International Journal on Advanced Science Engineering Information Technology

Vol.15 (2025) No. 1
ISSN: 2088-5334

Productivity and Technical Efficiency of Organic Rice Farming in Camarines Sur, Philippines

Hanilyn A. Hidalgo [a], Renato A. Villano [b], Mae SA. Lustre [a], Keith Eduard S. Hidalgo [c]

[a] *Central Bicol State University of Agriculture, San Jose, Pili, Camarines Sur, Philippines*
[b] *University of New England, Armidale, NSW, Australia*
[c] *Ateneo de Naga University, Ateneo Avenue, Naga City, Philippines*
*Corresponding author: *hanilyn.hidalgo@cbsua.edu.ph*

Abstract—**Producing an optimum supply level is a critical barrier in the chain flow of organic rice. Low productivity is one of the main reasons rice farms cannot quickly address the market requirement for organic rice. The paper aimed to assess the productivity and technical efficiency of the organic rice farms in Camarines Sur and explore the factors affecting the yield of organic rice. By exploring the performance of organic rice farms in the province, this study provides empirical evidence to develop an economically effective farming system that will boost productivity at the farm level. Using farm-level data from 60 certified organic rice farms collected over four cropping seasons, we adopt the stochastic production analysis framework to analyze the productivity and technical efficiency determinants of certified organic farming households in Camarines Sur, Philippines. The results showed significant evidence of variations in farmers' productivity and further improvement opportunities. The average technical efficiency is 0.75, ranging from 0.30 to 0.96. Labor availability, capital, and area planted to organic rice were the main factors affecting overall productivity. Results also highlighted the importance of access to irrigation, availability of full-time labor, and farming experience in improving farmer's technical efficiency. The findings of this study reinforce the need for a deeper understanding of the role of government, particularly in increasing investment in agricultural training and rural education, in agricultural production of smallholder farming households, and in the provision of support mechanisms for enabling improvement in the organic rice industry.**

Keywords—**Technical efficiency; productivity; organic rice.**

Manuscript received 28 Feb. 2024; revised 12 Oct. 2024; accepted 10 Jan. 2025. Date of publication 28 Feb. 2025.

I. Introduction

Rice is an essential component of the diet of billions of people around the world. It serves as a primary source of calories and essential nutrients such as iron which is an important element found in rice [1]. Historically, conventional white rice was the predominant choice for consumers, but the growing number of health and environment-conscious consumers stimulates the interest in natural and organic products [2], [3], [4], [5]. Globally, the increasing consumer preference for organic rice is fueled by the belief that it offers superior nutrition and safety compared to conventionally produced varieties[6], [7], [8]. Organic farming significantly enhances the economic performance of rice farms by reducing costs and increasing profitability [9]. Emerging Asian economies embraced a proactive approach to advancing organic farming practices [10].

While conventional rice farming systems predominate among Filipino rice farmers by heavily relying on inorganic fertilizers, to enhance paddy rice yield, organic agriculture, as defined by the International Federation of Organic Agriculture Movement (IFOAM) as a type of farming system that promotes the environmental, socially, and economically sound production of food, fibers, and biofuels. Such a system takes natural soil fertility as the key to productivity without chemical-based fertilizers and pesticides, [11], [12], [13], [14], increasing the craze for organic products. While it is considered a widely accepted farming approach, issues on productivity, management, and waste utilization need to be optimized to ensure long-term sustainability [15].

Though it is still used in niche marketing, the supply side could not adhere to the increasing consumer demand. Farmers' capacity cannot quickly address the market requirements for organic products. At the rice farm level, there is a low level of awareness of organic farming activities and low absorption of market information [16]. As a result, demand is always more extensive than supply. Furthermore, those engaged in organic agriculture face production, certification, and marketing difficulties. One significant challenge in organic rice marketing is the limited availability of market information and marketing channels, which reduces overall efficiency[10]. Similarly, some experienced lower profitability from an organic method because of delayed market agreements and payment. Reducing input inefficiencies and efficient marketing system are necessary to increase farmer's income [17]. Participation in contract farming for example has shown a significant positive impact on the technical efficiency of organic rice farming [18].

Studies showed that the organic rice farming system could produce higher results than the conventional system in terms of volume. In Nepal, the average yield of organic rice is 3.15 mt/ha. This figure is higher than its national average of rice yield at 2.90 mt/ha. In another study in Lao, organic rice farmers enjoy a relatively higher profit than conventional rice farmers. This result was attributed to the cost efficiency and premium pricing factors of organic rice farming. In addition, the farmers were under a contract farming arrangement where they were assured of buyers after harvest. Organic rice farming showed higher productivity levels than inorganic farming in some regions of Indonesia, with an increase in production reaching 7,163.80 Kg/MT/Ha [19], despite being hindered by community perceptions, limited appreciation of organic products [20], lack of sources of organic fertilizer and certification, their belief is strong in the future of organic farming [21]. In the Philippines, [22] revealed that the yields generated by the organic rice farming system are relatively higher by 17% than the yields of conventional farms. This was further strengthened when the government integrated organic farming into its policy reforms. The implementation of the Organic Agriculture Act of 2010 paved the way for more opportunities to venture into organic farming. The law became the farmers' pillar in the development and promotion of organic products in the country. However, contrary to the benefits and impacts of organic farming, the number of organic rice farmers has not changed significantly over the past few years. Farmers are still concerned about whether organic farming will provide them with the desired production given its benefits to the environment such as preventing degradation of soil functions as a result of hazardous agrochemicals and inorganic fertilizers [23].

Organic farming relies on preserving soil fertility and ideally involves a self-sustaining farming system encompassing both plants and animals, which promotes efficient nutrient recycling. Utilizing organic fertilizer changes the soil community structure and increases the abundance of beneficial bacteria such as *Bacilli* and *Flavobacteriales* [24]. In rice farming for example, conventional farming imposes greater environmental impacts than organic farming including carbon footprints [25], [26], thus it serves as an alternative production method that addresses human welfare by ensuring safe agricultural output [27] which leads to food safety and security.

Correspondingly, understanding the composition and structure of the rice field ecosystem is important and can also be applied in integrated pest management. Sonico [28] study the beneficial and harmful insects the species richness, evenness, and diversity in an organic rice field in Barangay Langkong, M'lang, North Cotabato, Philippines. It was determined that 2,659 were classified as harmful and 1,137 as beneficial among the 3,796 insects that were collected. In the same area, all weed species exhibited less than 50% uniformity, suggesting reduced competitiveness against rice indicating that appropriate weed control practices can effectively manage these weeds [29].

Some projects and industries provide evidence of the benefits of organic farming. For example, the Tigray project in Ethiopia non-market-driven organic agriculture initiated in 1996 in response to land degradation, food security, and livelihood challenges. Here, farmers have used innovations and organic practices such as composting, crop diversification, and improved water management to solve problems such as overgrazing, soil erosion, and depletion of water resources, which exacerbate rural poverty and hunger. The Tigray Project showed that there were higher yields achieved through organic management practices. Farmers gained evidence and confidence to withdraw costly synthetic fertilizers. There was a greater diversity of crops, higher groundwater tables, and improved farm resilience. In addition, the community had better nutrition and new income opportunities.

In the context of Palestinian olive-growing farms in the West Bank, it was observed that organic farming significantly enhances input efficiency, particularly in terms of labor and cost, compared to conventional agricultural practices [30]. In China, the adoption of organic fertilization has improved the rice yield by 8.3 percent, which are mainly from farm manure enhancing the nutrient content of the soil [31], [32].

Several technical efficiency studies have been conducted in rice farming. According to [33], during planting, speed, and accuracy are the main conditions for increasing agricultural productivity. Moreover, increased output is positively and significantly associated with the land area and the utilization of high-quality seeds [34]. In post-harvest processing, rice milling is an important activity to achieve high-quality rice [35]. In Vietnam, Hien *et al.* [36] found that farmers who adopted more sustainable practices obtained higher technical efficiency and scale efficiency with scores of 90 % and 91 % respectively. The positive correlation observed between the number of sustainable agriculture practices applied and efficiency emphasizes the significance of adopting sustainable agriculture practices in rice-producing households. Furthermore, efficiency in various aspects could be enhanced if farmers increased their farm sizes and minimized the excessive use of inputs [37]. Furthermore, Vietnamese farmer's economic factors, their awareness of organic farming, and market confidence in agricultural outcomes have a predominant impact on their intention to adopt organic rice farming [38].

While several studies have extensively examined organic farming in general, there is a dearth of relevant literature explicitly scrutinizing the difference between conventional and organic rice farming in terms of yield per hectare, labor, cost of inputs, and prices. The productivity and efficiency of organic farming have been considered in several empirical studies. Different indicators are employed to elicit the performance of organic farmers, including on-farm and estimated ones. In the case of organic rice farming, limited studies have been conducted in the context of the Philippines. Hence, this study aims to fill this gap, particularly in two main areas (i) this paper will provide evidence of the technical efficiency of certified organic rice farmers and (ii) elicit implications for further improvement of the performance of the organic rice sector. The paper aimed to assess the productivity and technical efficiency of the organic rice farms in Camarines Sur and explore the factors affecting the yield of organic rice.

II. Materials and Method

To better understand the performance of organic farmers, we examine the level of productivity and efficiency of individual farmers. Productivity is measured as a partial productivity measure (hereafter, referred to simply as productivity), which provides a similar measure as long as all farmers have access to the same production technologies and there are no scale economies. Examples of productivity indicators are yield (kg/hectare), costs/ha, profit/ha, and total production per season. By efficiency, we measure the performance of farmers based on their existing resources. A farm is technically efficient when it achieves the maximum possible output for a given set of inputs used in production. A technically inefficient farm can increase production without requiring any more input. Technical efficiency shows the capacity of farmers to reach the maximum attainable output. Information about productivity and efficiency is useful for benchmarking, design of the appropriate extension, research, and policy support [39], [40], [41]. Specifically, we use stochastic frontier analysis to examine the performance of organic rice farmers. Below is a basic summary of the ideas and models estimated in this study.

A. The Basic Model

The efficiency measurement is based on the input-output relationship at a particular point in time. As the efficiency measure is expected to reflect the overall capability of resource management, the frontier production function-based measure of efficiency is more suitable. The frontier production function sets the standard against which the technical efficiencies of individual farmers are measured.

A stochastic frontier production function is applied to cross-sectional data to model organic rice production in the Philippines. The model of [42] is used following the original models of [43] and [44]. It has the general form:

$$Yi = f(xi,\beta) \exp(ei) \quad (1)$$

where *Yi* is the output of farm *i* (i = 1, 2, …, N); *X*i is the corresponding matrix of inputs; a is the vector of parameters to be estimated; and *ei* is the error term that is composed of two independent elements, *Vi* and *Ui*, such that $ei \equiv Vi - Ui$. The *Vi*s is assumed to be symmetric identically and independently distributed errors that represent random variations in output due to factors outside the control of the farmers and the effects of measurement error in the output variable, left-out explanatory variables from the model, and statistical noise. They are assumed to be normally distributed with mean zero and variance *su2.* The parameters of both the stochastic frontier models are consistently estimated by the maximum likelihood method. The variance parameters of the likelihood function are estimated in terms of $\sigma^2 \equiv \sigma^2{}_V + \sigma_U{}^2$.

B. The Empirical Model

Most previous studies on efficiency analysis have specified the Cobb-Douglas and translog production functions to represent the production technology. The Cobb-Douglas functional form imposes severe *a priori* restrictions on the technology involved by restricting the production elasticities to constant and the input substitution elasticities to be unity. Despite its limitations, the Cobb-Douglas function has been widely used in farm efficiency analyses in developing and developed countries [45], [46]. Several studies have examined the effect of choice of functional form on efficiency measures derived from econometric stochastic frontier models, [47], [48], [49] confirmed that estimates of the production structure are sensitive to the choice of functional form. However, [50] and [49] suggest that the choice of functional form might not significantly impact measured efficiency levels. The translog production function is an alternative. However, this functional form violates fundamental theoretical properties, including inactivity, strong input and output disposability, and input and output closedness. The translog satisfies strong disposability of inputs and outputs when all second-order coefficients are zero, but if such is the case, the translog becomes the C-D (see [51],[52]. These studies examined the sensitivity of the production structure (such as production elasticities, returns to scale, technological change, and technical efficiency) to the different functional specifications.

In this study, we have estimated the Cobb-Douglas stochastic production function, defined as:

$$ln\, ln\, Y_{it} = \beta_0 + \sum_{i=1}^{6} \beta_i X_{it} + V_{it} - U_{it} \quad (2)$$

where Y_1 is the total output of rice in kilograms; X_1 is the *land* (area) cultivated in hectares; X_2 is total *labor* used in production (Inputs are expressed in pesos; costs of inputs can be used as an indicator of physical inputs when firms are faced with the same input market); X_3 is total *expenses* in purchased material and other inputs in pesos; X_4 is a dummy variable for topography (1=upland, 0 otherwise); X_5 dummy variable equal to 1 for farmers who irrigated their farm; X_6 is equal to 1 if the farmer applied organic fertilizer; and ; V_{it} represents statistical noise assumed to follow a normal distribution with mean zero and a constant variance ($V_i \sim iidN(0, \sigma_V^2)$; and U_i s a non-negative unobservable random error defined by the truncation (at zero) that represents technical inefficiency of the *i*-th farmer. The ®s and φ s are unknown parameters to be estimated and the subscripts, *j* and *i* refer to the *j*-th input (*j* =1,2…4) of the *i*-th farmer. *i*=1,2,..,I) and *k denotes k*[th] *dummy variable.*

Accordingly, technical efficiency of individual farmers (TE_i) is measured as:

$$TE_i = \exp(-U_i) \quad (3)$$

The measure of technical efficiency takes a value between zero and one. It measures the output of the i-th farmer relative to the output that could be produced by a fully efficient farmer using the same input resources.

C. Study Area and Data

The study focused on analyzing the performance of organic rice farming in the Province of Camarines Sur for four (4) cropping seasons. The study respondents were a total enumeration of the certified organic rice farmers in the Province of Camarines Sur. They were determined based on the list that was obtained from the Pecuaria Development Cooperative and the Department of Agriculture. At present, there are sixty-one (61) certified organic rice farms registered in Camarines Sur. All the identified respondents were interviewed except for one farmer who refused to participate in the survey.

Data gathering was done primarily through an interview utilizing a pre-tested survey instrument/questionnaire. Secondary data was also obtained from the enablers and supporters of the organic rice industry in Camarines Sur. These would include national government agencies (NGAs), non-government organizations, organic trade associations, research centers, and local government units. The gathered data went through statistical tests using Statistical Package for Social Sciences (SPSS), and stochastic frontier models are estimated to be using STATA.

III. Results and Discussion

A. Basic Statistics

Camarines Sur, a province of a major island in the Philippines, is the leading organic rice producer in its region. About seventy-five (75) farmers supply organic rice to the top and only certified producer-seller, the Pecuaria Development Cooperative Inc (PDCI). The number of farmers remained steady over the past five years. Although some were in a transition period, others could not strictly maintain the standards imposed by an organic method of farming. Since 2013, it has exported its rice to Singapore and China. In the last two years, the local market has changed to other organic rice suppliers from other regions. This posted an economic downturn for the farmers who depended on PDCI's market.

Out of the 75 farmers, only 61 are organic certified and included in the study. Basic information is presented in Table 1. The average number of years in farming is 19 years, and 75% of the respondents have been farming for more than 15 years. The average land area is 1.67 hectares, with a range from 0.3 to 20 hectares. Farms are generally small since 87% of the farmers have less than two hectares of rice fields. About 85% of the farms are irrigated, and 87% are characterized as lowland. Initially, only nine farmers were given organic certification in 2000 to 9.4 hectares of rice farms.

TABLE I
Basic characteristics of respondents

Item	Value
Average age of respondent (years)	49.8
Years in farming	
Average	19.45
Minimum	2
Maximum	50
Std. Deviation	9.8
Area operated (hectare)	
Average	1.67
Minimum	0.30
Maximum	20
Std. Deviation	2.51
Proportion of farms in lowland environment (%)	87
Proportion of farms with no irrigation (%)	15
Average permanent labor (laborer/hectare)	1.63

B. Cost and Return of Organic Farming in Camarines Sur

Input costs of the organic rice farm on a per hectare basis are composed of the following: seeds, organic fertilizer, irrigation, and sacks/packaging expenses. Harvesting and threshing had the highest labor cost while crop care had the lowest cost (see Table 2). The farmers sell their fresh rice grains to a cooperative where the post-harvest activities are done. This is to ensure uniformity of moisture content prior to milling. Four farmers, however, were found to sell milled rice to end-consumers as exhibited by the presence of post-harvest costs.

TABLE II
Cost and return of organic farming in Camarines sur

Item	Mean	Std. Deviation
Yield [a]	2777.98	578.27
Material inputs (PhP)		
Seeds	3128.05	168.57
Fertilizer	2805.62	400.60
Irrigation	5170.80	814.27
Sacks and packaging	690.16	145.44
Labor costs (PhP)		
Land preparation	5959.07	453.91
Planting	603.70	78.23
Crop care [b]	513.68	183.10
Harvesting and threshing	6869.07	1446.83
Post-harvest	251.82	70.12
Profit	32350.90	9969.14

[a] – Assuming 50kg per cavans divided by the area operated.
[b] – Including pesticide application, weeding and fertilizer application.

In a study by [53], total costs for operating most organic farming systems are lower than those for comparable conventional farms. There are differences in the relative importance of individual cost elements. The restrictions on fertilizers, pesticides, and feed concentrate on organic farms result in reductions in these costs of production as cited in [53]. Land, fertilizer, seeds, and labor positively affect production efficiency [54]. Inputs of fertilizer and energy were 34 to 53 percent lower, and pesticide inputs 97 percent lower on organic than conventional farms in 21 European countries[49]. Semi-organic farms, transitioning to organic farming, use small amounts of chemicals to balance ecological and health concerns [55].

More than half of the respondents reported high (0.77-1.01) to very high (1.02-1.26) farm productivity, while 46.67 percent reported low (0.51-0.76) to very low (0.25-0.50) farm productivity. As studied by PDCI, 54-70 cavans per hectare are considered high yield; exceeding 70 cavans is considered very high. There are several reasons for the low productivity levels as expressed by the respondents: 1) pest infestation (weeds and rice black bug); 2) erratic weather conditions (typhoons and strong winds); and 3) the poor yield brought about by varying organic farming practices.

As stated previously, farmers' organic rice production methods do not follow a definite or standard procedure. Organic farming has various approaches such as SRI and NFS or a combination of both. In Camarines Sur, the average yield of conventional rice production per hectare is 70 cavans (3.5 metric tons), similar to organic rice production per hectare, given the necessary condition and input requirements. Increasing the diversity of the soil bacterial community through bio-organic fertilizers made from decomposed organic materials and organic manure application could enhance rice productivity [46]. Furthermore, restoring soil fertility is crucial for long-term productivity [45].

C. Production Function Estimates

The maximum likelihood estimates of the Cobb-Douglas stochastic frontier production function is presented in Table 3. The ordinary least squares (OLS) estimates are considered the mean/average function, thus reflect the input-output relationships between the average farmers. The maximum likelihood estimates (MLE) show the frontier's production technology, thus reflecting the input-output relationships for the best-performing firms. The estimated values of the parameters are considered elasticities of output concerning changes in the respective inputs.

A likelihood ratio test (LR test statistic = 60.70, p-value = 0.000) to test the one-sided error shows that the inefficiency component is significantly different from zero. In fact, the value of gamma (g = 0.673) suggests that rice output variability could be attributed to inefficiency.

On average, the productivity of organic rice is significantly influenced by the area operated and labor inputs. A 1 percent increase in the area planted to organic rice is expected to increase output by 0.26 percent. These results are consistent with those reported by [56] As expected, organic farming is labor-intensive; hence productivity is positively influenced by this input. The sign for irrigation is unexpected and significant for average farmers but insignificant for best-performing farms. The results indicate that farmers who irrigate their farms are less productive than those who do not. However, this result can be regarded as an indicator of the severity of the drought problem rather than the negative effects of having irrigation. On the other hand, the most significant input is labor. As noted above, labor costs in land preparation, planting, and harvesting have the highest share of the cost of production. We found no statistical significance in the output of farmers located in the lowland and upland areas.

D. Technical Efficiency Estimates

The summary statistics of estimated technical efficiencies are presented in Table 4. On average, technical efficiency is 0.750 ranging from 0.300 to 0.964. This result suggests that organic farmers are considered to be efficient (TE > 0.70), and there are opportunities to increase output by 25% using existing resources. The performance of farmers is improving over time, as indicated in the upward trajectory of average technical efficiencies. This positive change of technical efficiency was significant (e= 0.158) and is significant at 1 percent level. Moreover, the coefficient of variation of technical efficiency estimates decreases over time. This may imply that over time, inefficient farmers in the first period can catch up hence lower variability of scores in the fourth season (15.1%).

TABLE III
ESTIMATES OF COBB-DOUGLAS PRODUCTION FUNCTION FOR SELECTED ORGANIC RICE FARMERS IN CAMARINES SUR, PHILIPPINES

Variables /Parameters	**OLS Estimates Coff.**	**St. Error**	**T-ratio**	**MLE Estimates Coff.**	**St. Error**	**T-ratio**
Constant	0.632	0.753	0.839	-2.237	1.209	-1.851
Land	0.261	0.088	2.971[a]	0.017	0.131	0.129
Labor	0.705	0.056	12.527[a]	1.034	0.104	9.988[a]
Material Inputs	0.069	0.060	1.146	0.066	0.081	0.811
Topography	0.035	0.085	0.408	0.071	0.110	0.644
Irrigation	-0.201	0.061	-3.317[a]	-0.055	0.073	-0.755
Organic Fertilizer	-0.061	0.087	-0.699	0.064	0.104	0.612
Sigma^2	0.097			0.143	0.045	3.156[a]
Gamma				0.673	0.131	5.121[a]
Eta				0.158	0.056	2.829[a]
LLF	55.590			25.240		

[a] significant at 1% level.

TABLE IV
DESCRIPTIVE STATISTICS OF ESTIMATED TECHNICAL EFFICIENCIES FOR SELECTED ORGANIC RICE FARMERS IN CAMARINES SUR, PHILIPPINES.

Item	*Crop1*	*Crop2*	*Crop3*	*Crop4*	*All Seasons*
Mean	0.704	0.742	0.772	0.806	0.750
Median	0.734	0.768	0.797	0.829	0.778
Mode	0.903	0.916	0.928	0.938	0.903
Standard Deviation	0.174	0.154	0.139	0.122	0.156
Sample Variance	0.030	0.024	0.019	0.015	0.024
Minimum	0.300	0.357	0.415	0.472	0.300
Maximum	0.944	0.952	0.958	0.964	0.964
CV (%)	24.7	20.7	18.0	15.1	21.8

Note: crop1-4 refers to four cropping seasons

At least two-thirds of farmers obtained a technical efficiency score of more than 75% and almost 10% of farmers obtained a score below 50%. The sparse distribution of efficiency scores shows varying levels of performance among the organic farmers in the study area.

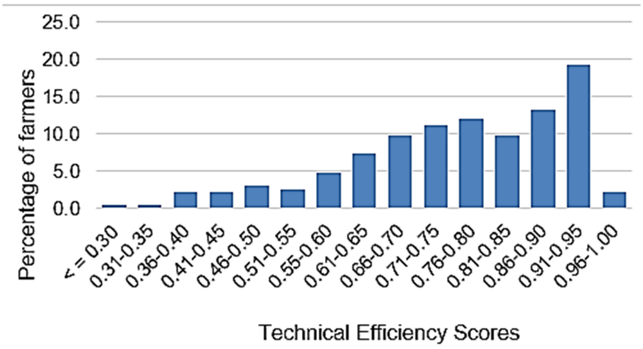

Fig. 1 Distribution of combined technical efficiency indicators for selected organic rice farmers in Camarines Sur, Philippines.

The preceding results show that, as expected, the area planted for organic rice is significantly affecting output. Average farmers are more responsive to changes in area than those who are already operating at the frontier. We found evidence of inefficiency in the production system. However, moving the average farmers towards the frontier becomes difficult because of the restrictions perpetrated by environmental and/or agroecological resource constraints. For example, smaller and fragmented farm sizes do not allow for mechanization and thus will force farmers to use traditional farming methods. The technical efficiency of organic rice farming in some areas of the Philippines is lower compared to conventional rice farming systems, indicating the need for more labor and management skills [57].

The organic rice industry is a labor-intensive industry wherein the majority of production processes are conducted manually. Similar to a study in Vietnam on rice efficiency, labor is a significant factor in production [39]. The cost associated with land preparation, planting, and harvesting is one of the bottlenecks in increasing the productivity of organic rice farmers. While the reliance on manual labor is a challenge for farmer operators, organic farming becomes a source of livelihood for many agricultural workers within the community. Based on the survey conducted, the industry employed a total of one hundred thirteen (113) permanent workers and two hundred fifty-three (253) "on-call" laborers who worked on a part-time basis every cropping season.

We found evidence of inefficiency in organic rice production, and the result highlighted opportunities to improve output by almost 25% on average. However, we are not able to determine the key determinants and sources of inefficiency. Other factors that affect organic rice productivity need to be explored, such as the effect of natural calamities and climate change [58]. Our results showed that the technical efficiency scores vary between farms but showed improvement over time. Potential avenues to improve the performance of organic farmers are worth noting. One of the factors that is difficult to change for the farmers is the area planted. The importance of area planted to output may also suggest maximizing the land using the natural farming system. While profitability does not entirely depend on the productivity of the organic rice farms, the farmers and the cooperative can look into maximizing gains on sale price per unit and minimizing the costs of production. In China, eco-compensation was found to be a driving factor in improving their farming system [59]. The natural farming system shows great potential by using readily available and inexpensive materials; it also speeds up plant growth and increases harvest.

Support to farmers may be necessary through formal and non-formal training to improve farmers' knowledge and understanding of organic rice farming whereby actual scenarios are given as case material to stimulate positive change towards environmental behavior [60]. A technical and entrepreneurial training program may be provided by the cooperative to the farmers to improve productivity and profitability at the farm level. Further, the Department of Agriculture can make a separate road map for organic rice in Bicol, Philippines. This road map will promote the high potential for premium and marketability of organic rice to interested farmers who plan to shift to organic rice production. This will provide directions on how to meet the increasing demand for organic rice.

Promotion, dissemination, and complete monitoring of the standards of the organic certification are suggested to effect behavioral changes in farmers. Internal Control System (ICS) will also bring down the cost of organic certification to smallholders by establishing a group that can do much of its monitoring. Another is to consider the reality of the inconsistent and varying practices of farmers. PDCI, as the main driver and buyer of organic rice in the industry, must design clear, definite, and standardized training on the methods and procedures of organic agriculture. With the ICS, the need to formulate effective schemes on how to assure customers of the integrity of the existing organic production system should be looked into. The scheme will go beyond labels and third-party certifications. Relevant to this is the need to review the ways of implementing sanctions to violators effectively.

Finally, as the scores improve over time, it is possible to generate demonstration sites and/or enhance farmer-to-farmer learning and cooperation. While not covered in this paper, the significance of social capital, education, and training on adopting organic farming and related farming practices will help us better understand the factors affecting the productivity and efficiency of smallholder organic rice farmers. The role of extension services is essential for effective farm adaptation strategies [61].

The paper aimed to assess the productivity and technical efficiency of the organic rice farms in Camarines Sur and explore the factors affecting the yield of organic rice by using Cobb–Douglas stochastic frontier analysis (SFA). A structured questionnaire was used to collect the profile and farming activities of 60 certified organic rice farmers. The study found the area planted and labor availability greatly influence the productivity of organic farms. Irrigation was significant for average farmers and not for the best-performing farms. There is also strong evidence of variations in farmers' productivity, which implies further opportunities for improvement with a technical efficiency of 0.75. With labor and size as critical factors of output, it implies that organic farming is a choice of sustainability and not productivity. However, conflicts about industrial and agricultural sustainability have yet to be addressed by the growing industry of organic rice to meet food security [62], [63].

IV. Conclusion

Producing an optimum supply level is a critical barrier in the chain flow of organic rice, not only in the province of Camarines Sur but throughout the Philippines and across countries. Over time, the demand for organic rice has been in an upward shift and is continually increasing. However, there are claims that low productivity is one of the main reasons rice farms cannot quickly address the market requirement for organic rice. In this study, labor availability, capital, and area planted to organic rice were the main factors affecting overall productivity. Organic farming entails a greater quantity of labor than the conventional rice farming methods to comply with the principles of the natural farming system strictly. Meanwhile, increasing the planted area requires a challenging task because of the restrictions imposed on areas considered organic areas. Therefore, the decision to engage in the organic method appears to result from strong advocacy for agricultural sustainability. Nevertheless, similar to Indonesian rice farming, our results show that organic rice farmers are efficient given their existing resources [21]. There is still an opportunity to improve overall productivity via improvement in efficiency. Improvement in efficiency is evident in the increasing scores of technical efficiencies over the four cropping seasons. These performance indicators and experiences may be documented and used to demonstrate to new entrants in organic farming.

Results also highlighted the importance of access to irrigation, availability of full-time labor, and farming experience in improving farmer's technical efficiency. The findings of this study reinforce the need for a deeper understanding of the role of government, particularly in increasing investment in agricultural training and rural education, in agricultural production of smallholder farming households, and in the provision of support mechanisms for enabling improvement in the organic rice industry.

In general, to perpetuate this driving force, the farmers may be supported with updated market information using either traditional or digital platforms that are seamlessly accessible; a holistic entrepreneurial capability training program that may be required as part of a monitoring scheme whenever farm inputs are freely provided to them; and incentives such as lower lending interest rates or tax exemption for organic rice production to foster the growth of organic rice farming in the province. While this study focused only on the factors of production, further studies may explore aspects comprising other components of livelihood such as social, financial, and human capital may be analyzed for further investigation.

ACKNOWLEDGMENT

The authors would like to thank the Central Bicol State University of Agriculture, Philippines for the assistance in the conduct of the survey; and the members of Pecuaria Development Cooperative, Inc. for their active participation in the data gathering.

REFERENCES

[1] S. J. Rachmawatie, E. Purwanto, A. T. Sakya, and W. S. Dewi, "Increasing Fe content in rice plants with the application of liquid fertilizer from *Moringa oleifera* and golden snail," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 13, no. 6, pp. 1–10, 2023, doi:10.18517/ijaseit.13.6.18501.

[2] F. Giampieri et al., "Organic vs conventional plant-based foods: A review," *Food Chem.*, vol. 383, p. 132352, 2022, doi:10.1016/j.foodchem.2022.132352.

[3] N. Shah, P. Shah, and M. Patel, "Pricing decisions with the effect of advertisement and greening efforts for a greengrocer," *Sustainability*, vol. 14, no. 21, p. 13807, 2022, doi: 10.3390/su142113807.

[4] Y. Yu, Y. He, and X. Zhao, "Impact of demand information sharing on organic farming adoption: An evolutionary game approach," *Technol. Forecast. Soc. Change*, vol. 172, p. 121001, 2021, doi: 10.1016/j.techfore.2021.121001.

[5] V. Haider, F. Essl, K. P. Zulka, and S. Schindler, "Achieving transformative change in food consumption in Austria: A survey on opportunities and obstacles," *Sustainability*, vol. 14, no. 14, p. 8685, 2022, doi: 10.3390/su14148685.

[6] C. Bergman and M. Pandhi, "Organic rice production practices: Effects on grain end-use quality, healthfulness, and safety," *Foods*, vol. 12, no. 1, p. 73, 2023, doi: 10.3390/foods12010073.

[7] R. Yuan, S. Jin, and W. Wu, "Interactive effects of information and trust on consumer choices of organic food: Evidence from China," *Appetite*, vol. 192, p. 107115, 2024, doi:10.1016/j.appet.2023.107115.

[8] P. Y. Vélez-Terreros, D. Romero-Estévez, G. S. Yánez-Jácome, K. Simbaña-Farinango, and H. Navarrete, "Comparison of major nutrients and minerals between organic and conventional tomatoes: A review," *J. Food Compos. Anal.*, vol. 103, p. 103922, 2021, doi:10.1016/j.jfca.2021.103922.

[9] Y. C. Chang, Y. H. Luh, and M. F. Hsieh, "Economic effects of sustainable agri-food production in Taiwan: Does spatial agglomeration make a difference?," *Br. Food J.*, vol. 125, no. 12, pp. 1–15, 2023, doi: 10.1108/BFJ-10-2022-0879.

[10] O. Hérique and N. Faysse, "A large-scale public programme to promote organic rice farming in Thailand: Building solid foundations to enable farmers to engage?," *Org. Agric.*, vol. 11, no. 1, pp. 1–15, 2021, doi: 10.1007/s13165-020-00320-4.

[11] C. Benbrook, S. Kegley, and B. Baker, "Organic farming lessens reliance on pesticides and promotes public health by lowering dietary risks," *Agronomy*, vol. 11, no. 7, p. 1266, 2021, doi:10.3390/agronomy11071266.

[12] T. T. K. Ho et al., "Compost to improve sustainable soil cultivation and crop productivity," *Case Stud. Chem. Environ. Eng.*, vol. 6, p. 100211, 2022, doi: 10.1016/j.cscee.2022.100211.

[13] P. Liu et al., "Manure substitution with appropriate N rate enhanced the soil quality, crop productivity and net ecosystem economic benefit: A sustainable rainfed wheat practice," Field Crops Res., vol. 304, p. 109164, 2023, doi: 10.1016/j.fcr.2023.109164.

[14] S. Tian et al., "Organic fertilization promotes crop productivity through changes in soil aggregation," *Soil Biol. Biochem.*, vol. 165, p. 108533, 2022, doi: 10.1016/j.soilbio.2021.108533.

[15] M. C. Manna et al., "Organic farming: A prospect for food, environment and livelihood security in Indian agriculture," *Adv. Agron.*, vol. 170, pp. 1–50, 2021, doi: 10.1016/bs.agron.2021.06.003.

[16] M. E. S. Piadozo, F. A. Lantican, I. M. Pabuayon, A. R. Quicoy, A. M. Suyat, and P. K. B. Maghirang, "Rice farmers' concept and awareness of organic agriculture: Implications for sustainability of Philippine organic agriculture program," *J. Int. Soc. Southeast Asian Agric. Sci.*, vol. 20, no. 2, pp. 1–10, 2014.

[17] E. Istiyanti, S. U. Badriyah, and R. R. Rachman, "Production and marketing of semi-organic rice in Bantul Regency, Special Region of Yogyakarta," in *E3S Web Conf.*, vol. 316, p. 02038, 2021, doi:10.1051/e3sconf/202131602038.

[18] R. Mazhar et al., "Contract farming and technical efficiency: A case of export-oriented organic rice farmers in Pakistan," *Land*, vol. 11, no. 11, p. 1953, 2022, doi: 10.3390/land11111953.

[19] T. Amelia, E. Eliza, and S. Edwina, "Analysis of income of organic rice farmers in Nagari Kamang Mudiak Village, Kamang Magek Sub-District, Agam Regency, West Sumatera," *J. Agribus. Community Empower.*, vol. 4, no. 2, pp. 1–10, 2021, doi: 10.32530/jace.v4i2.296.

[20] G. S. Samidjo, B. H. Isnawan, and Triyono, "Implementation of organic rice cultivation to realize sustainable agriculture," *Appl. Ecol. Environ. Res.*, vol. 21, no. 5, pp. 4943–4955, 2023, doi:10.15666/aeer/2105_49434955.

[21] Sujianto et al., "Farmers' perception, awareness, and constraints of organic rice farming in Indonesia," *Open Agric.*, vol. 7, no. 1, pp. 1–10, 2022, doi: 10.1515/opag-2022-0090.

[22] T. C. Mendoza, "Evaluating the benefits of organic farming in rice agroecosystems in the Philippines," *J. Sustain. Agric.*, vol. 24, no. 2, pp. 1–20, 2004, doi: 10.1300/J064v24n02_09.

[23] A. S. Panwar et al., "Effect of organic farming on the restoration of soil quality, ecosystem services, and productivity in rice–wheat agro-ecosystems," *Front. Environ. Sci.*, vol. 10, p. 972394, 2022, doi:10.3389/fenvs.2022.972394.

[24] J. Liu et al., "Long-term organic fertilizer substitution increases rice yield by improving soil properties and regulating soil bacteria," *Geoderma*, vol. 404, p. 115287, 2021, doi:10.1016/j.geoderma.2021.115287.

[25] E. Amirahmadi et al., "Environmental life cycle assessment in organic and conventional rice farming systems: Using a cradle to farm gate approach," *Sustainability*, vol. 14, no. 23, p. 15870, 2022, doi:10.3390/su142315870.

[26] N. Arunrat, S. Sereenonchai, and C. Wang, "Carbon footprint and predicting the impact of climate change on carbon sequestration ecosystem services of organic rice farming and conventional rice farming: A case study in Phichit province, Thailand," *J. Environ. Manage.*, vol. 289, p. 112458, 2021, doi:10.1016/j.jenvman.2021.112458.

[27] Z. Ferdous, F. Zulfiqar, A. Datta, A. K. Hasan, and A. Sarker, "Potential and challenges of organic agriculture in Bangladesh: A review," *J. Crop Improv.*, vol. 35, no. 1, pp. 1–20, 2021, doi:10.1080/15427528.2020.1824951.

[28] M. G. I. Sonico, "Insect diversity in an organic rice farm in Brgy. Langkong, M'lang, North Cotabato, Philippines," *Southeastern Philippines J. Res. Dev.*, vol. 27, no. 1, pp. 1–10, 2022, doi:10.53899/spjrd.v27i1.189.

[29] S. H. T. Mamora, "Floristic composition and diversity of weeds in organic rice fields in Langkong, M'lang, Cotabato," *Southeastern Philippines J. Res. Dev.*, vol. 26, no. 1, pp. 1–10, 2021, doi:10.53899/spjrd.v26i1.123.

[30] K. Kashiwagi and H. Kamiyama, "Effect of adoption of organic farming on technical efficiency of olive-growing farms: Empirical

evidence from West Bank of Palestine," *Agric. Food Econ.*, vol. 11, no. 1, p. 16, 2023, doi: 10.1186/s40100-023-00266-7.

[31] L. Liu, H. Li, S. Zhu, Y. Gao, X. Zheng, and Y. Xu, "The response of agronomic characters and rice yield to organic fertilization in subtropical China: A three-level meta-analysis," *Field Crops Res.*, vol. 263, p. 108049, 2021, doi: 10.1016/j.fcr.2020.108049.

[32] I. Khan et al., "Organic amendments improved the productivity and bio-fortification of fine rice by improving physiological responses and nutrient homeostasis under salinity stress," *Plants*, vol. 12, no. 8, p. 1644, 2023, doi: 10.3390/plants12081644.

[33] S. S. Hidayat, D. Rahmawati, M. C. Ardi Prabowo, L. Triyono, and F. T. Putri, "Determining the rice seeds quality using convolutional neural network," *Int. J. Inform. Vis.*, vol. 7, no. 2, pp. 1–10, 2023, doi:10.30630/joiv.7.2.1175.

[34] N. Kusumaningsih, "The technical efficiency of rice farming and mobile phone usage: A stochastic frontier analysis," *Food Res.*, vol. 7, no. 1, pp. 1–10, 2023, doi: 10.26656/fr.2017.7(1).595.

[35] A. Haryanto, S. P. Adi, S. Suharyatun, F. K. Wisnu, and M. Telaumbanua, "Performance and prospects of mobile rice mill unit," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 12, no. 5, pp. 1–10, 2022, doi: 10.18517/ijaseit.12.5.15001.

[36] N. T. T. Hien, H. T. Tam, K. Shimada, H. H. Anh, N. Van Cuong, and L. C. Tru, "Technical efficiency of sustainable and conventional rice farming: Evidence from the Mekong Delta of Vietnam," *Chem. Eng. Trans.*, vol. 106, pp. 1–6, 2023, doi: 10.3303/CET23106058.

[37] L. C. Bich Tho and C. Umetsu, "Sustainable farming techniques and farm size for rice smallholders in the Vietnamese Mekong Delta: A slack-based technical efficiency approach," *Agric. Ecosyst. Environ.*, vol. 326, p. 107775, 2022, doi: 10.1016/j.agee.2021.107775.

[38] N. C. Dinh, T. Mizunoya, V. H. Ha, P. X. Hung, N. Q. Tan, and L. T. An, "Factors influencing farmer intentions to scale up organic rice farming: Preliminary findings from the context of agricultural production in Central Vietnam," *Asia-Pac. J. Reg. Sci.*, vol. 7, no. 3, pp. 1–20, 2023, doi: 10.1007/s41685-023-00279-6.

[39] R. B. S. Chandel, A. Khan, X. Li, and X. Xia, "Farm-level technical efficiency and its determinants of rice production in Indo-Gangetic Plains: A stochastic frontier model approach," *Sustainability*, vol. 14, no. 4, p. 2267, 2022, doi: 10.3390/su14042267.

[40] X. Zhu, C. Li, and H. Zhou, "Cost changes and technical efficiency of grain production in China against a background of rising factor prices," *Sustainability*, vol. 14, no. 19, p. 12852, 2022, doi:10.3390/su141912852.

[41] M. Mivumbi and X. Yuan, "Sustainable environmental economics in farmers' production factors via irrigation resources utilization using technical efficiency and allocative efficiency," *Sustainability*, vol. 15, no. 5, p. 4101, 2023, doi: 10.3390/su15054101.

[42] G. E. Battese and T. J. Coelli, "A model for technical inefficiency effects in a stochastic frontier production function for panel data," Empir. Econ., vol. 20, no. 2, pp. 325–332, 1995, doi:10.1007/BF01205442.

[43] D. Aigner, C. A. K. Lovell, and P. Schmidt, "Reprint of: Formulation and estimation of stochastic frontier production function models," *J. Econom.*, vol. 234, pp. 1–20, 2023, doi:10.1016/j.jeconom.2023.01.023.

[44] W. Meeusen and J. van Den Broeck, "Efficiency estimation from Cobb-Douglas production functions with composed error," *Int. Econ. Rev.*, vol. 18, no. 2, pp. 435–444, 1977, doi: 10.2307/2525757.

[45] S. S. Dhaliwal et al., "Residual effect of organic and inorganic fertilizers on growth, yield and nutrient uptake in wheat under a basmati rice–wheat cropping system in North-Western India," *Agriculture*, vol. 13, no. 3, p. 556, 2023, doi:10.3390/agriculture13030556.

[46] X. Zhao, J. Li, X. Hu, B. Hu, G. Chu, and R. Tao, "Three decades of organic manure and chemical fertilizers co-application enhanced rice productivity through increasing the diversity and key network module of soil bacterial community," *J. Soils Sediments*, vol. 23, no. 1, pp. 1–15, 2023, doi: 10.1007/s11368-023-03477-z.

[47] K. Giannakas, K. C. Tran, and V. Tzouvelekas, "On the choice of functional form in stochastic frontier modeling," *Empir. Econ.*, vol. 28, no. 1, pp. 1–20, 2003, doi: 10.1007/s001810100120.

[48] G. E. Battese and S. S. Broca, "Functional forms of stochastic frontier production functions and models for technical inefficiency effects: A comparative study for wheat farmers in Pakistan," *J. Prod. Anal.*, vol. 8, no. 4, pp. 1–20, 1997, doi: 10.1023/A:1007736025686.

[49] R. J. Kopp and V. K. Smith, "Frontier production function estimates for steam electric generation: A comparative analysis," South. Econ. J., vol. 46, no. 4, pp. 1–20, 1980, doi: 10.2307/1057240.

[50] M. Ahmad and B. E. Bravo-Ureta, "Technical efficiency measures for dairy farms using panel data: A comparison of alternative model specifications," *J. Prod. Anal.*, vol. 7, no. 4, pp. 1–20, 1996, doi:10.1007/BF00162049.

[51] C. J. O'Donnell, "An aggregate quantity framework for measuring and decomposing productivity change," *J. Prod. Anal.*, vol. 38, no. 3, pp. 1–20, 2012, doi: 10.1007/s11123-012-0275-1.

[52] R. Villano, B. O. Asante, and B. Bravo-Ureta, "Farming systems and productivity gaps: Opportunities for improving smallholder performance in the Forest-Savannah transition zone of Ghana," *Land Use Policy*, vol. 82, pp. 1–20, 2019, doi:10.1016/j.landusepol.2018.12.010.

[53] G. Greer, W. Kaye-Blake, E. Zellman, and C. Parsonson-Ensor, "Comparison of the financial performance of organic and conventional farms," *J. Org. Syst.*, vol. 3, no. 2, pp. 1–20, 2008.

[54] Muhardi and Effendy, "Technical efficiency and the factors that affect it in rice production in Indonesia," *Asian J. Agric. Rural Dev.*, vol. 11, no. 3, pp. 230–235, 2021, doi:10.18488/journal.ajard.2021.113.230.235.

[55] E. Istiyanti, R. Wulandari, and I. Widowati, "Technical efficiency of semi-organic rice farming in Sleman Regency, Special Region of Yogyakarta," in *E3S Web Conf.*, vol. 316, p. 02047, 2021, doi:10.1051/e3sconf/202131602047.

[56] R. Villano, B. Bravo-Ureta, D. Solís, and E. Fleming, "Modern rice technologies and productivity in the Philippines: Disentangling technology from managerial gaps," *J. Agric. Econ.*, vol. 66, no. 1, pp. 129–154, 2015, doi: 10.1111/1477-9552.12081.

[57] A. Narendar, N. Hanani, and S. Syafrial, "Technical efficiency of organic rice in Sumberngepoh Village, Lawang Sub-District, Malang District," *Agric. Soc. Econ. J.*, vol. 21, no. 4, pp. 1–10, 2021, doi:10.21776/ub.agrise.2020.021.4.7.

[58] T. M. Cao, S. H. Lee, and J. Y. Lee, "The impact of natural disasters and pest infestations on technical efficiency in rice production: A study in Vietnam," *Sustainability*, vol. 15, no. 15, p. 11633, 2023, doi:10.3390/su151511633.

[59] F. Li, K. Zhang, J. Ren, C. Yin, Y. Zhang, and J. Nie, "Driving mechanism for farmers to adopt improved agricultural systems in China: The case of rice-green manure crops rotation system," *Agric. Syst.*, vol. 192, p. 103202, 2021, doi: 10.1016/j.agsy.2021.103202.

[60] C. Vasconcelos et al., "Teaching sustainable development goals to university students: A cross-country case-based study," *Sustainability*, vol. 14, no. 3, p. 1593, 2022, doi: 10.3390/su14031593.

[61] M. Kamruzzaman, K. A. Daniell, A. Chowdhury, and S. Crimp, "The role of extension and advisory services in strengthening farmers' innovation networks to adapt to climate extremes," *Sustainability*, vol. 13, no. 4, p. 1941, 2021, doi: 10.3390/su13041941.

[62] C. F. Lu and C. Y. Cheng, "Exploring the distribution of organic farming: Findings from certified rice in Taiwan," *Ecol. Econ.*, vol. 212, p. 107915, 2023, doi: 10.1016/j.ecolecon.2023.107915.

[63] M. N. E. A. Siddique, L. A. Lobry de Bruyn, Y. Osanai, and C. N. Guppy, "Determining the role of land resource, cropping and management practices in soil organic carbon status of rice-based cropping systems," *Agric. Ecosyst. Environ.*, vol. 344, p. 108302, 2023, doi: 10.1016/j.agee.2022.108302.