Indonesian Journal of Multidisciplinary Sciences (IJoMS)
Vol. 5 No. 2 2026, 1683-1693
E-ISSN: 2963-7635 | P-ISSN: 2986-2426
Publisher: CV. Era Digital Nusantara

Production Elasticities and Allocative Efficiency of Rice Inputs in Technically Irrigated and Rainfed Areas of Tangerang Regency

Irfan Afandi[1], Dian Anggraeni[2], Aliudin[2], Khaerul Saleh[2], Dewi Firnia[3], Susiyanti[3]
[1] Master's Program in Agricultural Sciences, Graduate School, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia
[2] Department of Agribusiness, Faculty of Agriculture, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia
[3] Department of Agroecotechnology, Faculty of Agriculture, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia
Corresponding email: irfanblux@gmail.com

ARTICLE INFO

Article History
Submission : 07-07-2026
Received : 27-07-2026
Revised : 30-07-2026
Accepted : 01-08-2026

Keywords
Cobb-Douglas;
Production Function;
Economic Efficiency;
Rainfed Rice;
Rice Production;
Technical Irrigation

DOI:
10.59066/ijoms.v5i2.2775

ABSTRACT

This study estimated production elasticities and partial allocative-efficiency indicators for rice inputs in technically irrigated and rainfed areas of Tangerang Regency, Indonesia. Cross-sectional data were obtained from 88 farm units (44 in Sukadiri and 44 in Solear) and analyzed using log-linear Cobb-Douglas models. In addition to conventional ordinary least squares, the revision reports HC3 robust standard errors, Wald tests of returns to scale, a pooled regime-by-input interaction model, per-hectare sensitivity models, and bootstrap intervals for value-of-marginal-product-to-input-price ratios (VMP/Px). Cultivated area was positively associated with total output in both areas; urea was also positively associated with output in the rainfed sample. HC3 estimates supported these results. The sums of elasticities were 1.090 (95% CI: 1.043–1.138) and 1.117 (95% CI: 1.092–1.141), each statistically above one. Joint slope interactions were significant (Wald statistic = 11.643, $p = 0.040$), driven principally by the cultivated-area interaction; the urea slope difference itself was not significant. Per-hectare sensitivity models had much lower explanatory power (adjusted R^2 = 0.247 and 0.107), confirming that the near-perfect fit of total-output models largely reflects farm scale. Bootstrap VMP/Px intervals supported a positive allocative signal for cultivated area in both samples and urea in the rainfed sample, but were inconclusive for most other inputs. Findings are associative and location-specific because irrigation regime is confounded with district, the sample comprises 44 farms per model, and several predictors show substantial collinearity.

Introduction

Rice remains central to food security and rural livelihoods in Indonesia. Production growth is increasingly constrained by land conversion, fragmented holdings, rising input costs, and uneven water availability. These pressures make productivity improvement dependent not only on input quantities but also on how land, seed, fertilizer, and labor are allocated in relation to their marginal contributions to output (National Food Agency, 2022; Statistics Indonesia, 2023).

Efficiency concepts must be distinguished. Technical efficiency concerns producing the maximum feasible output from a given input bundle; allocative efficiency concerns choosing input proportions consistent with their prices and marginal products; economic efficiency combines both. Resource-use efficiency ratios such as VMP/Px are partial allocative indicators and do not estimate farm-specific technical efficiency. The present Cobb-Douglas approach was selected to estimate interpretable production elasticities and price-based marginal signals with a modest cross-sectional sample. Unlike stochastic frontier analysis or data envelopment analysis, it does not separate inefficiency from random noise or produce individual efficiency scores (Heriqbaldi et al., 2015; Wijaya et al., 2022).

Water supply is a major source of heterogeneity in rice production. Technical irrigation provides regulated conveyance and distribution of water, allowing farmers to coordinate land preparation, transplanting, fertilization, and harvesting more reliably. Rainfed systems depend more strongly on the timing and distribution of precipitation and are therefore exposed to moisture deficits during critical crop stages. Stable water availability can improve nutrient uptake, tiller formation, photosynthesis, panicle development, and grain filling, whereas water stress can reduce fertilizer effectiveness and increase yield risk (Yoshida, 1981; Arouna et al., 2023). Irrigation development may thus improve technical performance, but infrastructure alone does not guarantee economically efficient input allocation (Hernawati et al., 2024).

Tangerang Regency illustrates this contrast. In 2022, rice productivity averaged 50.45 quintals ha-1 in Sukadiri District and 48.44 quintals ha-1 in Solear District. Sukadiri contains an extensive technically irrigated area, whereas Solear includes a large rainfed rice area whose planting schedule is more dependent on seasonal rainfall (Tangerang Regency Agriculture and Food Security Agency, 2023). Differences in aggregate productivity, however, cannot identify which inputs drive production or whether their current quantities are economically optimal.

Previous Indonesian studies have examined rice-farm efficiency across regions, farm sizes, and irrigation technologies (Kusnadi et al., 2011; Pipih et al., 2020; Sinabang et al., 2021; Sumaryanto et al., 2023). This study contributes a harmonized comparison using identical variables, units, functional forms, robust inference, and formal regime-by-input interaction tests. Its contribution is the assessment of heterogeneous input responses across two contrasting rice-production areas, not identification of a causal irrigation effect. Because each water regime is represented by a different district, differences may also reflect soils, varieties, seasonal timing, extension access, labor markets, and management.

The study addressed three questions: which inputs are associated with rice output individually and jointly; whether production-response slopes differ formally between the two sampled areas; and which price-based marginal signals remain credible after accounting for statistical uncertainty. It estimated production elasticities, formally tested returns to scale, evaluated regime interactions, and calculated partial allocative-efficiency indicators for cultivated area, seed, urea, NPK fertilizer, and labor.

Method

Research Design and Study Area

A cross-sectional quantitative survey was conducted in Tangerang Regency, Banten Province, Indonesia. Sites were selected purposively: Sukadiri District represented technically irrigated rice fields and Solear District represented rainfed rice fields. Data referred to one production cycle in each location. Consequently, irrigation status is perfectly aligned with district and partly with planting period; soil properties, varieties, weather, and management were not available as regression controls. The estimates are therefore location-specific associations rather than causal effects of irrigation.

The population comprised 2,288 rice farmers in Sukadiri and 2,428 in Solear. The original sample calculation used the Slovin formula with a 15% margin of error and yielded 44 respondents per district (88 farm units). The five-predictor models retain 38 residual degrees of freedom per group; this is adequate for estimation of large effects but limited for small effects and policy generalization. Respondents were selected from farmer lists by simple random sampling; each respondent represented one farm unit and one season. Structured interviews recorded farm characteristics, input quantities and prices, output, and farm-gate paddy prices. Participation was voluntary, informed consent was obtained before interviews, and identifying and farm-level economic data were treated confidentially. The research formed part of an institutionally supervised master's study.

Variables and Production Model

Rice production (Y) was measured in tonnes per farm per production season. Explanatory variables were cultivated area (X1, ha), seed (X2, kg), urea (X3, kg), NPK fertilizer (X4, kg), and total family-plus-hired labor (X5, person-days or HOK; one HOK denotes one adult-equivalent workday). All observed quantities were positive, so no zero-value correction was required before natural-log transformation. The total-output Cobb-Douglas model was retained for comparability with the thesis, while an alternative model used yield (tonnes ha^{-1}) and seed, urea, NPK, and labor intensities per hectare to separate scale from intensity.

$$ln\, Y = ln\, A + \beta_1\, ln\, X_1 + \beta_2\, ln\, X_2 + \beta_3\, ln\, X_3 + \beta_4\, ln\, X_4 + \beta_5\, ln\, X_5 + \varepsilon$$

Estimation and Economic-Efficiency Criteria

Ordinary least squares was applied to separate natural-log models. Conventional estimates were audited and HC3 heteroskedasticity-robust standard errors and 95% confidence intervals were reported because each group contained 44 farms. Residual normality was assessed by Shapiro-Wilk and graphical diagnostics; the Park auxiliary regression used ln(residual²) as the dependent variable; multicollinearity was assessed by tolerance and VIF. Values approaching 10 were treated as substantive collinearity rather than evidence that the issue was absent. A pooled model included a rainfed-area indicator and its interactions with all five logged inputs; a joint Wald test assessed slope heterogeneity. Sensitivity models regressed logged yield on logged input quantities per hectare.

Returns to scale (RTS) were calculated as $\Sigma\beta i$ and tested using the robust Wald restriction H0: $\Sigma\beta i = 1$. Partial allocative efficiency was calculated as $VMPi/Pxi = (\beta i \times \bar{Y} \times Py)/(\bar{X}i \times Pxi)$, using farm-level seasonal means and observed 2025 farm-gate prices. Py was IDR 7,534,091 $tonne^{-1}$ in Sukadiri and IDR 7,002,273 $tonne^{-1}$ in Solear. Input prices (Sukadiri; Solear) were land opportunity cost IDR 7,902,907; 8,357,181 ha^{-1} $season^{-1}$, seed IDR 14,000; 17,511 kg^{-1}, urea IDR 2,411; 2,895 kg^{-1}, NPK IDR 2,955; 2,920 kg^{-1}, and labor IDR 150,000; 102,611 HOK^{-1}. Nonparametric farm-level bootstrap resampling (1,000 replications) generated percentile 95% intervals. Ratios based on nonsignificant elasticities or intervals spanning one were treated as inconclusive, not as direct prescriptions.

$$EE_{\mathrm{i}} = VMP_{\mathrm{i}} / P_{\mathrm{xi}} = (\beta_{\mathrm{i}} \times \bar{Y} \times P_{Y}) / (X_{\mathrm{i}} \times P_{\mathrm{xi}})$$

Results and Discussion

Participant and Farm Context

The groups were not demographically equivalent. Farmers in Solear were older and more experienced on average, had lower formal education, and participated more often in nonformal agricultural training. These observed differences, together with unmeasured land tenure, variety, soil, mechanization, credit, and water conditions, reinforce the need to interpret the regime comparison as contextual rather than causal.

Table 1. Selected Characteristics of Respondents

Characteristic	Technically irrigated	Rainfed	Interpretive note
Age (years), mean ± SD	48.36 ± 12.86	52.86 ± 11.99	Different age structure
Farming experience (years), mean ± SD	13.16 ± 11.37	18.25 ± 6.76	Rainfed group more experienced
Primary education, n (%)	15 (34.09%)	32 (72.73%)	Marked education imbalance
Any nonformal training, n (%)	12 (27.27%)	21 (47.73%)	Different extension exposure
Farm units analyzed	44	44	One farmer-season per unit

Source: Primary data, processed by the authors.

Input Use and Rice Production

Mean cultivated area was 0.90 ha in the technically irrigated sample and 0.55 ha in the rainfed sample (Welch p = 0.002). Mean farm output was consequently higher in

Sukadiri, whereas mean yield differed modestly and not significantly at the 5% level (6.29 versus 6.10 tonnes ha⁻¹; $p = 0.065$). Per-hectare quantities were calculated as each farm's input-output ratio and then averaged; they are therefore not identical to ratios of group means.

Rainfed farms used significantly more seed, urea, and labor per hectare, while the NPK-intensity difference was small. Standardized mean differences were -0.872 for seed, -0.645 for urea, and -1.161 for labor (technical minus rainfed), but only -0.082 for NPK. These are descriptive contrasts and do not establish inefficiency or an irrigation effect.

Table 2. Input Intensity, Variation, and Between-Group Comparisons

Variable	Technically irrigated mean ± SD	Rainfed mean ± SD	Welch p	SMD
Cultivated area (ha)	0.90 ± 0.55	0.55 ± 0.42	0.002	0.699
Yield (tonnes ha^{-1})	6.29 ± 0.49	6.10 ± 0.49	0.065	0.399
Seed (kg ha^{-1})	33.47 ± 22.36	55.23 ± 27.28	<0.001	-0.872
Urea (kg ha^{-1})	249.45 ± 76.35	338.34 ± 179.25	0.004	-0.645
NPK (kg ha^{-1})	272.41 ± 110.06	284.67 ± 179.22	0.700	-0.082
Labor (HOK ha^{-1})	66.94 ± 20.77	98.69 ± 32.63	<0.001	-1.161

Source: Primary data, processed by the authors.

Model Diagnostics and Overall Performance

Shapiro-Wilk p-values were 0.141 and 0.221, and Park-test p-values were 0.074 and 0.443. These tests did not reject residual normality or homoskedasticity at 5%, but graphical checks and robust inference remain important with $n = 44$. VIF values of up to 8.994 and 8.664 indicate substantial collinearity among total-scale inputs, which can inflate standard errors and destabilize individual slopes.

The total-output models were jointly significant and showed R^2 values of 0.996 and 0.998. Their near-perfect fit must not be interpreted as structural completeness: output, cultivated area, and total input quantities all scale with farm size. Per-hectare sensitivity models reduced adjusted R^2 to 0.247 and 0.107, confirming that scale explains much of the original fit.

Table 3. Diagnostics, Robust Inference, and Model Performance

Indicator	Technically irrigated	Rainfed
Observations / residual df	44 / 38	44 / 38
Shapiro-Wilk p	0.141	0.221
Park auxiliary F p	0.074	0.443
VIF range	3.725–8.994	3.288–8.664
R^2 / adjusted R^2	0.996 / 0.995	0.998 / 0.997

Indicator	Technically irrigated	Rainfed
Residual standard error	0.053	0.043
Conventional F-statistic	1,806.153***	3,193.152***
RTS estimate (HC3 95% CI)	1.090 (1.043–1.138)	1.117 (1.092–1.141)
Wald H0: RTS = 1, p	<0.001	<0.001

*Note: *** p < 0.001.*
Source: Primary data, processed by the authors.

Production Elasticities and Partial Effects
Table 4. Cobb-Douglas Estimates with HC3 Robust Inference

Variable	Technical coef. (HC3 SE)	95% CI	p	Rainfed coef. (HC3 SE)	95% CI	p
Constant	1.676 (0.221)	1.229–2.124	<0.001	0.954 (0.170)	0.611–1.298	<0.001
Cultivated area	1.055 (0.032)	0.989–1.120	<0.001	0.941 (0.026)	0.888–0.994	<0.001
Seed	0.004 (0.033)	-0.064–0.072	0.900	0.018 (0.019)	-0.020–0.057	0.344
Urea	0.028 (0.041)	-0.056–0.111	0.507	0.111 (0.034)	0.041–0.180	0.003
NPK fertilizer	0.006 (0.045)	-0.085–0.098	0.888	0.037 (0.023)	-0.010–0.085	0.123
Labor	-0.003 (0.048)	-0.100–0.094	0.954	0.009 (0.029)	-0.050–0.069	0.750

Source: Primary data, processed by the authors.

Cultivated area dominated both total-output models. A 1% increase in area was associated with 1.055% and 0.941% higher output, holding total quantities of other inputs constant. This ceteris-paribus condition is difficult to realize agronomically because expanding area generally requires additional inputs; the coefficients primarily capture farm scale and should not be read as unconstrained land-expansion effects.

Seed elasticities were small and nonsignificant in both systems (0.004 and 0.018). The absence of a significant response implies that adding seed within the observed range did not reliably increase production after other inputs were controlled. Rice yield depends not only on seed quantity but also on germination, vigor, variety, seedling age, spacing, and seedlings per hill. Excessive plant density can intensify competition for light, water, and nutrients and create a humid canopy that increases lodging and disease risk. Management should therefore emphasize seed quality and stand establishment instead of simply increasing kilograms of seed.

Urea was positively associated with output only in the rainfed-area model after HC3 correction (β = 0.111, p = 0.003). The pooled interaction for the urea slope was not significant (p = 0.123), so the evidence does not establish that the urea response is statistically larger than in Sukadiri. Soil moisture, application timing, variety, initial fertility, and reverse causality are plausible explanations, but they were not measured and remain hypotheses.

NPK fertilizer had positive but nonsignificant coefficients in both systems. Phosphorus supports root growth and energy transfer, while potassium regulates water balance, enzyme activation, assimilate transport, lodging resistance, and stress tolerance. However, crop response depends on initial soil nutrient status and moisture. A small estimated elasticity does not imply that phosphorus and potassium are agronomically unimportant; it indicates that variation in the observed application rates did not explain a statistically distinct change in output. Soil testing and site-specific nutrient management are therefore more defensible than blanket increases in compound NPK fertilizer (Chivenge et al., 2022; Girsang et al., 2025).

Labor coefficients were also nonsignificant: -0.003 under technical irrigation and 0.009 under rainfed conditions. The negative sign in Sukadiri should not be interpreted as proof that labor reduces output because the estimate was statistically indistinguishable from zero. Rather, it suggests that additional person-days did not improve production at prevailing management levels. Mechanization can substitute for manual labor in land preparation, transplanting, threshing, and harvesting, while the value of remaining labor depends mainly on timeliness and task quality (Paman et al., 2014; Haryono et al., 2021).

The elasticity sums were 1.090 and 1.117. Robust Wald tests rejected constant returns ($p < 0.001$ in both samples), with 95% confidence intervals entirely above one. Thus the fitted total-output functions exhibit increasing returns within the observed samples. Because these sums are dominated by cultivated-area slopes and the per-hectare models fit far less strongly, the result should not be converted into a recommendation to expand every input proportionally.

Formal Regime Comparison and Scale Sensitivity

The joint test of all five regime-by-input slope interactions was significant (Wald statistic = 11.643, p = 0.040), indicating that the response vectors are not identical. The cultivated-area interaction was significant, whereas seed, urea, NPK, and labor interactions were not. Therefore, significance in one separate model but not the other cannot by itself be taken as proof of a between-regime difference. In per-hectare models, none of the individual input-intensity coefficients was significant at 5%, and the rainfed model was not jointly significant.

Table 5. Formal Interaction and Per-Hectare Sensitivity Tests

Test / parameter	Estimate or statistic	p	Interpretation
Joint slope interactions	11.643	0.040	Response vectors differ jointly

Test / parameter	Estimate or statistic	p	Interpretation
Rainfed × cultivated area	-0.114	0.006	Area slope lower in rainfed sample
Rainfed × urea	0.083	0.123	No direct evidence of slope difference
Per-ha model: technical	Adj. $R^2 = 0.247$	F p = 0.034	Much lower scale-free fit
Per-ha model: rainfed	Adj. $R^2 = 0.107$	F p = 0.332	Model not jointly significant

Source: Primary data; HC3 robust inference.

Economic Efficiency and Management Implications

Table 6. Partial Allocative-Efficiency Ratios with Bootstrap Intervals

Input	Technical VMP/Px (95% CI)	Evidence	Rainfed VMP/Px (95% CI)	Evidence
Cultivated area	6.531 (6.155–7.031)	Positive signal*	4.985 (4.673–5.274)	Positive signal*
Seed	0.528 (-5.346–13.532)	Inconclusive	1.017 (-0.895–3.168)	Inconclusive
Urea	2.478 (-4.388–9.684)	Inconclusive	5.926 (2.165–8.929)	Positive signal*
NPK fertilizer	0.452 (-5.606–6.112)	Inconclusive	2.356 (0.278–6.269)	Uncertain
Labor	-0.016 (-0.580–0.422)	Inconclusive	0.047 (-0.249–0.279)	Low marginal signal

Note: Percentile intervals use 1,000 farm-level bootstrap replications.
*The elasticity is statistically significant and the interval remains above one. A ratio below one denotes a low marginal value relative to price only when the underlying coefficient is credible; negative or wide intervals are classified as inconclusive.
Source: Primary data, processed by the authors.

Cultivated-area ratios remained above one in both bootstrap distributions and were supported by significant elasticities. This is a partial allocative signal, not proof that farms should acquire more land. The analysis does not observe fallow-land availability, tenure, rental constraints, fragmentation, or feasibility. Practical implications should focus first on evaluating the use of existing land, reducing avoidable fallow periods, cooperative management, and water reliability before considering consolidation or expansion.

The rainfed urea ratio remained above one across its bootstrap interval and its elasticity was significant, supporting field testing of better-timed or redistributed nitrogen rather than a blanket dose increase. The technically irrigated urea interval was wide and crossed one and zero, so its point ratio does not support an underuse conclusion. Any trial should use split applications, crop-stage and soil-moisture checks, and environmental safeguards against nitrogen loss.

Bootstrap uncertainty was substantial for seed, NPK, and labor. Their point ratios should therefore not be classified as definitive underuse or overuse. Management should emphasize certified seed, spacing, soil-tested nutrient plans, timeliness, skills, and mechanization services. These actions require field verification and cost-benefit analysis rather than direct conversion of sample ratios into input prescriptions.

Taken together, the results show contextual heterogeneity rather than a ranking of irrigation systems. Technical irrigation did not eliminate allocation constraints, and the rainfed area was not uniformly less productive. Policy pilots should integrate water management, land-use feasibility, site-specific fertilization, machinery access, and extension, with outcomes evaluated prospectively.

Conclusion

Within these two samples, cultivated area was positively associated with total rice output in both districts and urea was positively associated with output in the rainfed district. Robust Wald tests supported increasing returns in the fitted total-output models, while per-hectare sensitivity models showed that much of their near-perfect fit came from farm scale. Formal interaction tests indicated joint slope heterogeneity, but only the cultivated-area interaction was individually significant; the apparent urea contrast across separate models was not a statistically confirmed slope difference. Bootstrap evidence supported partial allocative signals for cultivated area in both samples and urea in Solear, whereas evidence for other inputs was inconclusive. These findings should guide local field trials, not uniform input increases. Inference is limited by 44 farms per group, a 15% sampling margin, substantial VIF values, district confounding, total-output specification, omitted soil/weather/variety variables, possible input endogeneity, and price uncertainty.

References

Arouna, A., Dzomeku, I. K., Shaibu, A. G., & Nurudeen, A. R. (2023). Water management for sustainable irrigation in rice (Oryza sativa L.) production: A review. *Agronomy, 13(6)*, 1522. https://doi.org/10.3390/agronomy13061522

Chivenge, P., Sharma, S., Bunquin, M. A., & Hellin, J. (2021). Improving nitrogen use efficiency: A key for sustainable rice production systems. *Frontiers in Sustainable Food Systems, 5*, 737412. https://doi.org/10.3389/fsufs.2021.737412

Chivenge, P., Zingore, S., Ezui, K. S., Njoroge, S., Bunquin, M. A., Dobermann, A., & Saito, K. (2022). Progress in research on site-specific nutrient management for smallholder farmers in sub-Saharan Africa. *Field Crops Research, 281*, 108503. https://doi.org/10.1016/j.fcr.2022.108503

Dobermann, A., & Fairhurst, T. (2000). Rice: *Nutrient disorders and nutrient management*. Potash & Phosphate Institute and International Rice Research Institute.

Ghozali, I. (2021). *Aplikasi analisis multivariate dengan program IBM SPSS 26* (ed. ke-10). Badan Penerbit Universitas Diponegoro.

Girsang, S. S., Castillo, R. L., Syam, M., Zaini, Z., Kartaatmadja, S., Suyamto, Dela Torre, J. C., Pabuayon, I. L. B., Limpiada, R. A., Waluyo, Helmi, Samijan, Budiono, R., Hatta, M., Nurhayati, Kamandalu, N. B., Susanto, B., Parhusip, D., Abidin, Z., & Buresh, R. J. (2025). Site-specific nutrient management for rice using soil properties to adjust phosphorus and potassium supply from compound NPK fertilizer. *Field Crops Research, 326*, 109864. https://doi.org/10.1016/j.fcr.2025.109864

Gujarati, D. N., & Porter, D. C. (2009). *Basic econometrics* (5th ed.). McGraw-Hill.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis* (8th ed.). Cengage.

Haryono, D., Hudoyo, A., & Mayasari, I. (2021). The sustainable agricultural mechanization of rice farming and its impact on land productivity and profit in Lampung Tengah Regency. *IOP Conference Series: Earth and Environmental Science, 739(1)*, 012056. https://doi.org/10.1088/1755-1315/739/1/012056

Heriqbaldi, U., Purwono, R., Haryanto, T., & Primanthi, M. R. (2015). An analysis of technical efficiency of rice production in Indonesia. *Asian Social Science, 11(3)*, 91-102. https://doi.org/10.5539/ass.v11n3p91

Hernawati, Syaukat, Y., Firdaus, M., & Daryanto, H. K. (2024). The impact of the irrigation development program on rice farming technical efficiency: A case study in West Nusa Tenggara Province, Indonesia. *Journal of the International Society for Southeast Asian Agricultural Sciences, 30(1)*, 15-25.

Hilalullaily, R., Kusnadi, N., & Rachmina, D. (2021). Analisis efisiensi usahatani padi di Jawa dan luar Jawa: Kajian prospek peningkatan produksi padi nasional. *Jurnal Agribisnis Indonesia, 9(2)*, 143-153. https://doi.org/10.29244/jai.2021.9.2.143-153

Kusnadi, N., Tinaprilla, N., Susilowati, S. H., & Purwoto, A. (2011). Analisis efisiensi usahatani padi di beberapa sentra produksi padi di Indonesia. *Jurnal Agro Ekonomi, 29(1)*, 25-48.

Mottaleb, K. A., & Mohanty, S. (2015). Farm size and profitability of rice farming under rising input costs. *Journal of Land Use Science, 10(3)*, 243-255. https://doi.org/10.1080/1747423X.2014.919618

National Food Agency. (2022). *Situasi konsumsi pangan nasional tahun 2022*. National Food Agency of Indonesia.

Paman, U., Inaba, S., & Uchida, S. (2014). The mechanization of small-scale rice farming: Labor requirements and costs. *Engineering in Agriculture, Environment and Food, 7(3)*, 122-126. https://doi.org/10.1016/j.eaef.2014.03.001

Pipih, P., Aliudin, A., & Saleh, K. (2020). Efisiensi penggunaan input produksi usahatani padi sawah antara sistem irigasi teknis dan sistem pompanisasi. *Jurnal Agribisnis Terpadu, 13(1)*, 68-90. https://doi.org/10.33512/jat.v13i1.6898

Sinabang, L., Anggraeni, D., & Aliudin. (2021). Elastisitas produksi dan efisiensi penggunaan faktor produksi padi sawah pada berbagai tingkat luas lahan garapan di Kabupaten Tangerang. *Jurnal Ilmu Pertanian Tirtayasa, 3(2)*, 311-326.

Soekartawi. (2003). *Teori ekonomi produksi dengan pokok bahasan analisis fungsi Cobb-Douglas* (3rd rev. ed.). RajaGrafindo Persada.

Statistics Indonesia. (2023). *Proyeksi penduduk Indonesia 2020-2050: Hasil Sensus Penduduk 2020*. BPS-Statistics Indonesia.

Sumaryanto, S., Susilowati, S. H., Saptana, S., Sayaka, B., Suryani, E., Agustian, A., Ashari, A., Purba, H. J., Sumedi, S., Dermoredjo, S. K., Purwantini, T. B., Yofa, R. D., & Pasaribu, S. M. (2023). Technical efficiency changes of rice farming in the favorable irrigated areas of Indonesia. *Open Agriculture, 8(1)*. https://doi.org/10.1515/opag-2022-0207

Tangerang Regency Agriculture and Food Security Agency. (2023). *Rice and secondary-crop productivity data, 2018-2022*. Government of Tangerang Regency.

Wijaya, A., Rifin, A., & Hartoyo, S. (2022). Determining technical and resource-use efficiency in rice production in East Java. *Jurnal Manajemen & Agribisnis, 19(1)*, 48-60. https://doi.org/10.17358/jma.19.1.48

Yoshida, S. (1981). *Fundamentals of rice crop science*. International Rice Research Institute.