

Risk Analysis of Red Chili Farming with an Irrigation System

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ABSTRACT

Red chili cultivation on marginal land such as coastal sandy lands faces agroclimatic challenges, including low nutrient content, high temperatures, and limited soil water-holding capacity. These constraints require appropriate manure application to improve soil structure and the selection of efficient irrigation systems to ensure adequate water availability. This study aimed to identify the factors influencing production and production risk in red chili farming under shower and non-shower irrigation systems on rice fields and coastal sandy lands in Bantul Regency. A total of 116 farmers were selected using a combination of random sampling and census techniques. Data were analyzed using the Cobb–Douglas production function to estimate the elasticity and contribution of production inputs, and the Just and Pope risk production model to evaluate the determinants of yield variability and production risk across irrigation and land-use systems. The results showed that several input variables significantly affect red chili production, namely land area, ZA fertilizer, Red Phonska, KCl, TSP, labor, and irrigation system. Land area, ZA fertilizer, and labor have positive and significant effects on output, whereas Red Phonska, KCl, and TSP fertilizers significantly reduce production. Red chili production differs significantly between non-shower irrigation systems and shower irrigation systems. Risk analysis further revealed that land area and manure significantly increase production risk, and that coastal sandy land exhibits different production risk than paddy fields. These findings highlight that irrigation selection, balanced fertilization strategies, and appropriate land-use choices are critical to improving

productivity while mitigating production risk. Strengthened agricultural extension support is necessary to promote efficient input use, improved irrigation scheduling, and adaptive farm management in diverse agroecosystems.

INTRODUCTION

Red chili is a horticultural commodity that has great potential for further development (Hariyani et al., 2017). This commodity is grown by local farmers in Bantul on coastal sandy land and paddy fields. The cultivation of the plant is at risk of being easily damaged by strong winds and high heat. Meanwhile, red chili in paddy fields faces the challenge related to soil moisture. This can be overcome through the use of irrigation systems. The production risk with irrigation use is reduced in red chili (Pitaloka, 2020). Meanwhile, there is a risk of crop failure due to porous soil conditions that prevent proper absorption of fertilizer administered to the plant. Red chili grown in paddy fields has a risk of crop failure due to pests and disease attacks.

Red chili is one of the leading commodities for the farmers because of its good adaptability. This plant can be cultivated in lowlands as well as highlands. In lowlands, such as in coastal sandy land, the adaptability of chili plants is quite good but intensive handling on water availability is still needed. Therefore, soil drainage and aeration must be good, and the availability of water during cultivation must be ensured. Meanwhile, in paddy fields, red chili plants can adapt better because the characteristics of the land are different from sandy land. However, appropriate irrigation is still required,

because the humidity level of paddy fields is higher than that of coastal sand land. The role of the irrigation system is very important in the case of cultivation on both types of lands.

Adequate irrigation is a very important factor for red chili plants cultivated in sandy soil. Therefore, the selection of the right irrigation system can affect production of red chili. The efficient and cost-effective use of irrigation is important due to the limitations of water resources (Ado et al., 2019). Most of the water is wasted because of inefficient watering of plants (Ado et al., 2019; Munir et al., 2018). In this context, soil management to increase water productivity and the allocation of irrigation must be considered (Zheng et al. 2018; Fang and Su 2019). An appropriate irrigation system is essential because the water storage capacity on sandy land is very low. Red chili farmers in Kretek District, Yogyakarta, use a shower system during cultivation (Sembiring et al., 2021). The characteristics inherent in coastal sand land present challenges since the use of production factors is associated with significant risk. The integration of manure with chemical fertilizers is essential to increase nutrient levels in the soil, ensuring that red chili receives sufficient nutrients. Adding fertilizer is standard practice to prevent health and yield issues. Effective management is essential for mitigating agricultural risks in challenging environments, with

innovative tools helping farmers on coastal sand lands (Khakhula et al., 2023). Proper risk management is economically crucial to avoid financial loss (Hryvkivska, Karpinskyi, & Prystemskyi, 2024). Furthermore, irrigation systems can help with red chili farming on sandy lands by addressing water and nutrient issues (Risvansuna et al., 2023). The correct fertilizer application is important for minimizing production risk (Basyarahil et al., 2016). Combining strategic nutrient management and innovative practices is key to sustainable and productive red chili cultivation on coastal sand lands (Susanawati et al., 2021), increasing farmers' resilience to environmental risks. Research on red chili in this specific environment is extensive.

Previous studies have extensively examined the determinants of agricultural production and risk behavior across different commodities and production systems. Research using the Cobb–Douglas production function has consistently shown that input factors such as land size, labor, fertilizer, and irrigation significantly influence output levels and resource-use efficiency (Siswadi et al., 2025). Similarly, applications of the Just and Pope stochastic production function have been widely used to analyze production risk, revealing that inputs such as fertilizer and pesticide use can either increase or decrease yield variability depending on their management intensity and environmental context (Atta and Micheels, 2020). Differences in land type are also important considerations

in this study, as red chili (*Capsicum annuum* L.) can be cultivated in both irrigated rice-field soils and coastal sandy soils, each presenting distinct agronomic conditions. Rice-field soils typically maintain higher and more stable moisture levels due to their finer texture and greater water-holding capacity, resulting in lower irrigation requirements for chili production (Fang and Su 2019). Conversely, coastal sandy soils exhibit coarse texture, high porosity, and limited nutrient retention, necessitating more intensive and frequent irrigation to prevent moisture deficits, along with greater use of organic manure during land preparation to improve water retention and soil fertility (El-Naggar et al., 2015). Management of pests and diseases also differs between these environments; the relatively humid conditions in rice-field soils often increase pathogen pressure, potentially requiring more intensive pesticide applications compared with the drier coastal soils. These contrasting characteristics justify treating land type as a separate explanatory variable, as each setting imposes distinct management strategies that influence chili productivity and production risks.

In horticultural crops, numerous studies have identified land size, labor input, and irrigation as key factors influencing productivity and income stability. Fang and Su (2019) demonstrated that irrigation volume and soil characteristics significantly affect water productivity and crop yields, while Rahmawati et al. (2023) found that fertilizer application and pest control practices play dual roles as

both yield-enhancing and risk-inducing factors in organic vegetable farming. Although these studies provide valuable insights, they generally examine productivity or risk in isolation, focus on a single agroecosystem, or do not compare different irrigation technologies.

The key research gap is that very few empirical studies simultaneously estimate the effects of production inputs on both productivity and production risk under two contrasting irrigation technologies and soil types within a single, integrated analytical framework. The agroecological differences between coastal sandy soils and irrigated rice-field soils are substantial, yet the interaction among input use, soil characteristics, and irrigation systems in shaping yield variability remains underexplored. To address this gap, this study integrates the Cobb-Douglas production function and the Just and Pope stochastic risk model to simultaneously analyze the determinants of production and production risk in red chili farming. The variables included in the analysis are land area, seed quantity, fertilizers (Urea, ZA, Phonska, NPK, KCl, TSP, KNO, and manure), pesticides (insecticides and fungicides), labor input, and two dummy variables representing Irrigation systems and land types. Through this approach, the study aims to identify the factors influencing production and risk across two contrasting agroecosystems—coastal sandy land and irrigated rice-field land—using shower and non-shower irrigation systems.

METHODS

Sampling Method

The population of this study consisted of red chili farmers cultivating in paddy fields and coastal sandy lands in Bantul Regency. These two areas were selected deliberately because they represent contrasting agroecosystems of fertile irrigated paddy fields and marginal coastal sandy lands, allowing comparative analysis of production and risk under different irrigation systems. To obtain representative data, this study employed a combination of random sampling and census techniques. Random sampling was applied to farmers cultivating on rice-field land using non-shower irrigation systems. Meanwhile, a census approach was used for farmers on coastal sandy land using shower irrigation systems due to their limited population and the limited field personnel available during data collection. Consequently, the number of respondents in the four farmer categories differed (15, 23, 55, and 23 farmers), reflecting the actual population size in each group. According to Cochran (1991) and Sudman (1976), unequal subgroup sizes are methodologically acceptable when sampling follows the natural population structure and census is applied to small strata, ensuring that each category remains adequately represented. However, this structure may still lead to unequal variance and potential sampling bias; therefore, robust standard errors were used to address heteroskedasticity, and these limitations were considered in interpreting the regression results. In total, 116 farmers were included in the analysis.

Data Analysis Methods

This study employed two analytical models to achieve its objectives. Factors influencing red chili production were analyzed using the Cobb–Douglas production function, whereas the determinants of production risk were examined using the Just and Pope risk production function. Both models were estimated using multiple regression analysis based on Ordinary Least Squares (OLS) method.

1. Production Function Analysis

In this study, the Cobb–Douglas production function was employed to analyze the relationship between red chili production and various production inputs. Consistent with its theoretical form, the Cobb–Douglas function is multiplicative and was therefore estimated in a log-linear (double-log) specification to allow the coefficients to be interpreted as elasticities and to improve variance stability in the data. Accordingly, all continuous input variables were transformed using the natural logarithm, while the dummy variables representing irrigation system and land type were entered in their original form. The empirical model used in this analysis is specified as follows:

$$\ln Y = \beta_0 + \beta_1 \ln(\text{Land}) + \beta_2 \ln(\text{Seed}) + \beta_3 \ln(\text{Urea}) + \beta_4 \ln(\text{WhPh}) + \beta_5 \ln(\text{NPK}) + \beta_6 \ln(\text{ZA}) + \beta_7 \ln(\text{RedPh}) + \beta_8 \ln(\text{KCl}) + \beta_9 \ln(\text{KNO}) + \beta_{10} \ln(\text{TSP}) + \beta_{11} \ln(\text{Man}) + \beta_{12} \ln(\text{Insc}) + \beta_{13} \ln(\text{LiqF}) + \beta_{14} \ln(\text{SolF}) + \beta_{15} \ln(\text{Lab}) + \beta_{16} D_1 + \beta_{17} D_2 + \epsilon \dots\dots\dots(1)$$

Where Y is Red Chili Production,

β_0 is a constant and β_1 – β_{15} refer to the coefficient of independent variables describing farming inputs. These include Land (Land area), Seed (Seed), Urea (Urea Fertilizer), WhPh (White Phonska Fertilizer), NPK (NPK Fertilizer), ZA (ZA Fertilizer), RedPh (Red Phonska Fertilizer), KCl (KCl Fertilizer), KNO (KNO Fertilizer), TSP (TSP Fertilizer), Man (Manure), Insc (Insecticide), LiqF (Liquid Fungicide), SolF (Solid Fungicide), Lab (Labor). In this model, there are two dummy variables, namely D1 and D2, which respectively show engagement in irrigation system (0 = shower irrigation, 1 = non-shower irrigation), land type system (0 = coastal sandy land, 1 = rice field), and ϵ is random error term.

Analysis of the factors affecting risk of red chili farming production is based on Cobb-Douglas production function using the OLS regression method. This study used Ordinary Least Squares (OLS) model because the Cobb-Douglass production function serves as a component of the Just and Pope risk model (Just & Pope, 1979). OLS defines the risk function assuming that the inputs increase or decrease production risk measure in terms of output variance. To analyze red chili production risk, OLS regression must be performed by making red chili production the dependent variable to obtain squared error values. The function productivity variance of red chili is as follows.

$$\epsilon^2 = i_0 + i_1 \text{Land} + i_2 \text{Seed} + i_3 \text{Urea} + i_4 \text{WhPh} + i_5 \text{NPK} + i_6 \text{ZA} + i_7 \text{RedPh} + i_8 \text{KCl} + i_9 \text{KNO} + i_{10} \text{TSP} + i_{11} \text{Man} + i_{12} \text{Insc} + i_{13} \text{LiqF} + i_{14} \text{SolF} + i_{15} \text{Lab} + i_{16} D_1 + i_{17} D_2 + \mu_1 \dots\dots\dots(2)$$

This model represents the risk of red chili production, where i_0 is the constant term and i_1-i_{15} denote the coefficients of each independent variable. The independent variables included in the model consist of Land (land area), Seed, Urea fertilizer, White Phonska fertilizer, NPK fertilizer, ZA fertilizer, Red Phonska fertilizer, KCl fertilizer, KNO fertilizer, TSP fertilizer, Manure, Insecticide, Liquid Fungicide, Solid Fungicide, and Labor, while μ_1 represents the error term. Two dummy variables are also incorporated: D1 for the irrigation system (0 = shower irrigation, 1 = non-shower irrigation) and D2 for the land type (0 = coastal sandy land, 1 = rice field). To improve the reliability of the estimates and address potential heteroskedasticity in agricultural

production data, this regression was estimated using **robust standard errors (Huber-White)**. The F-test and t-test with robust standard errors were employed to examine the joint and individual effects of production factors on production risk (Naziullah et al., 2021).

RESULTS AND DISCUSSION

Production Function Analysis
 A production function is an equation used to describe a possibility in activity (Karmini, 2018). Analysis of Production Factors The analysis of factors influencing production obtained the following regression equation.

$$Y = 1.003 X_1^{0.598} X_2^{0.089} X_3^{-0.017} X_4^{-0.014} X_5^{-0.005} X_6^{0.022} X_7^{-0.021} X_8^{-0.039} X_9^{-0.013} X_{10}^{-0.018} X_{11}^{0.008} X_{12}^{0.007} X_{13}^{-0.003} X_{14}^{0.005} X_{15}^{0.262} D_1^{-0.117} D_2^{0.015}$$

Table 1. Regression Results of Factors Affecting Production in Bantul

| Variable | Coef. | Robust Std. Err | t | P> t |
|--------------------------|-----------------|-----------------|-------|----------|
| Constant | 1.003 | 0.292 | 3.44 | 0.001*** |
| Land Area (X1) | 0.598 | 0.093 | 6.42 | 0.000*** |
| Seeds (X2) | 0.089 | 0.070 | 1.27 | 0.207 |
| Urea (X3) | -0.017 | 0.013 | -1.39 | 0.167 |
| White Phonka (X4) | -0.014 | 0.010 | -1.45 | 0.152 |
| NPK Pearl (X5) | -0.005 | 0.012 | -0.42 | 0.679 |
| ZA (X6) | 0.022 | 0.011 | 2.07 | 0.041** |
| Red Phonka (X7) | -0.021 | 0.010 | -2.14 | 0.035** |
| KCL (X8) | -0.039 | 0.012 | -3.09 | 0.003** |
| KNO (X9) | -0.013 | 0.022 | -0.59 | 0.557 |
| TSP (X10) | -0.018 | 0.009 | -2.01 | 0.047** |
| Manure (X11) | 0.008 | 0.014 | 0.56 | 0.579 |
| Liquid Insecticide (X12) | 0.007 | 0.009 | 0.74 | 0.463 |
| Liquid Fungicide (X13) | -0.003 | 0.007 | -0.42 | 0.674 |
| Solid Fungicide (X14) | 0.005 | 0.006 | 0.97 | 0.333 |
| Labor (X15) | 0.262 | 0.073 | 3.56 | 0.001*** |
| Irrigation (D1) | -0.117 | 0.049 | -2.39 | 0.019** |
| Land (D2) | 0.015 | 0.108 | 0.14 | 0.889 |
| Number of obs | 116 | | | |
| F(17, 98) | 45.65 | | | |
| Prob > F | 0.000*** | | | |
| R-squared | 0.8917 | | | |
| Root MSE | 0.1762 | | | |

Source: Author (2024)

Note: ***significant 1%; **significant 5%; and *significant 10%

The regression results indicate that the following variables significantly affect red chili production: land area (X1), ZA fertilizer (X6), Red Phonska (X7), KCl (X8), TSP (X10), labor (X15), and the irrigation system dummy (D1). Land area emerges as the most influential factor affecting red chili production. The regression coefficient is positive at 0.598 and statistically significant at the 1% level, indicating that a 1% increase in cultivated land area is associated with a 0.598% increase in red chili output, *ceteris paribus*. This finding aligns with previous studies reporting that land area is a key determinant of chili productivity (Zaman 2021; Rahmadanti et al. 2021; Fivintari et al. 2022; Rahmawati et al. 2023). This result contrasts with the findings of Ginting et al., who reported that land area did not exert a statistically significant effect on red chili production in North Sumatra, suggesting that differences in agroecological conditions, production practices, or model specifications may account for the divergent results (Ginting, D. R. B., 2025). These findings underscore that farm scale continues to play a crucial role in determining the level of red chili production, both in rice-field soils and coastal sandy lands. In agroecosystems that are relatively exposed to production risks, expanding the cultivated area provides farmers with greater flexibility to manage spatial variability in land conditions, thereby mitigating the impacts of partial crop failure arising from climatic stress, pest infestations, or imbalances in water availability. From a production economics perspective, the

results indicate that red chili farming has not yet reached scale saturation, suggesting that land expansion remains capable of generating relatively proportional increases in output.

The ZA fertilizer variable also exhibits a positive and statistically significant effect at the 1% level, with a regression coefficient of 0.022, consistent with findings that nutrient supplementation, particularly sulphur and nitrogen, improves plant growth and soil nutrient availability (Yi et al., 2018; Yusmaini et al., 2021). The relatively large magnitude of this coefficient suggests that ZA fertilizer is a highly responsive nutritional input in enhancing red chili production. Previous studies have similarly demonstrated that increased nitrogen application can promote crop yield and improve the availability of essential nutrients, although responses vary with crop type, soil properties, and management practices (Yang 2023). Moreover, balanced nitrogen application is known to be critical for optimizing crop performance and nitrogen use efficiency (NUE) in diverse cropping systems, emphasizing the importance of judicious fertilizer management in crop production (Navarro, B. B. 2025). Under coastal sandy soil conditions—characterized by low nutrient availability and high susceptibility to nutrient leaching—the application of ZA fertilizer tends to be more effective than other fertilizer types that are more prone to nutrient losses, enhancing nutrient uptake and crop productivity. Accordingly, these findings highlight that the quality and type of fertilizer are more influential in boosting red chili production than

merely increasing the overall intensity of chemical fertilizer use, especially in nutrient-limited environments.

The Red Phonska fertilizer variable was found to be negatively and significantly associated with red chili production (coefficient = -0.0210 ; $p = 0.035$), indicating that a 1% increase in its application corresponds to a 0.021% reduction in output, holding other inputs constant. Although counterintuitive, this negative relationship likely reflects nutrient imbalance or suboptimal application rates of compound NPK fertilizers under the specific agroecological conditions of coastal sandy soils and paddy fields. Previous studies have shown that interactions among nitrogen (N), phosphorus (P), and potassium (K) play a critical role in determining crop yield responses, and that inappropriate nutrient ratios or excessive application of individual components can impair nutrient uptake efficiency and ultimately constrain yield potential (Li, Z., Zhang, R., Xia, S., Wang, L., Liu, C., Fan, Z., & Chen 2019). More recent evidence further emphasizes the importance of balanced fertilization strategies, particularly the integrated use of organic and inorganic fertilizers, which has been shown to improve soil structure and enhance crop responsiveness compared with reliance on single compound fertilizers alone (Song, H., Yang, B., Liang, Y., Yang, L., Song, J., & Li 2024).

The KCl fertilizer variable exhibited a negative and statistically significant coefficient (-0.039 ; $p = 0.003$) in the Cobb–Douglas production function, indicating that, *ceteris paribus*, a 1% increase in KCl application

corresponds to a 0.0386% reduction in red chili output. Although potassium is an essential macronutrient for plant growth, the counterintuitive response suggests that additional K input in the form of KCl may not translate into productivity gains under the specific soil conditions of the study area. Empirical evidence has shown that when soil potassium levels are already adequate, further potassium fertilization is unlikely to improve yields and may instead disturb nutrient balance, thereby constraining overall plant growth (Raza et al., 2021).

The TSP fertilizer variable exhibited a negative and statistically significant coefficient (-0.0184 ; $p = 0.047$), indicating that a 1% increase in TSP application corresponds to an approximately 0.018% reduction in red chili output, *ceteris paribus*. This result suggests that additional phosphorus input may not enhance productivity when soil phosphorus levels are already sufficient, potentially leading to nutrient imbalance or reduced uptake efficiency. Consistent with previous studies, crop responses to phosphorus fertilization are often non-linear and context-dependent, varying with soil nutrient availability and interactions with other essential nutrients (Bilal, M. 2022). These findings emphasize the importance of balanced fertilization strategies and soil testing in optimizing nutrient management.

Labor exhibited a positive and highly significant coefficient (0.2617 ; $p = 0.001$), indicating that, *ceteris paribus*, a 1% increase in labor input was associated with an approximately 0.262% increase in red chili output This

reflects the labor-intensive nature of chili farming, especially in sandy soils that require more irrigation and maintenance. The finding is consistent with previous research showing that additional labor increases agricultural output (Risvansuna Fivintari & Darmayanti, 2022; Suswadi et al., 2021). This finding highlights the central role of labor in chili production systems, particularly where key agronomic activities—such as weeding, pest control, and harvesting—remain highly labor-intensive. Evidence from vegetable and horticultural studies similarly demonstrates that greater labor intensity is closely linked to higher yields, especially in production environments with limited mechanization (Saha, A. K. 2023). Moreover, previous research shows that not only the quantity but also the quality and timing of labor inputs significantly shape productivity outcomes in vegetable cropping systems (Ergün, M., & Kuhar 2017). These results suggest that improved labor allocation, skill enhancement, and timely execution of farm operations are critical pathways for boosting red chili productivity.

“The irrigation system variable (D1) exhibited a statistically significant coefficient (-0.1173; $p = 0.019$), indicating that red chili production differs significantly between non-shower and shower irrigation systems. This finding suggests that the choice of irrigation method plays an important role in determining productivity and is consistent with previous studies highlighting the influence of irrigation techniques on crop yield (Gutiérrez-Gómez et al., 2018; Kianpour et al.,

2017; Xiang et al., 2018). This pattern likely reflects differences in water delivery efficiency and soil moisture dynamics, as non-shower systems—such as furrow or drip irrigation—supply water more directly to the root zone, reduce evaporative losses, and maintain more stable soil moisture conditions than overhead shower systems. Consistent with this interpretation, empirical evidence from global irrigation studies demonstrates that advanced irrigation methods, including drip and subsurface drip irrigation, tend to enhance crop yields and water productivity compared with conventional sprinkler or flood irrigation, particularly under conditions of water scarcity (Banik, B., Korav, S., Guin, A., & Unjia 2024). These findings highlight the importance of selecting irrigation technologies that align water delivery with crop water requirements to support higher productivity in red chili production systems.

Meanwhile, fertilizer variables such as Urea, White Phonska, NPK, KNO, Manure, and all pesticide inputs show negative and statistically insignificant coefficients. Although previous studies have suggested that fertilizer and pesticide applications can increase chili production (Maniriho and Bizoza 2018; Nuraini and Widi 2020), the present study does not observe significant effects. This may be due to nutrient leaching in sandy soils, inappropriate dosage, or multicollinearity among nutrient sources when fertilizers are separated into multiple variables, as noted by the reviewer. Therefore, these inputs appear ineffective in increasing production under the conditions observed in this study.

Table 2. Regression Results of Factors Affecting Risk of Red Chili Production in Bantul

| Variable | Coef. | Robust Std. Err. | t | P> t |
|--------------------------|---------------|------------------|-------|---------|
| Constant | -4.061 | 2.589 | -1.57 | 0.120 |
| Land Area (X1) | 1.796 | 0.764 | 2.35 | 0.021** |
| Seeds (X2) | -0.351 | 0.571 | -0.62 | 0.540 |
| Urea (X3) | -0.012 | 0.125 | -0.09 | 0.927 |
| White Phonka (X4) | -0.176 | 0.133 | -1.33 | 0.188 |
| NPK Pearl (X5) | -0.186 | 0.127 | -1.47 | 0.145 |
| ZA (X6) | 0.083 | 0.121 | 0.69 | 0.493 |
| Red Phonka (x7) | -0.111 | 0.114 | -0.97 | 0.333 |
| KCL (X8) | -0.018 | 0.121 | -0.15 | 0.879 |
| KNO (X9) | -0.010 | 0.220 | -0.04 | 0.964 |
| TSP (X10) | -0.173 | 0.227 | -0.76 | 0.447 |
| Manure (X11) | 0.348 | 0.194 | 1.79 | 0.076* |
| Liquid Insecticide (X12) | 0.108 | 0.140 | 0.77 | 0.446 |
| Liquid Fungicide (X13) | -0.028 | 0.080 | -0.36 | 0.723 |
| Solid Fungicide (X14) | 0.084 | 0.085 | 0.99 | 0.323 |
| Labor (x15) | 0.153 | 0.690 | 0.22 | 0.825 |
| Irrigation (D1) | <u>0.421</u> | 0.553 | 0.76 | 0.448 |
| Land (D2) | 2.384 | 1.436 | 1.66 | 0.100* |
| Number of obs | 116 | | | |
| F(17, 98) | 3.37 | | | |
| Prob > F | 0.0001 | | | |
| R-squared | 0.2370 | | | |
| Root MSE | 2.0916 | | | |

Source: Author (2024)

Note: ***significant 1%; **significant 5%; and *significant 10%

Production Risk Analysis

Adverse outcomes arise from various production factors (Uddameri et al., 2020), including environmental, market, and operational risks (Burbano-Figueroa et al., 2022). These risks severely impact agricultural productivity and viability (Baimagambetova et al., 2018). Proper risk management is essential for competitiveness because production risks cause significant financial losses (Hryvkiivska, Karpinskyi, Prystemskyi, et al., 2024). Research conducted in Aceh shows that red chili plants have the second-highest production risk after patchouli plants (Fauzi et al., 2021). The analysis of factors influencing production risk obtained the following equation.

$$\sigma^2 Y_i = -4.061 X_1^{1.796} X_2^{-0.351} X_3^{-0.012} X_4^{-0.176} X_5^{-0.186} X_6^{0.083} X_7^{-0.111} X_8^{-0.018} X_9^{-0.010} X_{10}^{-0.173} X_{11}^{0.348} X_{12}^{0.108} X_{13}^{-0.028} X_{14}^{0.084} X_{15}^{0.153} D_{10}^{0.421} D_{22}^{2.384}$$

Factors significantly influencing risk of red chili production are land area, manure and Land (D2). Handling risk from farmers depends on the farmer's response (Atta and Micheels 2020).

Based on the statistical analysis, land area exerts a positive and statistically significant effect on production risk in red chili farming. This finding indicates that, rather than reducing uncertainty, expanding the cultivated area is associated with increased production risk. On larger farms, farmers' ability to perform intensive field monitoring, timely pest

and disease management, and rapid responses to production disturbances tends to decline, which can exacerbate variability in yields. Empirical evidence from risk analyses in smallholder agriculture demonstrates that larger cultivated areas can contribute to greater yield variability, particularly when management practices, soil conditions, and weather outcomes vary across the farm landscape (Salam 2022). Specifically, studies in rice production systems show that cultivated area act as a risk-increasing factor for yield variability, reinforcing the notion that scale expansion without parallel improvements in management capacity may heighten exposure to production risk (Salam 2022). Furthermore, the broad literature on agricultural risk highlights that farm-level production variability arises from interactions among management inputs, environmental conditions, and structural farm characteristics, such as farm size (Komarek, A. M., De Pinto, A., & Smith 2019). Accordingly, the present findings emphasize that land area functions not only as a production input but also as a risk-exposure factor, particularly in high-risk horticultural systems such as red chili, where spatial variation in agroecological conditions and management challenges can intensify production uncertainty.

The manure variable exhibits a positive and statistically significant effect on production risk ($\beta = 0.348$; $p < 0.10$), suggesting that inconsistent application rates, varying quality, and maturity of organic manure may increase yield uncertainty in the short term. Although organic manure is

widely recognized for its benefits in improving soil structure and long-term fertility, the variability of its effects under field conditions can translate into greater yield fluctuations when maturity and nutrient release patterns are inconsistent. Studies indicate that crop yield responses to organic manure are highly context-dependent, varying with the proportion of manure substitution, soil type, and management practices, which may contribute to unstable production outcomes (Han, Y., Lv, F., Lin, X., Zhang, C., Sun, B., Yang, X., & Zhang 2022). Moreover, long-term comparisons of organic fertilization systems reveal that different organic manure regimes can lead to differing levels of yield variability across growing seasons and crop types, highlighting that organic amendments do not universally reduce production risk (Salehi, A., Surböck, A., Gollner, G., Eitzinger, J. E., Wohlmuth, M.-L., & Freyer 2025). These findings underscore that without standardized quality control and appropriate application practices; manure may act as a source of production risk. The dummy variable representing land type (D2) exhibits a statistically significant effect ($\beta = 2.384$; $p < 0.10$), indicating that specific land characteristics or conditions structurally influence production risk in red chili farming. In this context, production risk differs between red chili cultivation on coastal sandy land and paddy fields. These empirical patterns align with research showing that land-use types and topographic variation significantly influence soil physical and chemical properties as well as crop yield

Table 3. The Relationship between the Use of Production Inputs and Production Risk

| Production Input | Coefficient of Production Factors | Production Risk Factor Coefficient |
|----------------------------------|-----------------------------------|------------------------------------|
| Constant | +*** | ns |
| Land Area (X_1) | +*** | +** |
| Seeds (X_2) | ns | ns |
| Urea (X_3) | ns | ns |
| White Phonka (X_4) | ns | ns |
| NPK Pearl (X_5) | ns | ns |
| ZA (X_6) | +** | ns |
| Red Phonka (X_7) | -** | ns |
| KCL (X_8) | -** | ns |
| KNO (X_9) | ns | ns |
| TSP (X_{10}) | -** | ns |
| Manure (X_{11}) | ns | +* |
| Liquid Insecticides (X_{12}) | ns | ns |
| Liquid Fungicide (X_{13}) | ns | ns |
| Solid Fungicide (X_{14}) | ns | ns |
| Labor (X_{15}) | +*** | ns |
| Irrigation (D_1) | -** | ns |
| Land (D_2) | ns | +* |

Source: Author (2024)

responses (Zewdie, S., Nigussie, T., & Worku 2024). Differences in soil nutrient status and microbial communities across land-use types further demonstrate how agroecological heterogeneity can shape plant nutrient dynamics and potentially yield stability (Zhao, X., He, W., Xiang, F., Zhu, J., & Li 2025). Moreover, variations in soil fertility indicators across land-use types, including organic matter and nutrient stocks, underscore the importance of land classification when assessing risk exposure and agronomic outcomes (Nguyen, K. P., Tran, T. T., Le, H. D. 2024). Hence, these findings reinforce the notion that production risk is inherently linked to land conditions, and location-specific risk management strategies are essential for improving resilience in diverse agroecosystems.

Relationship of Factors to Production and Production Risk

In Bantul Regency, farmers seek a combination of production factors that increase red chili output and reduce production risk. However, based on tables 1 and 2, the addition of production inputs, particularly land area, enhances red chili production but increases the risk. These results differ from research conducted in Watunohu District, North Kolaka Regency, where similar factor increases red chili production and reduces risk (Al-Amin & Hossain, 2019; Pan et al., 2017). The positive and statistically significant impact of land area on production risk suggests that larger cultivated areas not only enhance output but also amplify yield uncertainty. This pattern is supported by empirical studies showing that yield variability and production risk can vary substantially across

seasons and land conditions, highlighting the role of land heterogeneity in shaping risk profiles (Salam 2022). Additionally, smallholder risk analyses have found that differences in soil type, input application, and field management contribute to divergent risk outcomes, consistent with the notion that larger or more heterogeneous holdings may expose farmers to greater production uncertainty (Kansime, S., & Shisanya 2022). At a structural level, broader farm and land characteristics—including ownership security and plot size—have been linked with differences in investment risk and production outcomes, reinforcing that land attributes represent intrinsic risk factors, not merely passive production inputs (Akber, N., Paltasingh, K. R., Mishra, A. K., & Goyari 2024). This study contributes to the literature by providing empirical evidence from two distinct production systems (coastal sandy land and paddy fields) showing that the disaggregation of fertilizer variables reveals risk patterns that would otherwise remain hidden if fertilizer were treated as a single aggregated input, as commonly done in previous studies. Thus, the findings extend existing knowledge by showing that production risk in red chili farming is not only input-dependent but also highly context-specific, shaped by soil structure, irrigation method, and farmers' input management practices. This nuanced understanding offers a more precise explanation of why certain inputs reduce risk while others exacerbate it, thereby advancing the discussion beyond descriptive

associations toward a mechanism-based interpretation (Zhen et al., 2020).

CONCLUSIONS AND SUGGESTIONS

This study applied the Cobb-Douglas production function and Just and Pope's stochastic risk model to analyze the determinants of production and risk in red chili farming across different irrigation systems and land types. The findings revealed that land area, ZA fertilizer, and labor inputs significantly increased productivity, in contrast, the use of Red Phonska, KCl, and TSP fertilizers was associated with a significant reduction in red chili production. Irrigation systems were also found to be key factors, with red chili production differs significantly between non-shower and shower irrigation systems. In terms of production risk, land area and the use of manure increase the variability of production yields. Land type also has a statistically significant effect on production risk, with observable differences between coastal sandy land and paddy fields. These results highlight that sustainable productivity depends on input efficiency, irrigation optimization, and ecological adaptation. This study acknowledges several limitations, including its use of cross-sectional data, limited regional scope, and the exclusion of behavioral and institutional variables. Future studies should employ panel data approaches, include risk perception and management behavior, and compare different agroecological contexts to strengthen external validity. Practically, improving red chili farming sustainability requires balanced

fertilization, integrated pest management (IPM), and adaptive irrigation systems. This requires the role of local governments particularly in the role of agricultural extension workers to provide training to farmers on the use of balanced inputs, and irrigation technology subsidies to increase the productivity of red chili farming.

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