94%), and 19.6 MJ/ha (0.54%), respectively.

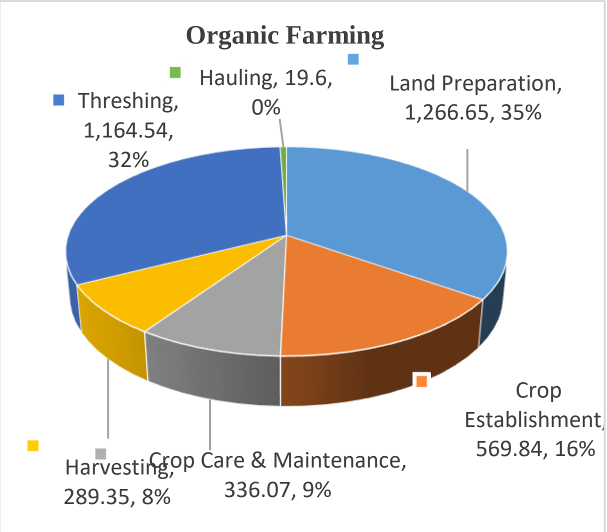

Fig. 1. Energy inputs for organic rice production

Concerning inorganic rice production, 87.02% of energy input was observed in crop care and maintenance with a mean value of 25,482.21 MJ/ha as shown in Figure 2. The remaining 12.98% of energy inputs were consumed in land preparation, threshing, crop establishment, hauling, and harvesting with a mean value of 1,687.78 MJ/ha (5.76%), 1,137.1 MJ/ha (3.88%), 511.04 MJ/ha (1.75%), 241.6 MJ/ha (0.83 %) and 223.82 MJ/ha (0.76 %), respectively.

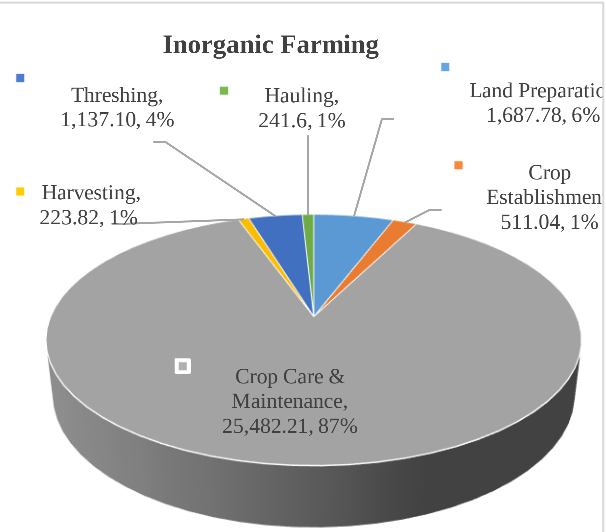

Fig. 2. Energy inputs for inorganic rice production

Inorganic rice production resulted to a remarkably higher energy input than organic rice production, as depicted in Figure 3. This is because the energy expended in producing inorganic fertilizers and pesticides is much higher than that of organic fertilizers and pesticides. Moreover, ducks were used in maintaining the cleanliness of the rice fields for organic farming since they fed on grasses and mollusks. In contrast, in inorganic farming, human labor and molluscide were utilized.

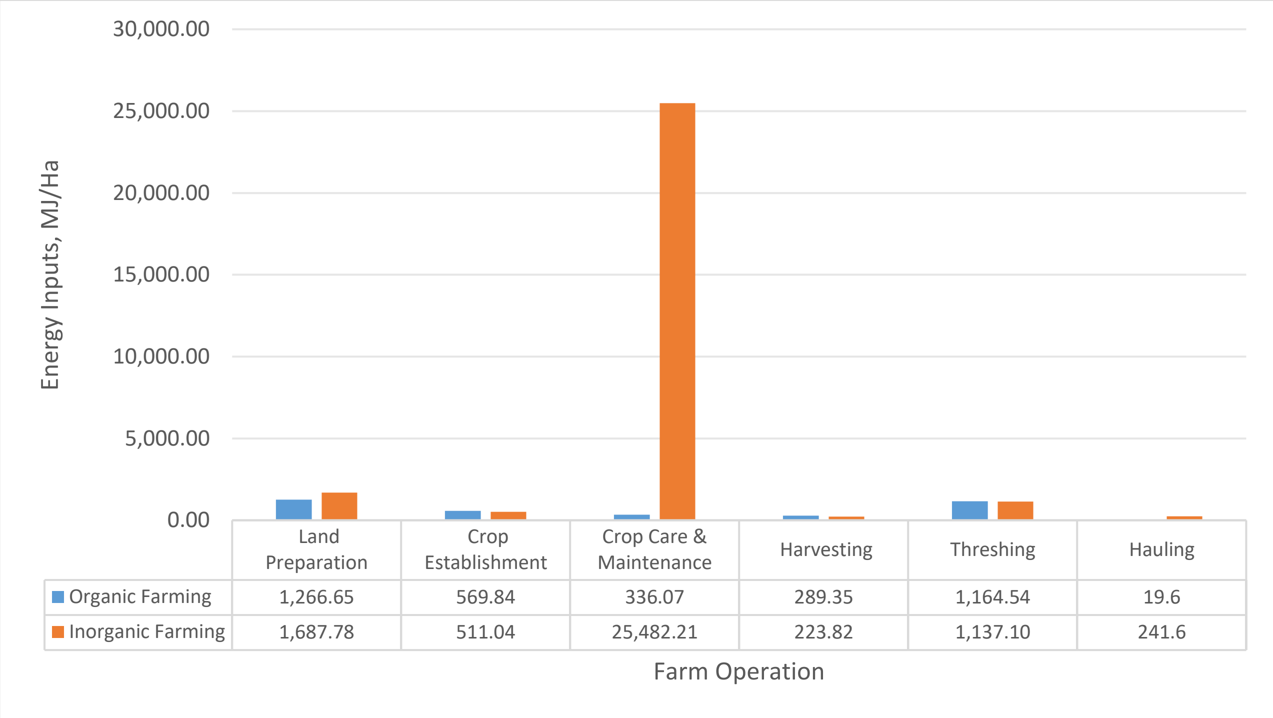

Fig. 3. Energy inputs comparison between organic and inorganic farming

The energy analysis did not incorporate irrigation energy input because supplemental irrigation water application during the land preparation stage was occasional. Agusan del Sur has a tropical climate characterized by wet and dry seasons. The data were gathered during the wet season from November 2023 to May 2024. Therefore, no water pumping is necessary in the rice production process. Rice farmers depend entirely on precipitation and free irrigation supplied by gravity flow from the water distribution system managed by the National Irrigation Administration.

3.2 Energy Consumption Based on Energy Sources

Energy inputs were categorized as direct and indirect energy. These two general categories were then classified according to sources. Direct energy includes fuel as well as human and animal labor, while Machinery/tools, seeds, fertilizers, and pesticides belong to indirect energy sources.

As shown in Table 3, the total energy inputs in organic rice production was 3,646.05 MJ/ha, of which 80.51 % are direct energy and the remaining 19.49% are indirect energy sources. It can be observed that fuel is the highest contributor to the energy input with a mean of 2,108.25 KJ/ha (57.82%), while the lowest contributor was the pesticides.

Table 3. Energy Inputs Categorized based on Energy Sources

Energy Source	Total energy consumption MJ/ha)			
	Organic Farming	Percentage (%)	Inorganic Farming	Percentage (%)
Direct Energy				
Fuel	2,108.25	57.82	2,502.42	8.55
Human	766.36	21.02	701.41	2.40
Animal	60.72	1.67	242.88	0.83
Sub-Total (A)	2,935.33	80.51	3,446.70	11.77
Indirect Energy				
Machinery/tools	114.20	3.13	138.77	0.47
Seed	301.32	8.26	301.32	1.03
Fertilizer	237.60	6.52	21,864.50	74.66
Pesticide	57.60	1.58	3,532.25	12.06
Sub-Total (B)	710.72	19.49	25,836.84	88.23
TOTAL (A+B)	3,646.05	100.00	29,283.54	100.00

Moreover, the total energy inputs in inorganic rice production was 29,283.54 MJ/ha, of which 88.23 % are indirect energy, and the remaining 11.77% are direct energy sources. It can be observed that fertilizer is the highest contributor to the energy input for inorganic rice production, with a mean of 21,864.5 MJ/ha (74.66%). This result can be attributed to the area's intensive application of inorganic fertilizer. Inorganic rice cultivation primarily relies on synthetic inputs, such as chemical fertilizers and pesticides, which are notorious for their high energy consumption during production and application [21]. The energy costs associated with producing, transporting, and applying these inputs far outweigh those of organic alternatives, which rely on naturally occurring fertilizers and biological pest control methods. During face-to-face interviews with farmers, it was found that the average fertilizer application per hectare for the whole cropping season was 100 kg of complete fertilizer, 200 kilograms of nitrogen, and 50 kg of potassium. Furthermore, the lowest contributor was the machinery/tools, with a mean of 138.77 MJ/ha (0.47%) since planting and harvesting operation was done manually, utilizing only human labor.

When synthetic fertilizers are overused in the production of inorganic rice, the ecosystem may suffer significantly as a result of reduced biodiversity, contaminated water supplies, and deteriorated soil quality [20]. Aside from its negative environmental impact, other consequences may jeopardize their farming enterprise's economic viability and long-term sustainability [21]. Switching to organic farming practices is one potential solution to the challenge of less sustainable agriculture. According to Reganold, et. Al [22], organic farming can enhance soil health, increase biodiversity, and lessen dependency on nonrenewable resources.

3.3 Energy Efficiency and Economic Analysis

The cost of organic and inorganic rice production in Agusan del Sur was computed and categorized according to field operations, as shown in Table 4.

For organic rice farming, the total cost of production was 38,777.33 pesos per hectare. It can be observed that crop establishment operation is the highest contributor to production cost, reaching 13,360.00 pesos per hectare, followed by crop care and maintenance, harvesting, threshing, land preparation and hauling amounting to 8,436.00 pesos per hectare, 7,128.80 pesos per hectare, 4,752.53 pesos per hectare, 3,700.00 pesos per hectare, and 1,400.00 pesos per hectare, respectively.

Table 4. Cost of rice production

OPERATIONS	Cost of Operation (Php/ha)	
	Organic Farming	Inorganic Farming
1. Land Preparation	3,700.00	4,665.00
2. Crop Establishment	13,360.00	11,320.00
3. Crop Care & Maintenance	8,436.00	25,995.00
4. Harvesting	7,128.80	4,900.00
5. Threshing	4,752.53	10,737.80
6. Hauling	1,400.00	2,925.00
Total Cost	**38,777.33**	**60,542.80**

For inorganic rice farming, the total cost of production was 60,542.8 pesos per hectare. It can be observed that crop care and maintenance is the highest contributor to production cost reaching 25,995.00 pesos per hectare, followed by crop establishment, threshing, harvesting, harvesting, land preparation, and hauling operation amounting to 11,320.00 pesos per hectare, 10,737.80 pesos per hectare, 4,900.00 pesos per hectare, 4,665.00 pesos per hectare, and 2,925.00 pesos per hectare, respectively. The extremely high cost of crop care and maintenance was due to the high cost of applied inorganic fertilizer, which also resulted in high energy input, as discussed in the previous section. The results show that the production cost of inorganic rice nearly doubles that of organic rice due to the high expense of synthetic fertilizer applied for crop care and maintenance. Cassman et al. [23] discovered that synthetic fertilizers can account for up to 30% of total production costs in inorganic rice cultivation. The high-cost structure has a direct impact on farmers' profitability. The economic sustainability of inorganic rice cultivation is diminishing, mainly due to rising costs for petroleum-based fertilizers and pesticides, which are vulnerable to global oil price fluctuations [20].

The cost and energy efficiency of rice production were assessed by calculating the ratios of output to input cost and output to input energy, respectively. It was assumed that if the BCR (Benefit-cost ratio) is greater than 1, the production system is profitable, otherwise it is losing. The same principle applies to the output/input ratio of energy in the energy use efficiency. Table 5 shows the energy efficiency and economic analysis of organic and inorganic Rice Production in Agusan del Sur, Philippines.

The total energy input per hectare for organic rice production was 3,646.05 MJ. At the same time, the estimated grain yield was 3,400 kg/ha, which resulted in an energy output of 51,000 MJ/ha using the average energy coefficients for paddy rice of 15 MJ/kg [18]. The energy use efficiency was 13.99; that is, 13.99 MJ was produced for every MJ of energy input. Moreover, its energy productivity indicates that 0.93 kg of paddy rice was made for every megajoules of energy input, or 1.07 MJ of energy was expended to produce 1 kg of paddy rice.

Table 5. Energy Efficiency and Economic Analysis in organic and inorganic Rice Production in Agusan del Sur, Philippines

Parameters	Organic Farming	Inorganic Farming
Yield (kg/ha)	3,400.00	4,368.00
Energy Efficiency		
Energy input (MJ/ha)	3,646.05	29,283.54
Energy output (MJ/ha)	51,000.00	65,520.00
Energy use efficiency	13.99	2.24
Specific energy (MJ/kg)	1.07	6.70
Energy productivity (kg/MJ)	0.93	0.15
Net energy (MJ/ha)	47,353.95	36,236.46
Economic Analysis		
Selling Price (Php/kg)	22.00	19.00
Gross Return (Php/ha)	74,800.00	82,992.00
Total Cost of Production (Php/ha)	38,777.33	60,542.80
Net return (Php/ha)	36,022.67	22,449.20
Benefit/Cost Ratio	1.93	1.37

For inorganic rice production, the total energy input per hectare was 29,283.54 MJ, while the average grain yield was 4,368.00 kg/ha, which resulted in an energy output of 65,520.00 MJ/ha. The energy use efficiency was 2.24; that is, 2.24 MJ of energy was produced for every MJ of energy input. Moreover, its energy productivity indicates that 0.15 kg of paddy rice was produced for every megajoules of energy input, or 6.70 MJ of energy was expended to produce 1 kg of paddy rice.

The Benefit-cost ratio was computed to determine the cost efficiency of rice production in the two farming management. For organic rice production, farmers' gross return and total expenses were 74,800.00 pesos per hectare and 38,777.33 pesos per hectare, respectively. This resulted in a net return of 36,022.67 pesos per hectare, which corresponds to a benefit-cost ratio of 1.93, indicating a profit of 93 cents for every 1 peso production cost.

For inorganic rice production, farmers' gross return and total expenses were 82,992.00 and 60,542.80 pesos per hectare, respectively. This resulted in a net return of 22,449.20, approximately 38% lower than organic rice farming. Its benefit-cost ratio of 1.37 manifests a profit of 37 cents for every 1 peso production cost.

4. CONCLUSIONS AND RECOMMENDATION

The cost and energy efficiency of two different rice farming practices in Agusan del Sur were assessed to help farmers, resource managers, and policymakers develop alternative practices and energy-efficient plans for conserving nonrenewable energy inputs while maintaining production levels and avoiding economic burdens on farmers.

Results revealed that the average yield of organic and inorganic rice production was 3,400 kg/ha and 4,368 kg/ha, respectively. Fertilizer application is more intense in inorganic production, which resulted in higher direct energy inputs than in organic production. It was also found that economic and energy efficiency in organic farming is higher than in inorganic farming systems.

To summarize, fertilizer use on inorganic farms within the research area may be greater than required for crop production. This idea is not to reduce the usage of inputs in rice fields but to use them more efficiently by assessing the soil's nutrient composition to determine the optimal amount of fertilizer application for the best crop performance. This idea will not only promote sustainable agriculture but will also mitigate environment degradation. Furthermore, government authority and agricultural organizations must invest in research, offer financial incentives, and provide training programs to assist farmers in adopting sustainable rice production methods. It is also recommended that a study be conducted on the potential variability in energy inputs caused by different climatic conditions across seasons or years to determine whether this variability has a significant impact on the energy efficiency and economic viability of rice production, particularly in regions with low precipitation throughout the year, which could result in expensive irrigation.

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