Analysis of Factors Affecting Rice Farming in the Lower Bengawan Solo Basin, Bojonegoro Regency

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Abstract. The agricultural sector is still a priority in the development of the agricultural economy in Indonesia. Bojonegoro Regency has a priority in agricultural development through food commodities, especially rice plants and makes Bojonegoro Regency a food barn. This makes rice fields close to the Bengawan Solo River get irrigation from the Bengawan Solo River. The purpose of this study is to determine the influence of production factors on rice yield in the Bengawan Solo Downstream Watershed, Bojonegoro Regency. The sample used was 60 farmers who were purposive taken. The analysis method used uses the Cobb Douglas production function method. The production factors used are land, fertilizer and seeds. The study revealed that the model effectively explained the variation in rice production within the study area. Among the production factors analyzed, land was found to have the most significant influence on rice output. This finding indicates that larger cultivated areas tend to result in higher rice production. The results highlight the importance of optimizing land use and managing agricultural resources efficiently to enhance rice productivity in the downstream area of the Bengawan Solo watershed, Bojonegoro Regency.

1 Introduction

Rice is an important food commodity because it is a staple food for almost a part of the world's population and one of the sources of income for the Indonesian population[1]. Rice is still an interesting concern for many parties both in terms of production, consumption and distribution because rice has strategic value with all its dilemmas and problems. In addition, rice is one of the important food crops in food security and is one of the livelihoods for rural people in developing countries, especially in Asia [2]. The Indonesian government continues to develop food self-sufficiency by increasing food security, one of which is by increasing the productivity of rice plants on the land used [3]. The food security approach generally focuses on production that aims to increase food supply by increasing productivity. The characteristics of rice farming in Indonesia are scattered and small-scale locations with

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varying productivity and quality [4]. Food security can be improved with technical efficiency, especially in rice production center areas such as East Java [5].

One of the problems of rice in East Java Province is related to the production and use of production factors in rice farming. Farmers can still increase rice production by using efficient production factors to increase income. One of the studies to determine the influence of input on output is using Cobb Douglas production function analysis [6]. Reduced production inputs such as water availability and reduced nutrients will affect the productivity of rice plants, thereby reducing farmers' income [7]. In addition, the land cultivated for rice farming has an influence on rice productivity [8].

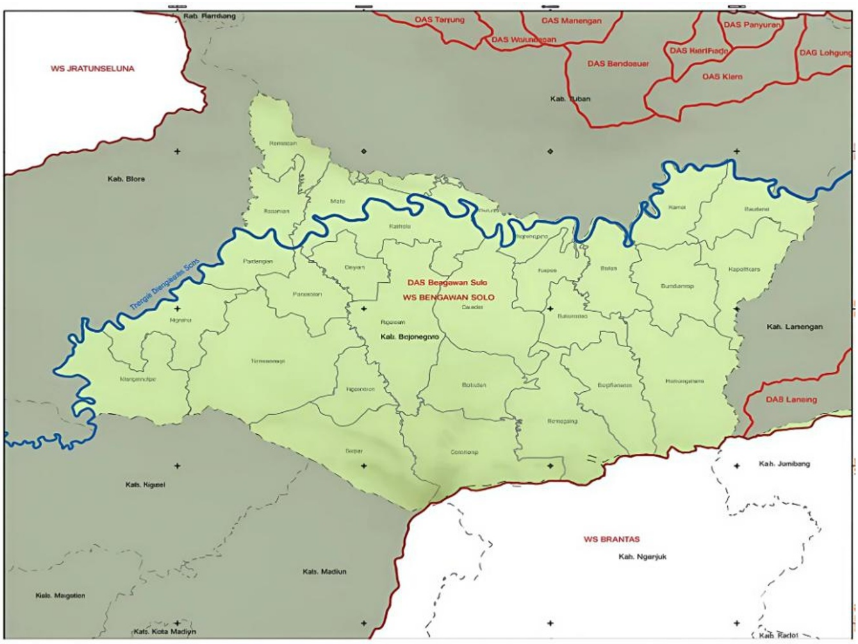

Fig. 1. Map of Bojonegoro Regency passed by the Bengawan Solo River

Bojonegoro Regency is located in the tropical region of East Java Province which only has two seasons, namely the dry season and the rainy season (Fig. 1). In the dry season, some areas in this region experience drought and water difficulties, while in the rainy season, some areas in this region experience flooding. This condition will affect the productivity of rice plants. This area is an area that is passed by the Bengawan Solo River as one of the important sources of irrigation for agriculture in this area. Some areas that are close to the flow of the Bengawan Solo River, for irrigation depend on the availability of water in the Bengawan Solo river. Weather and climate affect the water discharge of the Bengawan Solo River. In the rainy season, water discharge is abundant while in the dry season the water discharge decreases. In addition, environmental problems occur in the upstream part of the Hilir watershed caused by improper land cultivation, erosion and sedimentation resulting in siltation of the Bengawan Solo river. Fluctuating climate conditions and water availability due to seasonal changes, along with environmental issues in the Bengawan Solo watershed, may affect agricultural productivity, particularly rice cultivation. Therefore, it is important to understand the factors that influence rice production in this area. This study aims to analyze the effects of land, seed, and fertilizer production factors on rice farming output and the scale of production. This study aims to analyze the influence of production factors on rice farming in the Bengawan Solo Downstream Watershed.

2 Research method

This research was conducted purposively in Bojonegoro Regency considering that Bojonegoro is one of the third largest rice-producing after Lamongan and Ngawi.

2.1 Population and sampling

The population in this study consists of rice farmers in Bojonegoro Regency whose irrigation sources originate from the Bengawan Solo River. The sample was determined purposively, comprising 60 rice farmers representing areas with these characteristics.

2.2 Data measuring and collection

The data collected in this study consist of primary and secondary data. Secondary data were obtained from relevant references and institutional records related to the research topic, while primary data were collected through questionnaires distributed to respondents. The sampling method used was purposive sampling, because only 60 rice farmers met the specific criteria required in this study — namely, farmers whose rice fields are irrigated by the Bengawan Solo River and who are actively engaged in rice farming activities.

2.3 Variable and data analysis

2.3.1 Variables and data analysis

The data used in the analysis using the Cobb Douglas production function model, which is a production function that describes the technical relationship of converting inputs into outputs [9]. The production function of Cobb Douglas is formulated by:

$$Y = a\, x_1^{b1} x_2^{b2} x_3^{b3} e \tag{1}$$

$$Ln\, y = ln\, a + b1 ln x1 + b2\, ln\, x2 + b3\, ln\, x3 + e \tag{2}$$

Where, Y = rice production (kilograms per planting season); a = constant (intercept); b_1, b_2, b_3 = regression coefficients of each production factor; X_1 = land area (hectares); X_2 = seed quantity (kilograms); X_3 = urea fertilizer used (kilograms); e = error term.

The bound variable used is the variable of production output. The classical assumption test used is the normality test, the multicollinearity test and the heteroskedasticity test. The normality test is used to find out whether the data analyzed is normally distributed. The multicollinearity test is used to test whether the regression model finds a correlation between independent variables. The heteroskedasticity test is used to determine whether or not there is a deviation from the classical assumption, namely the existence of variance from the residual variance in an observation.

2.3.2 Business Scale of in the production process

The Cobb Douglas production function used can determine the scale of the business in the production process. By knowing the scale of the production business, farmers can find out whether their farming can continue or not. The scale of the production business is expressed by return to scale. Return to scale experienced the principle of increasing return to scale, constant return to scale and decreasing return to scale [10]. Decreasing return to scale, if $(b1 + b2) < 1$, means that the proportion of the addition of factors of production exceeds the proportion of the increase in production. Constant return to scale, if (b1 + b2) = 1, means that the proportion of the addition of the factor of production will be equal to the proportion of the increase in production. Increasing return to scale, if (b1 + b2) > 1, means that the proportion of additional production exceeds the proportion of additional factors of production.

3 Results and discussion

3.1 Cobb Douglas production function test

To test Cobb Douglas's production function is to convert this function into a natural logarithmic function. The natural logarithmic function refers to the multiple linear regression function that has a classical assumption test that must be met in order for the model to use multiple linear regression analysis. The normality test of this study can be found that the data used is spread normally. Based on the normality test, it can be explained in the following Fig. 2.

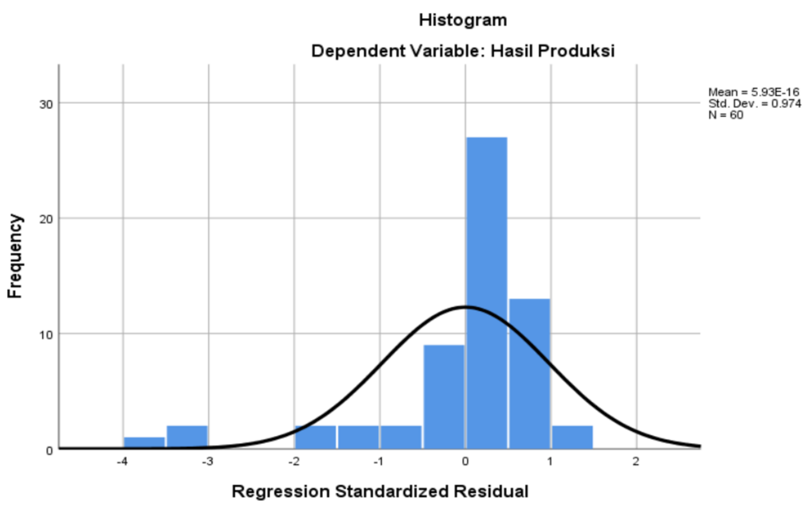

Fig. 2. Normality test

The multicollinearity test can be described in Table 1 below.

Table 1. Multicollinearity test

Parameter	Tolerance	Bright
Land	0.313	3.195
Seed	0.494	2.025
Urea fertilizer	0.353	2.819

Based on the results of the multicollinearity test presented in Table 1, it is known that the tolerance values for the variables Land, Seed, and Urea fertilizer are 0.313, 0.494, and 0.353, respectively, while their Variance Inflation Factor (VIF) values are 3.195, 2.025, and 2.819, respectively.

All tolerance values are greater than 0.10, and all VIF values are less than 10, indicating that there is no indication of multicollinearity among the independent variables in the regression model.

This result suggests that each independent variable, namely land, seed, and urea fertilizer has a relatively independent relationship and does not strongly influence one another.

Therefore, the Cobb-Douglas regression model employed in this study satisfies one of the classical assumptions of multiple linear regression, namely the absence of multicollinearity, implying that the estimated results obtained are stable and reliable for further analysis.

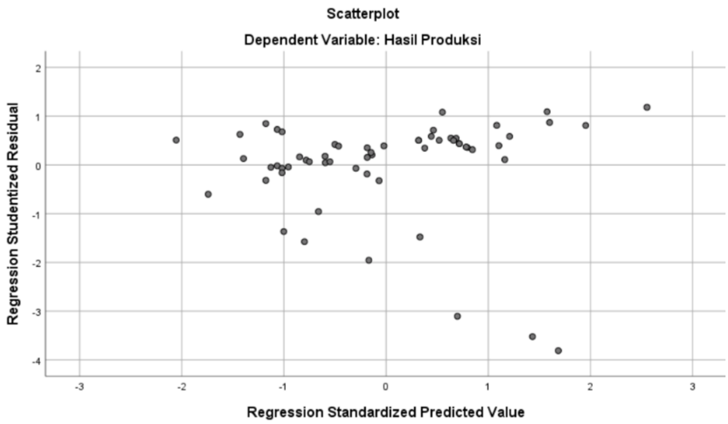

Fig. 3. Heteroscedasticity test

The heteroskedastic test shows no deviation in classical assumptions the interpretation regarding heteroscedasticity (non-constant variance) is based on the absence of a discernible pattern in the residual plot (Fig. 3). Visual inspection of the scatterplot, which compares the studentized residuals against the standardized predicted values, reveals no evidence of heteroscedasticity, which would constitute a violation of a core regression assumption. The distribution of the data points appears random and does not form any systematic pattern, such as a cone shape that would suggest a widening or narrowing of variance across the range of predicted values. Conversely, the residuals are relatively evenly scattered and remain within a consistent boundary of variability around the horizontal zero line. Therefore, it is concluded that this regression model does not suffer from Heteroscedasticity, implying that the error variance is constant and, consequently, the Ordinary Least Squares (OLS) regression estimates are considered both valid and efficient.

Table 2. Results of Cobb Douglas production function analysis

Parameter	Unstandardized (b)	Standard deviation (sb)	T-count	P value	
Consist	16155	93442	1.729	0.089	NS
Land	0.677	0.165	4.090	0.000	S
Seed	0.089	0.127	0.725	0.472	NS
Urea fertilizer	0.039	0.172	0.220	0.827	NS
F count	20.119				
R square	0.519				
Adjusted R square	0.493				
Durbin Watson	1.983				

The analysis results indicate that the R^2 value of 0.519 means the model can explain approximately 51.9% of the variation in rice production through the input variables of land, seeds, and fertilizer. The Durbin-Watson value of 1.983 shows no autocorrelation in the model, indicating that the model is valid. Based on the Cobb-Douglas equation, the land parameter of 0.677 indicates that a 1% increase in cultivated land will increase rice production by 0.677%, assuming seeds and fertilizer remain constant. The seed parameter of 0.089 means that a 1% increase in seed usage only increases production by 0.089%, while the fertilizer parameter of 0.039 shows a relatively small effect.

The calculated F-value of 20.119 is greater than table F-value of 2.78 at α = 0.05, indicating that land, seeds, and fertilizer inputs simultaneously have a significant effect on rice production. However, from the partial tests, only land has a significant effect, with t-count 4.090 > t-table 2.000 (α = 0.025). Seeds (t = 0.725) and fertilizer (t = 0.220) do not have a significant partial effect.

These findings are consistent with previous studies emphasizing the importance of land in determining rice productivity. Sari et, al, 2023 [11] stated that land area plays a dominant role because it determines the planting capacity of farmers, while Sari et.al, 2023 [11] showed that although inputs such as seeds and fertilizer are important, significant production increases are more determined by land availability. Moreover Probowati, 2025 [12] emphasized that land limitations are the main constraint on increasing rice production in river basin areas, while other inputs contribute only marginally. Gandarum, et.al, 2025 [13] added that optimal land management, including planting patterns and rotation, plays a crucial role in improving rice yields. Nur, et.al, 2024 [14] also found that in the downstream area of the Bengawan Solo watershed, land area is positively correlated with production, whereas seeds and fertilizer only provide minor additional effects if land area remains limited [15].

3.2 Return to scale

From Table 2, based on the calculation of the regression model coefficients, the total of the input coefficients (Land, Seed, and Urea fertilizer) is 0.805, which is less than one. This indicates that the production function operates under Decreasing Returns to Scale. In other words, a 1% increase in all input would result in only a 0.805% increase in output, implying that input expansion does not proportionally translate into output growth. This condition suggests that massive input additions are not effective in achieving proportional production increases. Therefore, strategies to enhance output should focus on input efficiency and optimal management, particularly land, which contributes most significantly to production.

4 Conclusion and recommendation

This study indicates that only land has a significant partial effect on rice production, while seeds and fertilizer do not have a significant impact. The return to scale value of less than 1 indicates decreasing returns to scale, meaning that proportional increases in inputs do not result in proportional increases in output. These findings highlight that optimizing the use and management of land is the key factor in increasing rice productivity, while seeds and fertilizer serve as supporting inputs.

References

1. L. Zhang, J. Song, X. Hua, X. Li, D. Ma, M. Ding, Smallholder Rice Farming Practices across Livelihood Strategies: A Case Study of the Poyang Lake Plain, China, Elsevier Ltd, J. Rural Stud. **89**, 199 (2022) https://doi.org/10.1016/j.jrurstud.2021.12.001.
2. T.T. Nguyen, M.H. Do, D. Rahut, Shock, Risk Attitude and Rice Farming: Evidence from Panel Data for Thailand, Elsevier B.V., Environ. Challenges **6**, 100430 (2022) https://doi.org/10.1016/j.envc.2021.100430.
3. M. Hatta, Sulakhudin, R. Burhansyah, G.C. Kifli, D.O. Dewi, J.C. Kilmanun, D. Permana, K. Supriadi, R. Warman, H. Azis, P.T. Santari, D.P. Widiastuti, Food Self-Sufficiency: Managing the Newly-Opened Tidal Paddy Fields for Rice Farming in Indonesia (A Case Study in West Kalimantan, Indonesia), Elsevier Ltd, Heliyon **9**,

e13839 (2023) https://doi.org/10.1016/j.heliyon.2023.e13839.

4. P.A.W. Putro, E.K. Purwaningsih, D.I. Sensuse, R.R. Suryono, Kautsarina, Model and Implementation of Rice Supply Chain Management: A Literature Review, Elsevier B.V., Procedia Comput. Sci. **197**, 453 (2021) https://doi.org/10.1016/j.procs.2021.12.161.
5. R. Hakim, T. Haryanto, D.W. Sari, Technical Efficiency among Agricultural Households and Determinants of Food Security in East Java, Indonesia, Nature Publishing Group UK, Sci. Rep. **11**, 1 (2021) https://doi.org/10.1038/s41598-021-83670-7.
6. T. Saepudin, A. Amalia, Analysis of Rice Production Approach To Cobb Douglas Production Function in Tambakdahan Sub-District Subang District, Agric. Soc. Econ. J. **22**, 121 (2022) https://doi.org/10.21776/ub.agrise.2022.022.2.6.
7. M.A. van Aalst, E. Koomen, D.D. Tran, H.M. Hoang, H.Q. Nguyen, H.L.F. de Groot, The Economic Sustainability of Rice Farming and Its Influence on Farmer Decision-Making in the Upper Mekong Delta, Vietnam, Elsevier B.V., Agric. Water Manag. **276**, 108018 (2023) https://doi.org/10.1016/j.agwat.2022.108018.
8. K.H. Koirala, A. Mishra, S. Mohanty, Impact of Land Ownership on Productivity and Efficiency of Rice Farmers: The Case of the Philippines, Elsevier Ltd, Land Use Policy **50**, 371 (2016) https://doi.org/10.1016/j.landusepol.2015.10.001.
9. D.L. Debertin, Agricultural Production Economics Second Edition, *Agricultural Production Economics Second Edition* (2012).
10. A. Shinta, Ilmu Usaha Tani, *Ilmu Usaha Tani* (2011).
11. M.N. Sary, D. Rahmawati, Respons Pertumbuhan Dan Produksi Benih Padi (Oryza Sativa L.) Varietas Inpari 32 Sawah Terhadap Pemberian Pupuk Granul, Agropross Natl. Conf. Proc. Agric. 497 (2023) https://doi.org/10.25047/agropross.2023.506.
12. D.D. Probowati, F. Pertanian, P. Agribisnis, U. Bojonegoro, A. Kampus, J. Lettu, K. Kapas, Analisis Pendapatan Dan Produksi Usahatani Padi Pada Lahan Irigasi DAS Hilir Bengawan Solo Di Kabupaten Bojonegoro Ketersediaan Pangan (Colman & Young , 2010). Sektor Pertanian Memiliki Peranan Penting Termasuk Di Propinsi Jawa Timur (Ajiwasesa , 2023 , (2025).
13. L. Gandharum, D.M. Hartono, H. Sadmono, H. Sanjaya, L. Sumargana, A.D. Kusumawardhani, F. Alhasanah, D.B. Sencaki, N. Setyaningrum, Advancing Land Use Modeling with Rice Cropping Intensity: A Geospatial Study on the Shrinking Paddy Fields in Indonesia, Geographies **5**, 1 (2025) https://doi.org/10.3390/geographies5030031.
14. N. Nur, E. Yusuf, A. Gunanto, Harga, Pertumbuhan Dan, Beras Penduduk, Jumlah Terhadap Ketersediaan Beras Indonesia, **13**, 67 (2024).
15. M. Siddique, M. Sarkar, M.C. Rahman, A. Chowdhury, M. Rahaman, L. Deb, Rice Farmers' Technical Efficiency under Abiotic Stresses in Bangladesh, Asian J. Agric. Rural Dev. **7**, 219 (2017) https://doi.org/10.18488/journal.1005/2017.7.11/1005.11.219.232.