International Journal on Advanced Science Engineering Information Technology

Vol.14 (2024) No. 4
ISSN: 2088-5334

Input-Output Modeling in Rice Farming: An Empirical Evidence from Indonesia

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***Abstract*—Food sovereignty is a social, political, and economic issue. One of the key food sources is rice, which is developed through rice farming. This makes rice farming a strategic role in people's lives and becomes a bargaining instrument for the State. Therefore, building a rice farming input-output model is important for farmers as farming actors, the public, and the government as a policy maker. This study aims to build a rice farming input model and, secondly, to analyze the role of each input on rice production in Indonesia. The practical implications of this research are significant, as it provides a comprehensive understanding of the factors influencing rice production, which can inform policy decisions and improve farming practices. This study was conducted in Turikale Subdistrict, Maros Regency, South Sulawesi. Data was obtained from 247 farmers. The analysis was conducted using multiple regression analysis in which the dependent variable is rice production, while the independent variables are land, seeds, fertilizers, pesticides, labor, and farm management. The results showed the input-output model Y = 222.126 + 2834.494X1 + 65.164X2 + 0.541X3- 0.630X4 + 0.123X5 + 758.749X6 + ε. From the F test, it is known that all independent variables together (simultaneously) affect the dependent variable at the 95% confidence level. While the t-test is known to be partially variable, land, seeds, and crop management significantly affect rice production. Three other variables, fertilizers, pesticides, and labor do not significantly affect rice farming production. This research combines two aspects in one input-output analysis: technical aspects (land, seeds, fertilizers, pesticides, and labor) and non-technical aspects, namely crop management. Combining two aspects in one input-output modeling is statistically possible and, at the same time, finds its novel starting point.**

***Keywords*—Input-output modeling; rice farming; food; farming management.**

Manuscript received 10 Aug. 2023; revised 9 Nov. 2023; accepted 28 Mar. 2024. Date of publication 31 Aug. 2024.

I. INTRODUCTION

The pursuit of state sovereignty has become a complex and multi-faceted issue. a country's power lies in the strength of its weapons and in ensuring food availability for its entire population. Food can also be used as a weapon to strengthen a country's position through diplomacy and international trade [1], [2]. Governments have recognized that ensuring a reliable and sustainable food supply is not merely a matter of economic well-being but a crucial component of maintaining national sovereignty, as food is a vital commodity that should be a primary concern for governments [3]–[6]. Therefore, attention to food availability is essential currently. The social and cultural functions of food are also critical in shaping a country's identity and can serve as a means of diplomacy and bargaining power in international relations [7]–[10]

Furthermore, the ability of a country to produce and distribute its food can be a significant source of leverage in diplomatic negotiations. The issue of food is not merely how the state ensures its availability to the community, but equally important is how the state regulates the development of food crops at the farm level. Food can be used as a diplomatic tool, with countries leveraging their food production and export capacities to achieve broader geopolitical objectives [11]–[13]

Ultimately, the role of food in maintaining national sovereignty is a complex and multifaceted issue that requires a nuanced understanding of social, cultural, and political dynamics. Governments have to prioritize the development of coherent national food policies that address the various challenges and opportunities presented by the food system. Food handling at the farm level is closely related to how farmers can manage their crops so that optimal food production can be achieved [14], [15].

Food consumption in Indonesia mainly comes from rice farming products. Given the growing population and increasing demand for rice, optimizing rice production is crucial. To improve the productivity and efficiency of rice farming, a study of the relationship between production inputs and outputs is needed [16], [17]. Input-output modeling of rice farming offers a systematic approach to analyze and predict production outcomes based on various input factors. The model can assist farmers and policymakers in optimizing resource allocation, improving production efficiency, and identifying potential areas for improvement in farming practices. Modeling input-output commonly used analytical tools are Cobb-Douglass, multiple regression analysis, stochastic Frontier model, data envelope analysis (DEA), and crop simulation models. Each analytical tool has advantages and disadvantages [18]–[20]. This study uses multiple regression analysis.

Technical and non-technical aspects support rice farming. Technical aspects relate to soil fertility, availability of agricultural land, pest and disease control, and irrigation. [21]–[23], while non-technical aspects rely on the managerial skills of farmers in managing their farms [24]. Research in Asia and Africa indicates that rice farming uses production factors in diverse ways. Research in Asia and Africa shows that rice farming uses production factors in diverse ways. These production factors are land, fertilizer, pesticides, and labor [25]–[27]; [28]. Research in Bangladesh, India, and Vietnam shows the excessive use of chemical fertilizers in rice farming. Limited land area, unbalanced use of pesticides, and unskilled labor characterize rice farming in Pakistan and Indonesia. [28]–[31].

Several studies have been conducted on the contribution of production factors to rice production. Generally, they are divided into two aspects. *First*, research that places land, seeds, fertilizers, and labor as production factors that most determine the importance of rice farming success. Research at this point is mainly on the small scale of land, low farmer skills, and uneven distribution of fertilizers. This case is typical in Indonesia [32]–[34]. *Second*, studies look at climate, irrigation, and access to capital as the main determinants of rice production. This level of research assumes that farmers already have sufficient understanding and skills in fertilizer and pesticide application. It also appears that the local government has successfully developed improved seed varieties, so the focus is no longer on micro-technological aspects. This group of studies is widely produced in China, Vietnam, and Japan, where agricultural technology has developed rapidly [35]–[38]. However, research that considers production factors such as land, seeds, fertilizer, pesticide, labor, and farmers' managerial ability in managing rice farming has not been found.

From various studies on rice farming, it can be seen that most of the analysis carried out relies on technical aspects such as fertilizer, land area, pesticides, and the use of labor. Meanwhile, non-technical elements, in this case, the farmers' managerial ability to manage rice farming, are carried out separately from these technical aspects. in practice, the two elements cannot be separated from one another. Therefore, this study was conducted to analyze the use of technical and non-technical factors simultaneously and, second, to model input-output on rice farming, including land factors, seeds, fertilizers, pesticides, labor, and management of rice farming. The purpose of this research is also a point of difference with other studies. Combining technical and non-technical aspects to find an input-output model is presumably the novelty of this study.

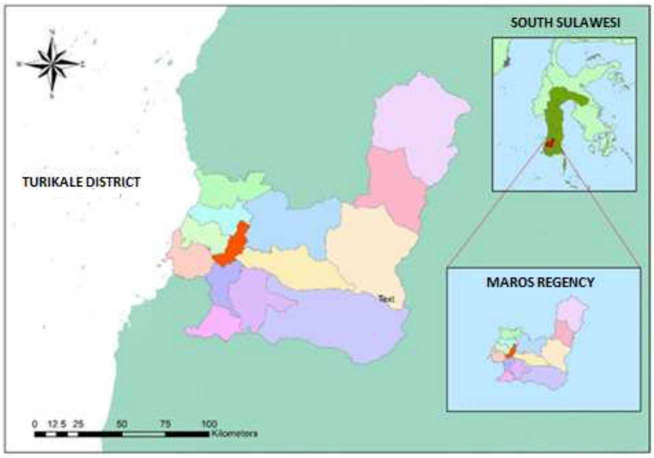

Fig. 1 Map of Turikale district, Maros regency

II. MATERIALS AND METHOD

A. Materials

Determining materials in a study depends on three things: the type of research, the background of the subject or unit of analysis where the data is collected, and the scope of the research area. Due to the focus of this research on input-output modeling of rice farming, it is determined that this type of research is quantitative. Data in quantitative research can be collected through structured interview protocols. However, to be sure which topic to use in the protocols, the respondents' background or character and the research area's scope were considered. Also, in this research, a questionnaire with open-ended responses was designed. The form of the questionnaire is determined by the respondents' backgrounds and the coverage area. The instruments used in this research were carried out when visiting respondents at the research location.

B. Method

1) Research setting: The research was conducted from February to April 2023. The choice of location was based on the consideration that most farmers in Turikale cultivate rice as their main crop. In addition, the managed rice fields are irrigated, representing the condition of rice fields in South Sulawesi. This research was conducted in Turikale District, Maros Regency, South Sulawesi Province. The location map is presented in Figure 1.

2) Sampling: The sample is part of the population's number and characteristics. The population was determined based on the characteristics of the primary type of farming, namely rice farming. Therefore, the number of rice farmers was obtained as many as 1,234 people. The sample was acquired randomly by 20 percent. Through this calculation, the number of samples obtained is as many as 247 respondents**.**

3) Data collection: The data used are primary and secondary. Primary data was collected using a questionnaire filled out by respondents in the study. In addition to questionnaires, data was also obtained through in-depth interviews with several farmers to get complete insights into rice farming practices, especially those related to crop management. Secondary data is obtained from statistical records or publications relevant to this study.

4) Data analysis: Before discussing data analysis, it is essential to be informed about the data type. Data on rice production, land area, fertilizers, pesticides, and labor are numerical. At the same time, data on crop management is categorical data. Data on crop management was developed from 8 (eight) activities: replanting, fertilizing with the recommended dose, controlling pests and diseases, using certified seeds, planting on time, spacing, controlling irrigation, and evaluating maintenance. Each activity item is assigned a percentage according to its level of urgency. Suppose the activities performed by farmers are $\geq 50\%$. In that case, they will be given a score of 1 (well-performing management), and activities performed by $< 50\%$ will be given a score of 0 (not performing management activities). This score is a dummy in the multiple regression analysis.

The data analysis method used in this research is multiple linear regression. The multiple linear regression equation is as follows:

$$Y = \alpha + \beta 1\ X1 + \beta 2\ X2 + \beta 3\ X3 + \beta 4\ X4 + \beta 5\ X5 + \beta 6\ X6 + \varepsilon \quad (1)$$

Where:
Y = Rice production (kg)
X1 = Land (ha)
X2 = Seeds (kg)
X3 = Fertilizer (kg)
X4 = Pesticide (liter)
X5 = Labor (Man-day)
X6 = Farming management (dummy)
ε = standard error

III. Results and Discussion

A. *Farmer's Characteristics*

Farmer characteristics are one of the determining factors in implementing agricultural sector policies. Age, education, and farming experience are inherent characteristics of farmers and are essential to examine. Farmers' decisions about what to do with their farms depend on the availability of production facilities and their background. For this reason, reviewing farmer characteristics is essential and cannot be separated from the overall input-output discussion. This section will present farmer characteristics in terms of age, education, farming experience, and ownership status.

The results indicate that farmers' age conditions range from 32 to 60, with an average age of 51. If the age of farmers is sorted into the categories of young and old farmers, most rice farmers are quite old. Figure 2 presents the age distribution of rice farmers. Another characteristic that can be seen is farmer education. It is known that farmers generally have a not-too-high education; this is also seen in farmers involved in rice farming in Turikale District, Maros Regency, South Sulawesi. This educational background concerns farmers' decisions to use superior varieties, fertilizers, pesticides, and farming management. Figure 3 shows the education of rice farmers.

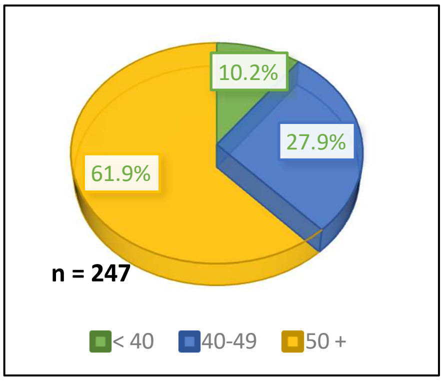

Fig. 2 Farmer by Age

The information in Figure 3 shows that most farmers' educational background is based on low education (Elementary School/ES and Junior High School/JHS), reaching more than 50%. Those with Senior High School (SHS) are below 40%, and those in higher education (HE) are less than 10% when linked to the age of the farmers (Figure 3), which is understandable because more than half of the farmers are old. The assumption is that those born 50 years ago are in a condition where education facilities still need to be adequate in the rural areas of South Sulawesi, including Maros District, where this research was conducted.

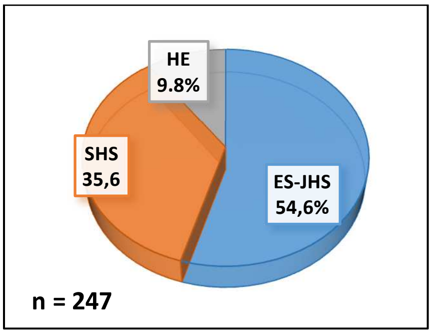

Fig. 3 Farmer by Education

In addition to farmers' education and age, experience in rice farming is equally essential. This experience is often seen as having two faces. First, farmers with high experience can do their farming using best practices. Second, those with long experience will feel established with what has been passed so that if there are innovations in rice farming, this group has the potential to become a group of opponents. Figure 4 presents an overview of farmers' long experience in rice farming.

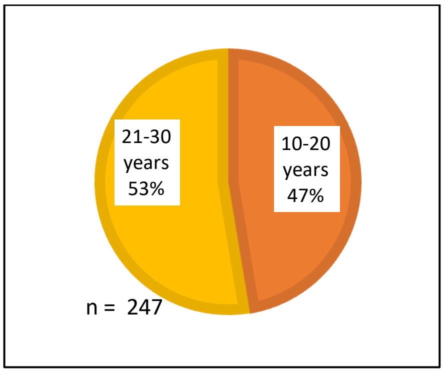

Fig. 4 Farmer by Experiences

Figure 4 shows that most rice farmers have been in business for 21-30 years. This picture aligns with the description of farmers' ages, which shows that most farmers are at the old age group (Figure 1). The long period in rice farming can also be interpreted as a condition where farmers have no choice but to earn a livelihood during the year. Various production factors contribute to farming, including land, seeds, fertilizers, pesticides, labor, and farm management. This study also combines these various production factors as inputs and rice production's output. Some can be substituted for what is necessary from various production factors. Fertilizers and pesticides can be substituted even with pesticides. If the condition of the plant is good, then pesticides can be ignored. Labor can be replaced by machines.

However, land and seeds are absolute factors of production that must exist. Seeds can be seen from two aspects: seeds in terms of seed quantification (kg) and seeds in terms of varieties. Meanwhile, land is a single variable with only one quantification: land area. The distribution of land area for rice farmers can be seen in Figure 5.

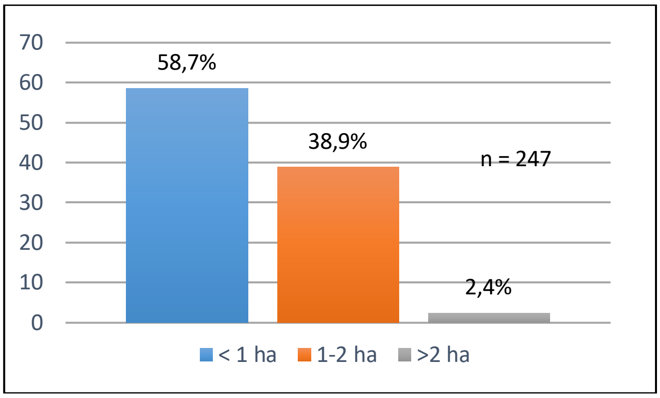

Fig. 5 Farmer by Land for Rice Farming

The study successfully found that land for rice farming is mostly under 1 ha (59%), while land above 2 ha is only controlled by 2.4% of farmers. This situation will undoubtedly affect the building of input-output modeling of rice farming. How these effects look will be discussed in another section of this paper. The description of the size of land owned by farmers clearly shows that, generally, rice farmers need large areas of land to continue their farms. This characteristic is typical of farmers in Indonesia. This study applies one unique variable in the modeling: farming management combined with other technical variables such as seeds, fertilizers, and others. Implementing management included in the input-output modeling clarifies how farmers manage rice production.

Figure 6 provides an overview of the relationship between land area and farmers' decision to apply cropping management. This study showed that those with more extensive landholdings will implement crop management. Farmers with a land area above 2 hectares all apply rice farm management. In contrast, farmers with less than 1 ha of land, proportionally, mostly do not use farm management (65.5%).

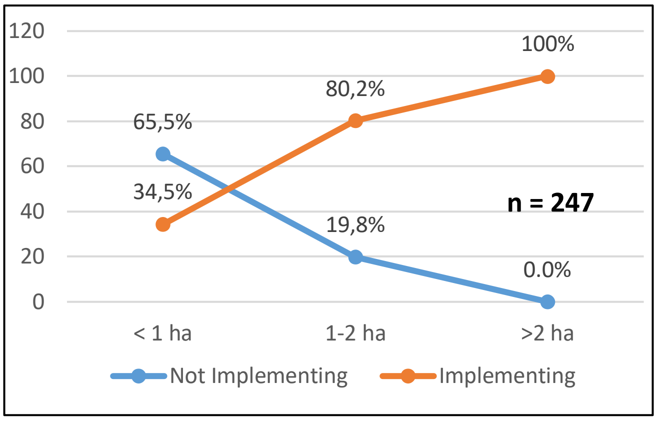

Fig. 6 Farmer by Land for Rice Farming and implementing Farmer Management

B. *Input-Output Modelling on Rice Farming*

As stated in the previous section, this study uses multiple regression analysis to construct the rice farming input-output model. Hence, this section will be conducted in three stages. First, the full results of the statistical analysis are presented, and second, the theoretical and practical legitimacy is interpreted. Practical legitimacy is based on in-depth interviews with rice farmers in the research location. Third, efforts should be made to legitimize the discussion associated with the conditions of other regions. This was done to explain the results of statistical calculations. Thus, the results derived from this research are expected to be used by other relevant stakeholders as input for farmers in making tactical decisions and as input for decision-making at the policy level. The next section is organized based on the three stages previously mentioned.

1) *Multiple regression equation of rice farming:*

The multiple regression equation used to discuss the input-output of rice farming is presented in Table 1.

TABLE I
REGRESSION COEFFICIENTS OF RICE FARMING, 2023

Model	Unstandardized Coefficients	
	B	Std. Error
Constant	222.126	64.494
Land (ha)	2834.494	230.943
Seeds (kg)	65.164	9.995
Fertilizer (kg)	0.541	.329
Pesticide (lt)	-0.630	17.236
Labor (Man-day)	0.123	7.634
Farming Management	758.749	66.733

Dependent Variable: Rice Production (kg)

The equation becomes:

$$Y = \alpha + \beta 1\ X1 + \beta 2\ X2 + \beta 3\ X3 + \beta 4\ X4 + \beta 5\ X5 + \beta 6\ X6 + \varepsilon \quad (2)$$

$$Y = 222.126 + 2834.494X1 + 65.164X2 + 0.541X3 - 0.630X4 + 0.123X5 + 758.749X6 + \varepsilon \quad (3)$$

The results of the multiple regression analysis summarized in Table 1 are described as follows:

- Constant Value (α): The average rice production is 222,126 kg if the inputs X1, X2, X3, X4, X5, and X6 do not increase (no change) or are equal to 0. In this context, the constant value (α) of 222,126 kg is the expected value of variable Y (rice production); if X1 to X6 is entirely equal to 0, then the constant value is only an intrinsic value or value that is not the actual value.

- Land Area (X1): The result of the regression coefficient of land area 2834.494 states that if the land area increases by 1 ha, the production will increase by 2834.494 kg.
- Seeds (X2): The regression coefficient of 65.164 states that if the seeds increase by 1 kg, rice production will be 65.164 kg.
- Fertilizer (X3): The regression coefficient of fertilizer 0.541 states that if fertilizer increases by 1 kg, rice production will increase by 0.541 kg.
- Pesticides (X4): The regression coefficient of pesticide -0.630 indicates that if the use of pesticide increases by 1 liter, the production will decrease by 0.630 kg.
- Labor (X5): The result of the regression coefficient of labor of 0.123 states that if there is an increase in labor by 1 Man-day, production will also increase by 0.123 kg.
- Farming Management (X6): The regression coefficient of farming management, 758.749, stated that if farming management activities are poorly implemented, production will increase by 758.749 kg.

2) F Test

The statistical F test aims to show whether all independent variables influence the dependent variable. The test requirement is that H0 is rejected or H1 is accepted if the significance value of F statistic < α = 0.05 is also proven if F statistic> F table. If the significance value of F statistic < α = 0.05 and if F statistic > F table, then the independent variables in this study affect the dependent variable. The results of the F test results can be seen in Table 2.

TABLE II
F TEST RESULTS OF RICE FARMING

Model	Sum of Squares	df	Mean Squares	F	Sig
Regression	2506076104.655	6	417679350.776	2488.547	.000[b]
Residual	40281756.883	240	167840.654		
Total	2546357861.538	246			

a. Dependent Variable: Rice Production
b. Predictors (Constant), Farming Management, Land (ha), Pesticide (lt), Labor (Man-day), Fertilizer (kg), Seeds (kg).

Based on the results of the F test calculation in Table 2, show the influence of the variables of land area (X1), seeds (X2), fertilizers (X3), pesticides (X4), labor (X5), and farming management (X6) on production (Y) with a value of F statistic 2488.547> F table 2.14 with a significance of 0.000 more minor than the significance level used in this study which is 0.05, the result is 0.000 <0.05 which indicates that all independent variables together (simultaneously) affect the dependent variable at the 95% level of confidence.

3) T-test

The T-test determines the effect of each (partial) independent variable on the dependent variable. The testing process is carried out by comparing the t statistic value with the t table or by looking at the probability comparison (sig < α). The basis for decision-making is:

- If the significance value <0.05 and T statistic > T table then H0 is rejected, H1 is accepted.
- If the significant value> 0.05 and T statistic < T table, then H0 is accepted H1, is rejected.

TABLE III
T-TEST CALCULATION ON RICE FARMING

Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
Constant	222.126	64.494		3.444	.001
Land (ha)	2834.494	230.943	.558	12.274	.000
Seeds (kg)	65.164	9.995	.312	6.520	.000
Fertilizer (kg)	0.541	.329	.070	1.642	.102
Pesticide (lt)	-0.630	17.236	.000	-0.037	.971
Labor (Man-day)	0.123	7.634	.000	.016	.987
Farming Management	758.749	66.733	.118	11.370	.000

a. Dependent Variable: Rice Production (kg)

Partial testing using the T-test in Table 3 shows that of the six variables tested partially on rice paddy production, two categories of input variables affect rice production. The two categories consisted of three variables that had a significant influence and three variables that did not have a significant influence. The three variables that have a significant effect partially on rice production are land, seeds, and farming management. Three variables that do not significantly affect rice production are fertilizers, pesticides, and labor.

The question that needs to be asked concerning the t-test results is how the actual conditions in the field when the research took place produced two categories of influence variables on rice farming production. This study found that the three variables that significantly and partially influenced rice farming production were land, seeds, and farm management. Farmers admit their land is spread out in various places, not concentrated in one area. A farmer may own land with a total area of 2 hectares, but the land area consists of several fields. Farmers also recognize that in addition to the distribution of land, the fertility level of each land area is not the same. This depends on the position of the land and the flow of irrigation water that irrigates their rice fields. Therefore, because it cannot be substituted and is necessary, it is very logical if the land partially significantly affects rice farming production.

Seed is different from land, which cannot be substituted. Seed substitution occurs at the variety level. Farmers can plant various paddy varieties that have the potential to have high quality, such as pest and disease resistance, and can produce optimal rice grains. Seeds and land are complementary inputs. This means that the use of rice seeds is highly dependent on the land area farmers own. The results showed that farmers rely on seeds they have recognized for a long time and do not readily change to other varieties of rice seeds. The problem in the field farmers face is that the seeds recommended by the government often need to match the arrival time with the planting season. This causes farmers to frequently use seeds they produce themselves even though they have not been tested.

In addition to land and seeds, crop management is the variable that partially has a significant effect on rice farming production. Research shows that crop management is carried out by those with the power to make decisions. Power in decision-making does not depend on the landowner alone but can also be seen in sharecroppers. In sharecropper relations, the decision to implement crop management is in the hands of the sharecropper, while the owner farmer passively waits for the distribution of results. The decision to implement good crop management is related to the farmer's experience. Crop management, such as the decision to use pest and disease-resistant or superior seeds, the decision to carry out maintenance, or the decision to use certain fertilizers, significantly affects rice farming production.

Fertilizers, pesticides, and labor are input variables that partially do not affect rice farming production. These three input variables have one thing in common: they can be substituted. Chemical fertilizers used by farmers can be substituted with organic fertilizers. Likewise, chemical pesticides can be replaced with natural pesticides or specific techniques such as crop rotation or other treatments, such as using light to overcome insect attacks. Meanwhile, labor variables can be replaced with different equipment to improve rice farming efficiency.

C. Review of Independent Variables in Rice Farming Input-Output Model

In the previous section, the input-output model of rice farming was analyzed through multiple regression analysis. The results show that each of the six independent variables has its characteristics, which is essential to note. This section will explore the role of each input based on the results of the multiple regression analysis. The input-output analysis, as presented in Table I, shows two groups of inputs based on the regression coefficients. The first group includes inputs with significant regression coefficients. The other group has very small coefficients (not up to 1), and even one variable shows a negative number. This can also be seen in the T-test, where three variables (land, seeds, and crop management) with significant coefficients partially influence rice farming production (Table III).

In the first input group, this study shows that the potential for rice production can still be increased. This can be done through the extensification of farming, namely the addition of land or the printing of new rice fields. The land is not just a means of agricultural production as an expanse; land for farmers can be collateral to obtain agrarian credit, which can be used to increase capital to finance their farms. Culturally, land is also a symbol of one's social status in the countryside. One's prominence is also largely determined by land ownership. Land is thus not merely an expanse where rice grows but can also function as credit collateral and a symbol of social status [39].

The problem farmers face in Indonesia concerning land is that land ownership is narrow and scattered in various places. Local farmers rarely have rice farming land that stretches widely in one stretch. Generally, the land needs to be more cohesive, resulting in efficient rice farming management. This differs from rice farming land owned by transmigrants who receive 2 hectares of land to manage. The land is centralized, making it easier for farmers to use equipment in rice farming.

In addition, technology is needed for seeds that provide optimal yields, are resistant to pests and diseases, and can adapt to climate change. However, it is equally essential to increase the capacity of farmers to manage their farms. The current farmers are older. They have experience but need to gain more knowledge of technology. The government must pay serious attention to these older farmers so that they can keep up with agricultural developments, including updated information on marketing, prices, and the quality of paddy desired by the market [24], [40].

The three variables with small regression coefficients, and some even minus, are fertilizers, pesticides, and labor. The results show that farmers are highly dependent on chemical fertilizers, which can cause soil fertility to decline over time. As a result, farmers will continue to increase the fertilizer used until production yields decline.

In addition to the chemical content of fertilizers that can cause soil damage, the availability of fertilizers in Indonesia is currently minimal. Farmers must register to become members of farmer groups and enter the need to buy subsidized fertilizers based on land area; fertilizers are also often late in reaching farmers. The scarcity of fertilizers means that farmers must purchase non-subsidized fertilizers, which are very expensive. The scarcity of fertilizers has caused the price of non-subsidized fertilizers to increase, and in some cases, this scarcity has contributed to the illegal trade in subsidized fertilizers.

IV. Conclusion

Research on input-output using multiple regression allows the combination of technical and non-technical variables as independent variables. The technical variables are land, seeds, fertilizers, pesticides, and labor. The non-technical variable in this research is farm management. This combination provides a new perspective on the input-output model of rice farming that can examine the contribution of each factor to rice production in Indonesia. From multiple regression analysis, the land, seeds, and farm management variables contribute significantly to rice production. In another articulation, this study succeeded in showing that these three inputs have the potential to be developed to achieve optimal production. This study benefits farmers by optimizing farm management variables and expanding land for optimal rice production. This analysis is also helpful for the government as a policy maker in developing a sustainable agricultural development design.

References

[1] N. Koch, “Food as a weapon? The geopolitics of food and the Qatar–Gulf rift,” *Security Dialogue*, vol. 52, no. 2, pp. 118–134, Jun. 2020, doi: 10.1177/0967010620912353.

[2] A. C. Corrales-Øverlid, “Food as a social weapon: Peruvian immigrant entrepreneurs claiming home, belonging, and distinction in Southern California,” *Ethnic and Racial Studies*, vol. 46, no. 15, pp. 3338–3359, Mar. 2023, doi: 10.1080/01419870.2023.2193244.

[3] K. Pawlak and M. Kołodziejczak, “The Role of Agriculture in Ensuring Food Security in Developing Countries: Considerations in

the Context of the Problem of Sustainable Food Production," *Sustainability*, vol. 12, no. 13, p. 5488, Jul. 2020, doi:10.3390/su12135488.

[4] B. Neimark, S. Osterhoudt, H. Alter, and A. Gradinar, "A new sustainability model for measuring changes in power and access in global commodity chains: through a smallholder lens," *Palgrave Communications*, vol. 5, no. 1, Jan. 2019, doi: 10.1057/s41599-018-0199-0.

[5] G. Soffiantini, "Food insecurity and political instability during the Arab Spring," *Global Food Security*, vol. 26, p. 100400, Sep. 2020, doi: 10.1016/j.gfs.2020.100400.

[6] J. M. L. Laforge, B. Dale, C. Z. Levkoe, and F. Ahmed, "The future of agroecology in Canada: Embracing the politics of food sovereignty," *Journal of Rural Studies*, vol. 81, pp. 194–202, Jan. 2021, doi:10.1016/j.jrurstud.2020.10.025.

[7] D. Tommasi, "Control of resources, bargaining power and the demand of food: Evidence from PROGRESA," *Journal of Economic Behavior & Organization*, vol. 161, pp. 265–286, May 2019, doi:10.1016/j.jebo.2019.04.008.

[8] B. Wood, O. Williams, V. Nagarajan, and G. Sacks, "Market strategies used by processed food manufacturers to increase and consolidate their power: a systematic review and document analysis," *Globalization and Health*, vol. 17, no. 1, Jan. 2021, doi: 10.1186/s12992-021-00667-7.

[9] Oscar Ingasia Ayuya, "Ethnicity, social connectedness, and the rural-urban food continuum: Food security among urban informal settlement dwellers in Kenya," *Heliyon*, vol. 10, no. 9, p. e30481, May 2024, doi:10.1016/j.heliyon.2024.e30481.

[10] H. Lu and A. Carter, "Social determinants of rural food security: Findings from Michigan's Upper Peninsula," *Journal of Rural Studies*, vol. 107, p. 103256, Apr. 2024, doi: 10.1016/j.jrurstud.2024.103256.

[11] R. H. Bates, "Governments and Agricultural Markets in Africa," *The Role of Markets in the World Food Economy*, pp. 153–183, Jul. 2019, doi: 10.1201/9780429314391-9.

[12] C. Henderson, "The power of food security," *Globalizations*, pp. 1–13, May 2022, doi: 10.1080/14747731.2022.2075616.

[13] K. Sohag, M. M. Islam, I. Tomas Žiković, and H. Mansour, "Food inflation and geopolitical risks: analyzing European regions amid the Russia-Ukraine war," *British Food Journal*, vol. 125, no. 7, pp. 2368–2391, Nov. 2022, doi: 10.1108/bfj-09-2022-0793.

[14] K. E. Giller et al., "The future of farming: Who will produce our food?," *Food Security*, vol. 13, no. 5, pp. 1073–1099, Sep. 2021, doi:10.1007/s12571-021-01184-6.

[15] M. Crippa, E. Solazzo, D. Guizzardi, F. Monforti-Ferrario, F. N. Tubiello, and A. Leip, "Food systems are responsible for a third of global anthropogenic GHG emissions," *Nature Food*, vol. 2, no. 3, pp. 198–209, Mar. 2021, doi: 10.1038/s43016-021-00225-9.

[16] A. S. Putra, G. Tong, and D. O. Pribadi, "Food Security Challenges in Rapidly Urbanizing Developing Countries: Insight from Indonesia," *Sustainability*, vol. 12, no. 22, p. 9550, Nov. 2020, doi:10.3390/su12229550.

[17] Sutardi et al., "The Transformation of Rice Crop Technology in Indonesia: Innovation and Sustainable Food Security," *Agronomy*, vol. 13, no. 1, p. 1, Dec. 2022, doi: 10.3390/agronomy13010001.

[18] Y. Zhu, M. Li, S. Lu, H. Wang, J. Wang, and W. Wang, "Research on the Input–Output Model of the Rural Agricultural Eco-Economic System Based on Emergy Theory," *Sustainability*, vol. 14, no. 7, p. 3717, Mar. 2022, doi: 10.3390/su14073717.

[19] A. Kazeem, "Economic efficiency of rice farming: a stochastic frontier analysis approach," *Journal of Agribusiness and Rural Development*, vol. 58, no. 4, pp. 423–435, Dec. 2020, doi:10.17306/j.jard.2020.01377.

[20] F. N. Muteti, I. Akite, T. P. Mpofu, and B. Mugonola, "Determinants of technical efficiency among smallholder upland rice farmers in northern Uganda—a Cobb–Douglas stochastic frontier approach," *SN Business & Economics*, vol. 4, no. 1, Dec. 2023, doi:10.1007/s43546-023-00597-z.

[21] Y. Tsujimoto, T. Rakotoson, A. Tanaka, and K. Saito, "Challenges and opportunities for improving N use efficiency for rice production in sub-Saharan Africa," *Plant Production Science*, vol. 22, no. 4, pp. 413–427, May 2019, doi: 10.1080/1343943x.2019.1617638.

[22] S. Fahad et al., "Major Constraints for Global Rice Production," *Advances in Rice Research for Abiotic Stress Tolerance*, pp. 1–22, 2019, doi: 10.1016/b978-0-12-814332-2.00001-0.

[23] H. A. Ba, Y. de Mey, S. Thoron, and M. Demont, "Inclusiveness of contract farming along the vertical coordination continuum: Evidence from the Vietnamese rice sector," *Land Use Policy*, vol. 87, p. 104050, Sep. 2019, doi: 10.1016/j.landusepol.2019.104050.

[24] M. Connor, A. H. de Guia, A. B. Pustika, Sudarmaji, M. Kobarsih, and J. Hellin, "Rice Farming in Central Java, Indonesia—Adoption of Sustainable Farming Practices, Impacts and Implications," *Agronomy*, vol. 11, no. 5, p. 881, Apr. 2021, doi: 10.3390/agronomy11050881.

[25] K. P. Devkota et al., "Economic and environmental indicators of sustainable rice cultivation: A comparison across intensive irrigated rice cropping systems in six Asian countries," *Ecological Indicators*, vol. 105, pp. 199–214, Oct. 2019, doi: 10.1016/j.ecolind.2019.05.029.

[26] B. Lakitan, "Research and technology development in Southeast Asian economies are drifting away from agriculture and farmers' needs," *Journal of Science and Technology Policy Management*, vol. 10, no. 1, pp. 251–272, Mar. 2019, doi: 10.1108/jstpm-11-2017-0061.

[27] U. A. Naher, M. N. Ahmed, M. I. U. Sarkar, J. C. Biswas, and Q. A. Panhwar, "Fertilizer Management Strategies for Sustainable Rice Production," *Organic Farming*, pp. 251–267, 2019, doi:10.1016/b978-0-12-813272-2.00009-4.

[28] H. Kanthilanka, T. Ramilan, R. J. Farquharson, and J. Weerahewa, "Optimal nitrogen fertilizer decisions for rice farming in a cascaded tank system in Sri Lanka: An analysis using an integrated crop, hydro-nutrient and economic model," *Agricultural Systems*, vol. 207, p. 103628, Apr. 2023, doi: 10.1016/j.agsy.2023.103628.

[29] M. A. Salam, M. N. I. Sarker, and S. Sharmin, "Do organic fertilizer impact on yield and efficiency of rice farms? Empirical evidence from Bangladesh," *Heliyon*, vol. 7, no. 8, p. e07731, Aug. 2021, doi:10.1016/j.heliyon.2021.e07731.

[30] V.-N. Hoang, T. T. Nguyen, C. Wilson, T. Q. Ho, and U. Khanal, "Scale and scope economies in small household rice farming in Vietnam," *Journal of Integrative Agriculture*, vol. 20, no. 12, pp. 3339–3351, Dec. 2021, doi: 10.1016/s2095-3119(21)63612-2.

[31] A. Rosyada, R. E. Putra, and W. Gunawan, "Dynamics of Competitiveness and Efficiency of Rice Farming in Java Island, Indonesia," *3BIO: Journal of Biological Science, Technology and Management*, vol. 4, no. 2, pp. 105–119, Nov. 2022, doi:10.5614/3bio.2022.4.2.5.

[32] M. H. Alamri, A. Rauf, and Y. Saleh, "Analisis Faktor-Faktor Produksi Terhadap Produksi Padi Sawah di Kecamatan Bintauna Kabupaten Bolaang Mongondow Utara," *AGRINESIA: Jurnal Ilmiah Agribisnis*, vol. 6, no. 3, pp. 240–249, Aug. 2022, doi:10.37046/agr.v6i3.16145.

[33] R. I. K. A. Mantiri, D. C. Rotinsulu, and S. Murni, "Analisis Faktor-Faktor Yang Mempengaruhi Produksi Padi Sawah di Kecamatan Dumoga," *Jurnal Pembangunan Ekonomi Dan Keuangan Daerah*, vol. 18, no. 1, Jul. 2019, doi: 10.35794/jpekd.10766.18.1.2016.

[34] A. Qadir et al., "Commercial rice seed production and distribution in Indonesia," *Heliyon*, vol. 10, no. 3, p. e25110, Feb. 2024, doi:10.1016/j.heliyon.2024.e25110.

[35] M. Ishfaq et al., "Alternate wetting and drying: A water-saving and ecofriendly rice production system," *Agricultural Water Management*, vol. 241, p. 106363, Nov. 2020, doi: 10.1016/j.agwat.2020.106363.

[36] Y. Ren, Y. Peng, B. Castro Campos, and H. Li, "The effect of contract farming on the environmentally sustainable production of rice in China," *Sustainable Production and Consumption*, vol. 28, pp. 1381–1395, Oct. 2021, doi: 10.1016/j.spc.2021.08.011.

[37] C. Li, "Climate change impacts on rice production in Japan: A Cobb-Douglas and panel data analysis," *Ecological Indicators*, vol. 147, p. 110008, Mar. 2023, doi: 10.1016/j.ecolind.2023.110008.

[38] Md. S. Islam, R. W. Bell, M. A. M. Miah, and M. J. Alam, "Determinants of farmers' fertilizer use gaps under rice-based cropping systems: Empirical evidence from Eastern Gangetic Plain," *Journal of Agriculture and Food Research*, vol. 17, p. 101228, Sep. 2024, doi: 10.1016/j.jafr.2024.101228.

[39] L. L. Delina, I. Fuerzas, W. Dharmiasih, M. J. Dulay, and A. Salamanca, "Are capital assets under pressure? The state of and challenges to indigenous rice farming in the cultural ricescapes of Indonesia and the Philippines," *Journal of Rural Studies*, vol. 106, p. 103235, Feb. 2024, doi: 10.1016/j.jrurstud.2024.103235.

[40] N. Khan, R. L. Ray, G. R. Sargani, M. Ihtisham, M. Khayyam, and S. Ismail, "Current Progress and Future Prospects of Agriculture Technology: Gateway to Sustainable Agriculture," *Sustainability*, vol. 13, no. 9, p. 4883, Apr. 2021, doi: 10.3390/su13094883.