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FACTORS AFFECTING RICE PRODUCTION IN INDONESIA

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ABSTRACT

This study aims to analyze the factors influencing rice production in Indonesia, using secondary data from the Central Statistics Agency (BPS) and the Ministry of Agriculture for the period 2018-2024, covering 30 provinces in Indonesia. The regression model used is the Random Effect Model (REM). The results show that the variables of labor and harvested area have a significant positive effect on rice production, with a very small p-value (p<0.01), indicating that increasing labor and expanding harvested area contribute directly to increasing rice production. In addition, people's business credit shows a positive effect although it is not significant at the 5% level (p=0.139). The variables of fertilizer and staple seeds show a negative effect and are close to being significant at the 10% level, while pump irrigation does not show a significant effect on rice production. This study concludes that factors such as labor and harvested area have a significant impact on increasing rice production, while other factors, such as the use of fertilizer and seeds, show a smaller effect.
Keywords: Rice Production, Labor, People's Business Credit, Harvested Area, Agriculture

ABSTRAK

Penelitian ini bertujuan untuk menganalisis faktor-faktor yang memengaruhi produksi padi di Indonesia, dengan menggunakan data sekunder dari Badan Pusat Statistik (BPS) dan Kementerian Pertanian selama periode 2018-2024, yang mencakup 30 provinsi di Indonesia. Model regresi yang digunakan adalah Random Effect Model (REM). Hasil penelitian menunjukkan bahwa variabel tenaga kerja dan luas panen memiliki pengaruh positif yang signifikan terhadap produksi padi, dengan p-value yang sangat kecil (p<0.01), yang menunjukkan bahwa peningkatan tenaga kerja dan perluasan luas panen berkontribusi langsung terhadap peningkatan produksi padi. Selain itu, kredit usaha rakyat menunjukkan pengaruh positif meskipun tidak signifikan pada tingkat 5% (p=0.139). Variabel pupuk dan benih pokok menunjukkan pengaruh negatif dan mendekati signifikan pada tingkat 10%, sementara irigasi pompa tidak menunjukkan pengaruh signifikan terhadap produksi padi. Penelitian ini menyimpulkan bahwa faktor-faktor seperti tenaga kerja dan luas panen memiliki dampak besar terhadap peningkatan produksi padi, sementara faktor lainnya, seperti penggunaan pupuk dan benih, menunjukkan pengaruh yang lebih kecil.
Kata Kunci: Produksi Padi, Tenaga Kerja, Kredit Usaha Rakyat, Luas Panen, Pertanian

INTRODUCTION

Agriculture plays a major role in national economic development as it embodies the application of human thought and labor (Bakhri, 2020). Among various subsectors, rice holds a strategic position because it is directly linked to national food security. The public's dependence on rice makes rice production a key indicator of food price stability and purchasing power, particularly for vulnerable groups. Agricultural production is a crucial element in economic development, especially in developing countries like Indonesia.

As an agricultural country, Indonesia's agricultural sector contributes significantly to the economy, food security, and employment, particularly in rural areas (Amirotunnasikha, 2023). The agricultural industry plays a role as a food provider, a supplier of industrial raw materials, a source of commercial opportunities, and a source of farmer income (Sari & Trisniarti., 2023). Provinces such as East Java, Central Java, and South Sulawesi are known as major rice producers, while East Nusa Tenggara and Papua still face productivity constraints due to limitations in technology, infrastructure, and policies (Alamri et al., 2022).

Production variations between provinces are also evident in data from the Central Statistics Agency (BPS, 2024), which shows East Java as the highest producer, followed by Central Java and West Java, while West Papua and Highland Papua have the lowest production

due to limited land, geography, and infrastructure. In general, Java Island is the center of rice production due to the support of large land areas, agricultural technology, and better irrigation systems (Auliya et al., 2024).

A provincial-level approach is used to describe production conditions contextually, considering that geographic, socioeconomic, and infrastructure differences cause production variations between regions (Jannah et al., 2020), This inequality indicates that regions with good irrigation and policies have higher yields than regions with limited access to technology. (Ali et al., 2024).

Production fluctuations are also influenced by external factors such as climate change, seasons, and natural disasters (Auliya et al., 2024). Micro factors such as labor, fertilizer, seeds, and irrigation are also affected. Analysis of these factors is crucial for achieving stable production, considering that high production does not necessarily reflect farmer welfare (Wicaksana, 2023).

Labor is a crucial factor in rice production because Indonesia's agricultural sector remains labor-dependent, particularly in rural areas. Skills in implementing efficient agricultural technologies can increase production yields (Jannah et al., 2020). A trained workforce adopts technology more quickly, thereby increasing productivity (Muller et al., 2018). However, the uneven distribution of labor quality across provinces and the reduction in labor due to urbanization pose challenges for the agricultural sector (Ali et al., 2024).

In addition to labor, access to financing through People's Business Credit (KUR) plays an important role in increasing production by providing capital for the purchase of tools, superior seeds, and fertilizers, as well as supporting production activities and technology investment. (Stratulat, 2022). However, the uneven distribution of KUR between provinces is an obstacle for farmers in several areas (Burhansyah, 2021).

Harvested area affects productivity because larger land areas increase the potential yield, although land conversion is a constraint. However, efficient land management can still increase production even if harvested area is limited (Reavindo et al., 2016).

Efficient use of fertilizers, particularly urea, increases crop fertility and productivity, although distribution and affordability remain challenges (Juliyanti et al., 2021). Furthermore, superior seeds play a crucial role in increasing production due to their yield potential and resilience, making selecting the right variety key to rice productivity.

Rice production is highly dependent on water availability, so irrigation development has strong economic significance. Rehabilitation of irrigation networks has been shown to increase total rice productivity and input efficiency (Ahmadian et al., 2021). A good irrigation system, including pumped irrigation in water-scarce areas, can increase productivity by ensuring a stable water supply (Novizal & Juliansyah, 2022; Puspitasari, 2021).

Rice production is important to study because it reflects the effectiveness of agricultural resource use and plays a role in meeting national food needs (Loban, 2023). Rice is a key commodity that impacts Indonesia's economy and food security. Increased production contributes to price stability, reduced rice imports, and improved farmer welfare (Rahim et al., 2024; Razi & Wahyuni, 2022).

Much research has been conducted on rice production. Budiyanti, (2025) found a negative relationship between harvested area and production in Banten Province for the period 2015–2024. Syawaludin & Alfiyani (2025) shows that harvested area does not always have a significant effect without interaction with productivity. Anugrah et al., (2024) found that land area, fertilizer, pesticides, and irrigation significantly influenced lowland rice productivity, while seeds and labor were insignificant. Laim & Simamora (2022) showed that land area and labor had a significant influence, while other factors contributed less. In contrast, Alio et al., (2025) found a strong linear relationship between harvested area and production in Gorontalo Regency.

This study uses panel data from 30 provinces in Indonesia for the period 2018–2024 to analyze spatial and temporal differences in factors influencing rice production. This approach allows for a more comprehensive analysis because it captures variation across time and between provinces.

The research's novelty lies in the use of panel data to analyze interactions between variables and differences in rice production in greater detail, thus hopefully resulting in more targeted and data-driven policies. This research also complements previous studies, which generally focused on only one or two variables, by simultaneously integrating labor, KUR (People's Business Credit), harvested area, fertilizer, seeds, and irrigation.

Although these various factors have been studied, research gaps remain due to the limited analysis of interactions between production factors in the context of interprovincial differences and the limited availability of comprehensive and representative data. Therefore, this study uses cross-provincial panel data to provide a more accurate picture of production variations based on local characteristics.

Based on this, this study aims to analyze the influence of labor, People's Business Credit (KUR), harvested area, fertilizer, seeds, and irrigation on rice production in order to identify the contribution of each variable and formulate strategies to increase the effectiveness of sustainable agricultural sector management.

LITERATURE REVIEW

Production Theory

Production is an economic activity that creates goods and/or services and increases the utility *of* economic goods so that they are beneficial for current and future needs (Letwich., 1994 ; Arsi *et al*., 2023). In an economic perspective, production is understood as the process of creating added value through combining various inputs to produce outputs that are beneficial to society Modjo *et al*., (2025). In rice farming, production is influenced by the use of production factors such as land, labor, seeds, fertilizers, technology, and biophysical and climatic conditions (Aditya *et al*., 2021). Its success is determined by the availability of production factors and efficient input management (Seran *et al*., 2024), which in the production function is reflected as a combination of capital, labor, natural resources, and technology in producing output (Amalia & Arif, 2025) .

Agriculture

Agriculture comes from the Latin words *ager* (land) and *colere* (to cultivate), which conceptually encompasses the activities of managing natural resources to meet the needs of life (Sari & Trisniarti, 2023). In practice, agriculture is not only limited to cultivation activities, but also includes land management, production environment management, and post-harvest activities (Yuriansyah *et al*., 2020). Agricultural activities include various subsectors such as food crops, horticulture, plantations, and fisheries (BPS East Java, 2021).

Labor

Labor is the primary production factor determining the capacity and efficiency of rice farming. Its productivity is influenced by the division of labor, specialization, and marginal productivity, and it plays a role not only as physical labor but also as a manager and decision-maker in the production process. (Juliyanti et al., 2021; Anugrah et al., 2024). In rice farming, labor includes activities from land preparation to harvest.

People's Business Credit in the Agricultural Sector

The People's Business Credit (KUR) for the agricultural sector is a financing program designed to increase farmers' access to capital through a low-interest scheme, supporting input purchases, technology adoption, and investment in agricultural businesses, thus potentially increasing productivity (Burhansyah, 2021; Nurdin et al., 2025). However, its effectiveness is still hampered by low financial literacy, lack of mentoring, and procedural obstacles, requiring policy support and mentoring for optimal utilization (Wahyuni et al., 2020; Dwiyanto & Lestari, 2023).

Harvested Area

Harvested area is the area of food crops that can be harvested in a certain period and is an important production factor in determining the level of rice production (Wicaksana, 2023). The larger the harvested area, the greater the potential production, because rice production is calculated based on the multiplication of harvested area and productivity. Although significant, an increase in harvested area is not always followed by an increase in production because it is influenced by agroclimatic conditions, varieties, and cultivation management. Therefore, increased production also depends on the efficiency of land management and agricultural intensification (Rahim et *al*., 2024).

Fertilizer

Fertilizer is a strategic production input in agriculture that plays a crucial role in increasing productivity and yields, particularly in rice farming (Wicaksana, 2023). Economically, efficient fertilizer use increases yields, while inappropriate use reduces efficiency and damages the soil. Therefore, fertilizer subsidy policies are crucial to ensure availability and affordability, but their effectiveness depends on distribution, literacy, and technical assistance to farmers (Anugrah *et al*., 2024).

Seed

Superior seeds are a crucial production input for rice farming productivity and sustainability due to their high yield potential, resistance to pests and diseases, and adaptability

to specific environmental conditions (Purba *et al* ., 2022). In production theory, seed quality plays a key role in increasing the efficiency of other inputs, such as fertilizer, water, and labor (Milkiades *et al*., 2021). However, seed distribution and utilization are still hampered by access, logistics, and low farmer literacy. Therefore, strengthening the certified seed system, developing the local seed industry, and providing technical assistance are essential for equitable and sustainable productivity increases.

Irrigation

Pumped irrigation is a crucial input in rice production, particularly in water-scarce areas, as it increases the efficiency of other inputs such as fertilizer and seeds (Novizal & Juliansyah, 2022). This system provides water through pumping, thus supporting plant growth during critical phases (Puspitasari, 2021). However, its effectiveness is still hampered by infrastructure, operational costs, and management, necessitating integrated policies through technical assistance, institutional strengthening, and financial support to sustainably increase rice production (Syahid *et al*., 2022).

RESEARCH METHODS

Types of research

This study uses a quantitative approach with panel data to analyze the influence of labor, agricultural People's Business Credit (KUR), harvested area, urea fertilizer, seeds, and irrigation on rice production in Indonesia. The data used are secondary annual provincial-level data for the 2018–2024 period sourced from the Central Statistics Agency (BPS) and the Ministry of Agriculture. The analysis was conducted using panel data regression with the assistance of Stata 17 software.

Operational Definition of Variables

The dependent variable is rice production measured in tons per hectare. The independent variables include: (1) agricultural labor (people), (2) agricultural People's Business Credit (million rupiah), (3) rice harvested area (hectares), (4) distribution of subsidized urea fertilizer (tons), (5) rice seeds (tons), and (6) pumping irrigation (units). All variables are measured annually at the provincial level.

Data Analysis Techniques

The estimation model used is panel data regression with two approaches: the Fixed Effects Model (FEM) and the Random Effects Model (REM). The best model was selected using the Hausman test. To ensure model validity, classical assumption tests were conducted, including tests for normality, multicollinearity, heteroscedasticity, and autocorrelation. Hypothesis testing was performed using the t-test for partial effects and the F-test for simultaneous effects, with a significance level of 5%.

RESULTS AND DISCUSSION

Research result

Table 1. Hausman Test

Chi2 (6)	4.92
prob>chi2	0.5545

Source: Stata 17, processed

Based on the test results, a chi-square value of 4.92 was obtained with a probability of 0.5545. This probability value is greater than the 5 percent significance level ($\alpha = 0.05$), so H_0 is not rejected. These results indicate that there is no significant difference in coefficients between the Fixed Effect and Random Effect models.

Table 2. Normality Test

Variables	Obs	Pr (skewness)	Pr (kurtosis)	Adj chi2(2)	Prob > chi2
healthy	175	0.0000	0.0815	25.14	0.0000

Source: Stata 17, processed

Based on the test results, the Prob value was obtained > chi-square of 0.0000 in the joint test. This probability value is less than the 5 percent significance level ($\alpha = 0.05$), so H_0 is rejected. These results indicate that the residuals in the model are not normally distributed.

Table 3. Multicollinearity Test

Variable	VIF	1/VIF
Thousands of fertilizers	14.20	0.070441
Harvest area	8.21	0.121819
Thousands of tree seeds	7.62	0.131313
Ln Labor	2.52	0.397172
Ln kur	1.32	0.756824
Pump irrigation	1.24	0.805142

Mean VIF	5.85

Source: Stata 17, processed

Based on the test results, most variables have a VIF value below 10. The fertilizer_thousands variable has a VIF value of 14.20, while the harvested area_ha and bp_thousands have VIF values of 8.21 and 7.62, respectively. The mean VIF value of 5.85 indicates that in general the level of multicollinearity in the model is still within tolerable limits. Thus, it can be concluded that there is no multicollinearity problem.

Table 4. Heteroscedasticity Test

chi2(1)	19.10
Prob > chi2	0.0000

Source: Stata 17, processed

Based on the test results, a chi-square value of 19.10 was obtained with a probability of 0.0000. This probability value is smaller than the 5 percent significance level (α = 0.05), so H_0 is rejected. These results indicate a heteroscedasticity problem in the regression model, which means the error variance is not constant.

Table 5. Autocorrelation Test

F (1, 28)	936,922
Prob>F	0.0000

Source: Stata 17, processed

Based on the test results, the F-statistic value was obtained at 936.922 with a probability of 0.0000. This probability value is smaller than the 5 percent significance level (α = 0.05), so H_0 is rejected. These results indicate that there is first-order autocorrelation in the panel data model. Thus, the assumption of no autocorrelation in the regression model is not met. To address this problem, this study uses a robust estimation approach to autocorrelation, so that the coefficient estimation results remain consistent and can be interpreted validly.

Table 6. Robust Test Standard Error

Production Dependent Variable	BRAKE
Ln Labor	0.5107 *** (0.186)
Ln KUR	0.0323 (0.021)
Harvested area_ha	0.0269 *** (0.006)
Thousands of fertilizers	-0.0109 * (0.005)
Thousands of seeds	-0.0485 * (0.026)
Pump irrigation	-0.0000157 (0.0000454)
_cons	6.5552 *** (2,369)
R-squared	0.8186
N	175
* p<0.10, ** p<0.05, *** p<0.001	

Source: Stata 17, processed

The test results indicate the presence of heteroscedasticity and first-order autocorrelation in the model, resulting in inefficient initial standard errors. To address this, this study uses a Random Effects model with cluster robust standard error correction at the provincial level to increase the reliability of the estimates. The estimation results show that labor and harvested area have a positive and significant effect on rice production, while agricultural KUR, fertilizer, seeds, and pumped irrigation have no significant effect at the 5 percent level after correction. This approach is considered appropriate because it is able to produce consistent and valid estimates in analyzing factors that influence rice production.

Table 7. (Partial)

Variables	Coefficient	Std. Error	z	Prob > z
lntk	0.5107244	0.1862515	2.74	0.006***
Incursion	0.0323564	0.0218433	1.48	0.139
harvested_area_ha	0.0269913	0.0065812	4.10	0.000***
thousands of fertilizers	-0.0100364	0.0055850	-1.86	0.063*
bp_thousands	-0.0485666	0.0263716	-1.84	0.066*
irrigation pump	-0.0000157	0.0000454	-0.35	0.729
Constants (_cons)	6.555276	2.369862	2.77	0.006***

Source: Stata 17, processed

The t-test with a significance level of 5 percent shows that partially the labor (lntk) and harvested area (uaspanen_ha) variables have a positive and significant effect on rice production.

Labor is significant at the 1 percent level (t = 2.74; p-value = 0.006), while harvested area is also very significant at the 1 percent level (t = 4.10; p-value = 0.000), which indicates that increasing the number of labor and expanding the harvested area can increase rice production.

Meanwhile, People's Business Credit (LKUR) did not have a significant effect at the 5 percent level despite having a positive coefficient (p-value = 0.139). The fertilizer and seed variables showed a negative effect and only approached significance at the 10 percent level (each p-value = 0.063). The pump irrigation variable did not have a significant effect on rice production (p-value = 0.729). The model constant was significant at the 1 percent level, indicating the presence of other factors outside the research variables that also influence rice production.

Discussion

Agricultural Labor Influential on Rice Agricultural Production in Indonesia

Based on the results of panel data regression estimation using a Random Effect Model with cluster robust standard error correction, agricultural labor is proven to have a positive and significant effect on rice production in Indonesia. The labor coefficient of 0.5107, significant at the 1 percent level, indicates that a 1 percent increase in agricultural labor will increase rice production by approximately 0.51 percent, assuming other variables in the model remain constant. This finding provides strong empirical evidence that labor is a production factor that plays a strategic role in determining rice production levels in Indonesia.

The results of this study align with production theory, which states that output is a function of the combination of various production inputs, particularly labor as the primary input in the process of creating added value. Letwich (1994) emphasized that production is the process of utilizing production factors to produce goods and services that have utility. In the context of rice farming, labor is directly involved in all stages of the farming process, from land preparation, planting, plant maintenance, to harvesting. Therefore, increasing the labor force directly increases production capacity.

These empirical findings also reinforce the concept of the production function as formulated by Walter Nicholson and developed by Mankiw & Wilson (2012), which states that labor, along with capital and land, is the primary factor of production in determining output. The relatively high labor elasticity coefficient indicates that small changes in labor supply can result in significant changes in output. Thus, labor remains a crucial determinant of increasing rice production, particularly in agricultural systems that have not yet been fully embraced by mechanization and modern technology.

From an agricultural theory perspective, this study confirms that human resources continue to play a central role in national agricultural development. According to Sari & Trisniarti (2023), states that agriculture is an economic activity that relies heavily on human ability to manage natural resources. Rice production in Indonesia is determined not only by the availability of land and production facilities, but also by the ability of the workforce to manage farms effectively and efficiently. This aligns with the Ministry of Agriculture's (2022) view that places farmers as the primary actors in agricultural development.

In the context of labor theory, the results of this study are consistent with Adam Smith's view of the importance of the division of labor and specialization in increasing productivity. Agricultural labor contributes not only physical strength but also skills, experience, and managerial abilities in organizing production. Juliyanti et al., (2021; Anugrah et al., (2024), emphasize that farmers play a role as leaders in agricultural businesses, determining production success through decision-making regarding input use. Therefore, creasing the agricultural labor force will have a direct impact on output as long as the labor is used productively.

Empirically, the results of this study align with previous research showing that labor has a significant influence on agricultural production. Beattie & Taylor (1994) stated that production levels are highly dependent on farmers' decisions regarding input use, including labor. (Hafsah *et al.*, 2020) also emphasized that labor is a primary production factor in agriculture, along with land and capital. The consistency between the results of this study and previous research indicates that the influence of labor on rice production is stable and relevant across various regional contexts in Indonesia.

Thus, based on the empirical analysis, production theory, agricultural theory, and previous research, it can be concluded that agricultural labor has a positive and significant impact on rice production in Indonesia. This finding indicates that efforts to increase national rice production still rely heavily on strengthening the role of agricultural labor, both through

increasing the quantity and quality of human resources, while still considering the heterogeneity of characteristics between provinces in Indonesia's rice production system.

People's Business Credit (KUR) for Agriculture Influential on Rice Agricultural Production in Indonesia

Based on the results of panel data regression estimation using a Random Effect Model with cluster robust standard error correction, the People's Business Credit (KUR) for agriculture variable has a positive coefficient of 0.0323, but is not statistically significant at the 5 percent level of significance. This finding indicates that the increase in KUR distribution in aggregate has not been able to provide a significant impact on increasing rice production in Indonesia. Although the direction of the KUR relationship shows a positive correlation with production, the magnitude of the effect is relatively small and not statistically strong enough to conclude a direct effect on rice output.

Within the framework of production theory, capital is a key factor of production that plays a role in increasing the capacity and efficiency of the production process. The production function formulated by Nicholson and developed by Mankiw & Wilson (2012) positions capital (K) as an input that should drive increased output if used productively. In the context of rice farming, capital through the Smallholder Business Credit (KUR) is expected to increase farmers' ability to purchase quality production inputs, such as superior seeds, fertilizers, and agricultural technology, ultimately increasing productivity. However, the empirical results of this study indicate that this mechanism has not been functioning optimally.

These findings indicate a gap between the normative objectives of the KUR as a productive financing instrument and its actual utilization at the farmer level. As noted by Nurdin et al. (2025) and Hafsah et al., (2020) the effectiveness of KUR is highly dependent on farmers' ability to manage credit appropriately and productively. If credit is used for non-productive needs, household consumption, or simply to cover short-term operational costs without increasing production capacity, its impact on agricultural output will be limited. This condition aligns with the findings of Wahyuni et al. (2020) who stated that the lack of financial literacy and technical assistance are the main obstacles to optimizing KUR utilization in the agricultural sector.

Furthermore, the insignificant impact of the Smallholder Business Credit (KUR) on rice production can also be explained by the structural characteristics of Indonesia's agricultural sector, which is dominated by smallholder farmers. The relatively small scale of farming means that additional capital from KUR is insufficient to generate a significant surge in production, especially if it is not accompanied by land expansion or the adoption of more efficient technologies. Dwiyanto & Lestari (2023) emphasize that agricultural credit will have a greater impact on productivity if accompanied by increased farmer managerial capacity and adequate institutional support.

Thus, the results of this study indicate that the People's Business Credit (KUR) for agriculture has not had a significant direct impact on rice production in Indonesia. This finding does not deny the importance of KUR as an agricultural financing instrument, but rather emphasizes that KUR's effectiveness is largely determined by the quality of its utilization. Therefore, for KUR to significantly contribute to increased rice production, supporting policies are needed in the form of technical assistance, improved farmer financial literacy, and integration of financing with other agricultural productivity improvement programs.

Harvested Area Affects Rice Agricultural Production in Indonesia

Based on the results of panel data regression estimation using a Random Effect Model with cluster robust standard error correction, the harvested area variable is proven to have a positive and highly significant effect on rice agricultural production in Indonesia. The harvested area coefficient of 0.0269 and significant at the 1 percent level indicates that every additional hectare of harvested area will increase rice production by approximately 2.7 percent, assuming other variables in the model remain constant. This finding indicates that harvested area is one of the main determinants in the formation of national rice output, while also emphasizing the role of land as a strategic production factor in the agricultural sector.

These empirical results align with production theory, which states that output is a function of the combination of various production inputs, with land or natural resources central to the agricultural production process. Within the production function framework of Mankiw & Wilson (2012), land is positioned as a primary factor of production, alongside labor and capital. As harvested area increases, production capacity

increases due to the larger harvestable crop volume. This indicates that increases in rice output in Indonesia are still heavily influenced by land extensification and intensification.

This finding is also consistent with the definition of harvested area according to the Statistics Indonesia BPS) (2016), which states that harvested area is the area of food crops actually harvested during a given period. BPS) (2022) emphasizes that national rice production is calculated by multiplying harvested area by productivity, so changes in harvested area directly affect the resulting production volume. Therefore, an increase in harvested area will directly impact rice production, as long as productivity per unit area remains relatively constant or increases.

Empirically, the results of this study align with the findings of (Arsi *et al*., 2023) which state that harvested area is the most influential factor on rice production. Research (Rahim et al., 2024) shows that harvested area has a significant impact on food crop production, including rice, both lowland and upland rice. (Purba *et al*., 2022) emphasized that the area of rice harvest is highly dependent on the planting area and the effectiveness of the use of other production factors, so that increasing the harvest area is one of the main strategies in increasing production.

However, the significance of harvested area in this study also needs to be understood in the context of regional heterogeneity in Indonesia. Variations in agro-climatic conditions, land suitability, and the quality of farm management across provinces mean that the impact of harvested area expansion on production is not always uniform. As stated by Aditya et al., (2021) , regional biophysical conditions and climate are important determinants of successful agricultural production. Therefore, although aggregate harvested area significantly influences rice production, the effectiveness of increasing harvested area still depends on land suitability, the variety used, and the quality of cultivation management in each region.

Thus, based on empirical results, production theory, and previous research findings, it can be concluded that harvested area has a positive and significant impact on rice production in Indonesia. This finding confirms that the strategy for increasing national rice production still relies heavily on optimizing harvested land use, both through sustainable land expansion and through increasing cropping intensity and land management efficiency, while still considering resource limitations and environmental sustainability.

Fertilizer Affects Rice Agricultural Production in Indonesia

Based on the results of panel data regression estimation using a Random Effect Model with cluster robust standard error correction, the fertilizer variable shows a negative coefficient of -0.0109 and is significant at the 10 percent level of significance. This finding indicates that increased fertilizer use actually tends to reduce rice production, although the magnitude of the effect is relatively small. Empirically, these results indicate that the relationship between fertilizer and rice production is not always a positive linear one as expected in simple production theory, especially when fertilizer use has exceeded the optimal level or is not adjusted to the agroecological conditions of the land.

From the perspective of agricultural production theory, fertilizer is a variable input that functions to increase soil fertility and plant productivity by adding nutrients, particularly nitrogen, phosphorus, and potassium. (Wicaksana, 2023) explains that applying fertilizer in the right amount, timing, and type will increase the marginal product of other inputs such as labor and seeds, thereby increasing agricultural output. However, the same theory also asserts that excessive fertilizer use can lead to decreased production efficiency due to the law of diminishing returns. Under these conditions, additional fertilizer no longer increases crop yields and may even decrease them.

The negative findings in this study can be explained by indications of inefficiency in fertilizer use at the farmer level. Ahmadian et al., (2021) stated that inappropriate fertilizer dosage and application timing can lead to soil degradation, nutrient imbalance, and reduced plant nutrient uptake. Furthermore, excessive fertilization can increase soil acidity and deteriorate soil structure in the long term, ultimately negatively impacting rice productivity.

The results of this study are also in line with the findings of Laim & Simamora (2022) This indicates that low agricultural literacy and farmers' lack of understanding of proper fertilization techniques result in underutilization of fertilizer, leading to increased production. In the context of subsidized fertilizer policies, uneven distribution of fertilizer between provinces and delays in distribution also have the potential to lead to inappropriate fertilizer use for plant growth phases, thus reducing the

effectiveness of fertilizer in increasing crop yields.

Furthermore, fertilizer subsidy policies aimed at increasing production and farmer welfare do not always directly impact output if they are not accompanied by technical assistance. Maman et al., (2022) He explained that subsidized fertilizer policies need to be integrated with extension programs and monitoring of fertilizer use so that farmers can apply the appropriate dosage and type of fertilizer to their land's needs. Without such support, fertilizer subsidies have the potential to encourage excessive and inefficient fertilizer use.

Thus, based on empirical results and theoretical studies, it can be concluded that fertilizers have an impact on rice production in Indonesia, but the effect is negative and weakly significant. This finding suggests that the primary problem lies not solely in fertilizer availability, but rather in the efficiency and accuracy of its use. Therefore, increasing rice production through fertilizer policy is not sufficient by simply increasing the volume of fertilizer used. It also requires improved fertilizer management, farmer literacy, and ongoing technical assistance to ensure optimal fertilizer use positively impacts rice productivity.

Seed Quality Affects Rice Production in Indonesia

Based on the panel data regression estimation results using a Random Effects Model with cluster robust standard error correction, the staple seed variable shows a negative coefficient of –0.0485 and is significant at the 10 percent level. This finding indicates that increasing the use of staple seeds is negatively correlated with rice production, although the level of significance is relatively weak. Empirically, these results indicate that increasing the number of staple seeds does not automatically increase rice production output and, under certain conditions, can even reduce production yields obtained by farmers.

Theoretically, these results appear to contradict agricultural production theory, which places superior seeds as a key input in increasing crop productivity. (Purba et al., (2022) explains that high-quality seeds have relatively high elasticity of output because they carry genetic advantages in the form of high yield potential, resistance to pests and diseases, and adaptability to certain environmental conditions. Within the framework of the production function, seeds should act as an input that enhances the efficiency of the use of other inputs, such as fertilizer, water, and labor. However, the negative results in this study indicate that the role of seeds in practice does not fully reflect the ideal function as described in theory.

These empirical results indicate issues with the quality, suitability, and use of staple seeds at the farmer level. (Juliyanti *et al*., 2021) states that successful crop cultivation is largely determined by seed quality and the suitability of the variety to local agro-ecological conditions. Excessive seed use, selection of varieties unsuitable for soil and climate conditions, and low seed purity and viability can lead to decreased crop productivity. Under these conditions, increasing seed yields does not optimally increase plant density but instead creates competition between plants for nutrients, water, and light, ultimately reducing yields.

This finding is also in line with research (Maman *et al*., 2021) which emphasizes that limited access to certified seeds and low farmer literacy in selecting superior varieties suited to local conditions are major obstacles to increasing agricultural productivity. Spatial heterogeneity across Indonesian provinces, in terms of soil quality, microclimate, and agricultural infrastructure, increases the likelihood of mismatches between the seeds used and the growing environment. This condition results in seed use not having a uniform positive impact on rice production.

The results of this study indicate that seed policies that focus solely on increasing seed distribution or volume are not necessarily effective in increasing rice production. Saleh & Dirgantara (2023) emphasized that the success of a rice seed system is determined not only by seed availability but also by seed quality, a reliable certification system, and technical assistance to farmers on appropriate seed use. Without such support, increased seed use has the potential to reduce production efficiency, as reflected in the results of this study.

Thus, based on the results of the empirical analysis and its relationship to production theory and previous research, it can be concluded that the staple seeds in this study have a negative and weakly significant effect on rice production in Indonesia. This finding indicates that the main problem lies not solely in seed availability, but rather in quality, variety suitability, and the effectiveness of seed utilization at the farmer level. Therefore, increasing rice production through seed inputs requires a more

comprehensive approach, not only increasing seed quantity but also improving seed quality, adapting varieties to local agroecological conditions, and strengthening technical assistance within the national seed system.

Irrigation Affects Rice Agricultural Production in Indonesia

Based on the results of panel data regression estimation using a Random Effect Model with cluster robust standard error correction, the pump irrigation variable shows a very small and statistically insignificant coefficient on rice production in Indonesia. This result indicates that the presence of pump irrigation, as represented in the model, has not been able to provide a significant impact on increasing rice production. Empirically, this finding shows that the addition of pump irrigation units is not automatically followed by an increase in rice output, especially after controlling for variables such as labor, harvested area, capital, fertilizer, and seeds.

Theoretically, these findings appear to be inconsistent with agricultural production theory, which places water as a crucial input in the crop production process. Within the Cobb-Douglas production function framework, water availability through irrigation systems is viewed as a factor that can increase total factor productivity because water plays a role in optimizing the use of other inputs such as fertilizer, seeds, and labor. Novizal & Juliansyah (2022); Puspitasari (2021) state that adequate irrigation can increase technical production efficiency and maintain yield stability, particularly in rice crops, which are highly dependent on water availability throughout their growth phase.

However, the insignificant influence of irrigation in this study can be explained by several structural and contextual factors. First, the pump irrigation variable used in this study only represents the number or availability of irrigation facilities, without considering their quality, capacity, intensity of use, and operational sustainability. Available pump irrigation does not always function optimally due to limited water sources, high fuel operating costs, and farmers' limited ability to maintain irrigation facilities. This condition aligns with the findings of Harahap et al., (2023) & Syahid et al., (2022), which state that the effectiveness of pump irrigation is highly dependent on the support of infrastructure and water management institutions at the local level.

Second, pump irrigation in many regions of Indonesia generally complements existing technical irrigation systems, rather than serving as the primary source of water. Therefore, the marginal contribution of pump irrigation to production is relatively small, especially in areas with adequate surface or technical irrigation networks. Chairil et al., (2018) emphasized that without good coordination between infrastructure providers and farmer groups, irrigation facilities are often underutilized, thus limiting their impact on production.

Third, the insignificant effect of irrigation may also be influenced by regional heterogeneity and agro-climatic conditions between provinces. Rice production in Indonesia is influenced not only by water availability but also by climate factors, rainfall, soil type, and cropping patterns that vary across regions. Aditya et al., (2021) state that climate factors and land suitability play a crucial role in determining the success of agricultural production. Therefore, the presence of pump irrigation without suitable biophysical conditions and good cultivation management will not necessarily significantly increase production.

Considering the empirical results and theoretical explanations, it can be concluded that pump irrigation in this study has not been proven to have a significant impact on rice agricultural production in Indonesia. This finding does not negate the importance of irrigation in rice production systems, but rather indicates that irrigation effectiveness is largely determined by the quality of infrastructure, intensity of use, institutional management, and suitability to local agro-ecological conditions. Therefore, increasing rice production through irrigation development is not sufficient by simply increasing the number of facilities, but must be accompanied by improved management, technical assistance, and integration with other production inputs to optimally realize its impact on production.

CONCLUSION

Based on the results of panel data regression analysis using a Random Effects Model with cluster robust standard error correction, this study concludes that rice agricultural production in Indonesia is influenced by various production factors with varying degrees of influence. Agricultural labor and harvested area have been shown to have a positive and significant effect on rice production, indicating that the rice agricultural sector in Indonesia remains highly dependent on labor availability and land use as the main production factors.

Meanwhile, the People's Business Credit (KUR) for agriculture showed a positive but insignificant effect on rice production, indicating that increased access to financing has not directly driven output increases. Fertilizer and staple seed variables had a negative and weakly significant effect, reflecting inefficiencies in the use of these inputs. On the other hand, pump irrigation did not show a significant effect on rice production, indicating that the existence of irrigation facilities has not had an optimal impact without the support of effective management and utilization.

Based on the results of panel data regression analysis with the Random Effect Model approach, this study shows that rice production in Indonesia is influenced by various factors with different levels of significance, where labor and harvested area have a positive and significant effect, while People's Business Credit (KUR), fertilizer, seeds, and pump irrigation have not shown optimal effects. This finding confirms that increasing production depends not only on the amount of inputs, but also on the efficiency of their use, so it is recommended to improve the quality of the workforce, optimize and protect agricultural land, increase the effectiveness of KUR distribution, the efficiency of fertilizer and seed use, and improve irrigation management based on regional characteristics to support sustainable rice production increases.

Overall, the results of this study confirm that the factors influencing rice agricultural production in Indonesia are not only related to the quantitative addition of inputs, but are also largely determined by the efficiency of input use, the quality of farm management, and differences in regional characteristics between provinces.

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