Shallot Production Risk: Case Study in Gunungkidul Region Yogyakarta Province

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Abstract. Shallot is a horticultural product that has good economic value for being cultivated by smallholder. Does this commodity have lots of production risks? Shallot farmers often face production risksthrough inefficient use of off-the-field production facilities, weather and pest attacks. The present study was conducted to estimate the risk of shallot production and its determinant factors. The study was carried out in Kapanewon Wonosari, which is situated on the karst mountains of Java Island. In moorland ecosystem, shallots are mostly cultivated by farmers although the large scale irrigation system is at a critical stage of water deficit derived from boreholes. The production risk was quantitatively evaluated by the Coefficient of variation (CV) on average level and also analyzed by Ordinary Least Square (OLS) through Just and Pope risk function model. The risk measured for shallot production appear at high level (CV: 68.5%). As a result, the loss rate for shallot farming in Kapanewon Wonosari is 68.5%. Moreover, the OLS regression results indicate that pesticide cost and number of planting show a positive significant effect on production risk while farm experience and major sowing quarter through April to June have a negative impact.

1 Introduction

Horticulture sector is the backbone of Indonesian economy [1] with high economic growth report (4.22% compared to 0.53 in year 2021) as Gross Domestic Product (GDP)) rate from this sector signal its higher performance over other sectors [2]. The horticultural commodities which very influential to agricultural inflation is shallots (*Allium cepa* L) contributing 0.09% of the inflation in December 2022 [3]**.** Due to the rising inflation, production rank by 22,230 tons from last year and exports were down 41.1% while imports soared a whopping 88.2% [4]. Meanwhile, shallot consumption in 2022 increased to become 831.14 thousand tons from the previous year at 790.63 thousand tons it was reported [5]**.**

The production area of Gunungkidul Regency, Kapanewon Wonosari is one out of three shallot center areas in the Yogyakarta region, which makes Yogyakarta as a total producer ranked to be number nine after five other provinces [6]. Shallot crop estimated in 2023 at the highest of all crops planted, reaching an area of 210.089 ha with a total production reached

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18,037.42 tons [7]. The dry climate with an air temperature range from 25-35°C in Gunungkidul that is suitable for shallot farming, which requires water resources include jahe gajah (*Zingiber officinale* Roscoe) and *Apsema canna panacatia* Roxb. Because of the thick cover soluble carbonate rocks in karst areas, it has abundant perennial groundwater and many minerals [8,9]. But this groundwater is a subterranean source, which makes it difficult for use [10]. Most farmers in Gunungkidul have been forced to drill wells on their land because the limited surface water [11].

During 2017-2022 variability was observed in the level of shallot production in Gunungkidul, which has resulted to losses at yield and risks shallot income risk [12]. Just and Pope (1979), risks are inevitable in agricultural production processes; because farm activities take place under the influences of nature (weather, climate, soil minerals), which also difficult to manage for every farmer so it is quite necessary to identify these sources as primary. These production risks are then amplified by market, institutional, personal (also described as idiosyncratic) and financial risks [13,14]. This is already reflected in the relationship between volatility and producer prices. As shown in Figure 1, production sharply increased from 2020 to 2021, followed by a decrease in the average producer price at the Argosari Wonosari Market, from Rp34,189 to Rp24,489, and subsequently experienced a significant decrease from 2021 to 2022, resulting in a price increase to IDR 33,948 in 2022 [15]. Consequently, production fluctuations lead to price fluctuations; for instance, oversupply leads to price declines, and vice versa [15,16].

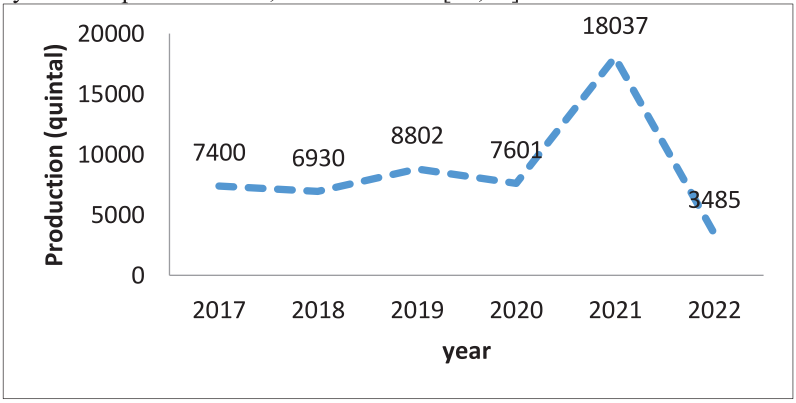

Figure 1. Shallot Production in Gunungkidul 2017-2022

Shallot management must be intensive due to the high risk of crop failure [17]. Nonetheless, the compensation for farmer's willingness to take such risks is a large income opportunity [18]. The problem of shallot production risk does not only occur in Indonesia, but is also in several countries such as India [19], Ethiopia [20], Polandia [21], and Iran [22]. Risk in farming cannot be avoided or eliminated, but it can be anticipated so that the associated losses are manageable. Production risk analysis is significant because it helps farmers determine the degree of allocation and alternative usage of inputs that can reduce yield losses. As a result, it is vital to analyze the level and production risk elements of shallot farming in order to develop an effective management strategy.

2 Material and Method

This study was carried out in September 2023. The research areas were purposefully chosen in Kapanewon Wonosari, Karangrejek, and Duwet districts as shallot centers, with a production quantity of 3,485 quintals in 2023, the most among the 17 Kapanewon [23]. The region is also karst mountainous, with dry soils. Furthermore, shallot farming in the region was exposed to production risk, resulting in a 13.5% decrese in harvested area in 2023 compared to 2022 [24]. The population in this study was all farmers who cultivated shallots in Karangrejek and Duwet districts with heterogeneous socio-economic characteristics so that sampling applied proportionate stratified random sampling. The sample used was 50 respondents with data collection techniques through interviews using a questionnaire.

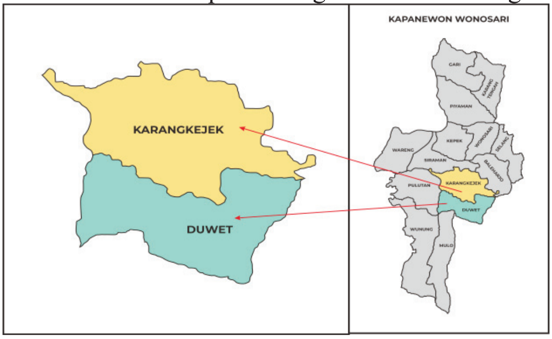

Figure 2. Map of The Research Area

To analyze the first objective in this study, regarding the level of production risk using coefficient of variation (CV). Coefficient of variation is computed by dividing the standard deviation by the average production yield [23]. The calculation formula for the coefficient of variation (CV) is:

$$\text{Coefficient Variation (CV)} = \frac{\sigma t}{\bar{x} y} \tag{1}$$

Where σt is the standard deviation and $\bar{x}y$ is the average yield. The following is the level of classification of the size of risk received, which is divided into two, namely [24]:

a) CV value ≤ 0.5 indicating low risk
b) CV value > 0.5 indicating high risk

The level of risk is influenced by differences in social and economic factors between farmers. Testing factors influencing production risk use OLS (Ordinary Least Squares) regression analysis with the Just and Pope (1979) production risk function, which states that production is influenced not only by various input parameters, but also by risk factors. According to Just and Pope (1979), the production risk function model is represented by the mean production function and the variance production function of production input factors. The Just and Pope function model can be expressed mathematically as follows:

$$y = A\left(\prod_{i=1}^{n} X_i^{ai}\right) e^{\epsilon}, \tag{2}$$

Where y is output; X_i is input factor ($X_i > 0$), and *e* is stochastic disturbance with E(*e)* = 0, V(*e*) > 0. The existence of the marginal effect of input utilization will have an impact on production variability, which can be expressed as follows:

$$V(y) = A^2\left(\prod_{i=1}^{n} X_i^{2ai}\right) V(e^{\epsilon}), \tag{3}$$

So that the change in output variability caused by changes in input is

$$\frac{\partial V}{\partial X_i} = \frac{2a_i A^2}{X_i}\left(\prod_{i=1}^{n} X_i^{2ai}\right) V(e^{\epsilon}) > 0, \tag{4}$$

It is assumed that $a_i > 0$, then the impact of an increase in input utilization will increase output variability when $a_i > 0$. However, the effect of an increase in input on average output cannot be paired directly with its impact on output variability, so Just and Pope (1979) developed a model to overcome this limitation:

$$y = f(x) + h\frac{1}{2}(x)\, e\ ,\ E(e) = 0,\ V(e) = 1 \qquad (5)$$

As a result, the influence of input changes on average output and output variability can be described in several ways. As a result, the Just and Pope model is used to quantify production risk as determined by output variability. Furthermore, the input factors are classified into two, risk reducing factors or input factors that reduce risk, and risk inducing factors, input factors that cause risk [25].

The first stage of estimating the production function involves testing classical assumptions with the Shapiro Wilk normality test, VIF multicollinearity test, and the Breusch-Pagan/Cook-Weisberg heteroscedasticity test. The steps for evaluating the production risk function are as follows [26–28]:

1. Regressing the value of InY (production) to the dependent variables $\text{In}X_1$ to DX_9 to obtain a BLUE (*Best Linear Unbiased Estimation*) by using the Cobb Douglas production function equation, as for the following regression equation model:
   The Cobb Douglas regression model:
   $$\text{LnY} = Ln\beta_0 + \beta_1 \text{Ln}X_1 + \beta_2 \text{Ln}X_2 + \beta_3 \text{Ln}X_3 + \beta_4 \text{Ln}X_4 + \beta_5 \text{Ln}X_5 + \beta_6 \text{Ln}X_6 + DX_7 + DX_8 + DX_9 + e_1 \qquad (6)$$
2. The $\text{In}X_1$ to DX_9 coefficients estimated from the Cobb-Douglass function are then used to calculate the value of ŷ by summing up the product of the coefficient of each variable with the actual variable.
3. Calculating the residual value (e) which will be used as the dependent variable in the Just and Pope production risk function by subtracting InY (actual production) - Lnŷ (estimated production) and squaring it to get the absolute value.
   Residual:
   $$|e| = (y - \hat{y})^2 \qquad (7)$$
4. Estimating the parameters of the production risk function by regressing |e| on In variables X_1 to DX_9 using the OLS method through Stata software.

The production risk value is calculated as the difference between actual (y) and estimated production (ŷ) using a regression model. Just & Pope's risk function model:

$$\text{In}|e| = \text{Ln}\theta_0 + \theta_1\text{LnX}_1 + \theta_2\text{LnX}_2 + \theta_3\text{LnX}_3 + \theta_4\text{LnX}_4 + \theta_5\text{LnX}_5 + \theta_6\text{LnX}_6 + \text{DX}_7 + \text{DX}_8 + \text{DX}_9 + e_2 \qquad (6)$$

Where:
Y = shallot production (kg)
|e| = residual
X_1 = land area (m^2)
X_2 = seedlings (kg)
X_3 = fertilizer cost (Rp)
X_4 = pesticides cost (Rp)
X_5 = labor and machinery cost (Rp)
X_6 = farm experience (year)
DX_7 = *dummy* planting frequency (1 = planted more than once in a year, 0 = otherwise)
DX_8 = *dummy* main growing season (1 = plant in the main growing season (Mei –Juli), 0 = otherwise)
DX_9 = *dummy* number of blocks (1= farmer planted more than one block, 0 = otherwise)
β_0, θ_0 = intercept
e_1, e_2 = *error term*
$\theta_{1\ldots}\theta_9$ = estimated parameter coefficient $X_1..X_9$

3 Result and Discussion

Table 3.1 shows the findings of the computation of CV as a measure of risk level of 0.685, or 68.5%, which is considered as high risk since CV >0.5. The high level of risk is due to the large variation or deviation of farmer productivity [29]. This means that farmers that plant shallots in Wonosari, an area surrounded by karst hills with dry soil, risk losing significant crop yields. These results aligns with studies [30] and [27] which also showed a high level of risk in shallot production with CV>0.5. The high variation in productivity was caused by weather change and pest & plant disease [31].

Table 3.1. Risk Level of Shallot Production in Wonosari, Gunungkidul Regency, DIY

Description	Value
Average Productivity	7.072,24 kg/ha
Standard Deviation	4.844,54
Coefficient Variation	0,68
CV (%)	68,50%

Changes in rainfall cause a decline in crop quality, which is an external risk for shallots [32,33]. High rainfall will result in waterlogged land [34] which makes the tubers rot. In addition, waterlogged land will bring in plant pests and diseases [35]. Farmers take preventive measures to avoid weather difficulties by building high beds so that the land does not become swamped in water after heavy rain. The optimal bed dimensions are 1.0 - 1.2 m wide and 30 cm high, with the goal of elevating the soil surface because shallots demand a lot of water yet are susceptible to puddles [36]. Farmers also use borehole-based irrigation systems to prevent water shortages during the dry season. Water from the well is moved into a reservoir (on the surface), which requires energy in the form of petrol fuel for a diesel engine or charging pulses for farmers using sibel. 44% of farmers use diesel for irrigation, with an average daily cost of Rp11,852.81, while 56% use sibel, with a daily cost of only Rp4,322.85. As a result, sibel irrigation will cost less than diesel. This aligns with study [37] and [38] which found that diesel irrigation requires higher costs.

Pest and plant disease attacks are another form of external risk that can be difficult to manage [39,40]. Pest infestation is a factor that causes descrease in production and even crop failure, resulting in yield losses of up to 60-70%, particularly in tropical countries [41]. There are 3 types of pests that often attack shallot plants in the research area; armyworms (*Spodoptera exigua*) shown in Figure 3.1, fungi (*Fusarium oxysporum f.sp cepae*) shown in Figure 3.2, and gerandong (leaf-miner fly) shown in Figure 3.3. The three types of pests have their own levels of damage, but the most extreme impact is from gerandong attacks (a term attached by farmers). Based on interviews with farmers, gerandong pests attack at night which makes the shallot leaves become unfilled, the tops of the leaves turn yellow, and eat part of the bulb. The pest is caused by the *Liriomyza chinensis* fly that lays eggs on the leaves and will hatch in 3-5 days into larvae that slit the mesophyll of the leaves, causing crop failure [42]. In addition, armyworm pests attack throughout the leaf growth stage, typically at night [3,43] which results decrease in shallot quality, namely drying and premature leaf fall. Shallots in the research area were also attacked by a disease from the fungal kingdom, *Fusarium oxysporum f.sp cepae*, which is often known as moler disease [44] and often attacks in the rainy season [45,46]. Moller disease attacks cause plants to wilt, rot at the roots, fall easily, rot in curled leaf tips, yellowing, rotting tubers, patches around the tubers, and eventually death [47,48].

Figure 3.1. Armyworm

Figure 3.2 Impact fusarium attack

Figure 3.3. Gerandong

Table 3.2. shows the descriptive statistics of the independent variables in this study. Differences in the socio-economic conditions of farmers greatly affect the level of risk and their risk attitude [49]. Farmers in Kapanewon Wonosari have an average land area of 1,530m^2, with land tenure options including owned and rented. Farmers grow shallots on moorland intercropped with chilies, eggplants, and peanuts. The land size impacts the amount of production [50]. Furthermore, the land area correlates with the number of seedling used. The seedlings used by farmers are Thailand-Nganjuk introduced varieties (Tajuk) with a harvest age of 52-59 days [51]. According to farmers' perceptions, the Tajuk variety is suitable for development in the area because it produces a large number of tillers, harvests faster (<60 days), and is more resistant to pests and plant diseases.

Table 3.2. Descriptive Statistics

Variable	Descriptive	Mean	Std. Dev.
Land Area (X_1)	Land area owned by farmers (m^2)	1,530	707.34
Seedlings (X_2)	Number of seedlings planted (Kg)	80.68	57.60
Fertilizer cost (X_3)	Total cost of fertilizer purchase (Rp)	1,926,880	1,819,773.40
Pesticide cost (X_4)	Total cost of pesticide purchase (Rp)	450,675,84	688,037.79
Labor and Machinery Costs (X_5)	Total cost for labor payment and tractor rental (Rp)	2,856,673.52	1.810,580.52
Farm Experience (X_6)	Farmer's length of experiences (year)	18	12.03
Planting Frequency (X_7)	1 = planted more than once in a year, 0 = otherwise	0.06	0.24
Main Growing Season (DX_8)	1 = plant in the main growing season (Mei – Juli), 0 = otherwise	0.90	0.30
Number of blocks (DX_9)	1= farmer planted more than one block, 0 = otherwise	0.66	0.48

Farmers try to maximise productivity, so they use many inputs that can increase production, such as fertilisers and pesticides [52]. Farmers purchase numerous varieties of K, N, P, chemical and organic fertilisers, and pesticides under various brand names so that the best strategy is to evaluate the cost. Furthermore, land cultivation activities demand labor from both outside and within the family, with an average cost of Rp2,856,673.52.

Socio-psychological conditions also influence the risk level accepted by farmers [53]. The average farm experience at the research sites was 18.1 years. Farm experience will influence the level of competence and knowledge, as well as how risks are evaluated and decisions made [54]. Furthermore, variables in planting frequency, main growing season (planting schedule), and land block ownership all influence the level of risk. This study covers shallot farming in the year 2023, and during that time, some farmers only plant once within the agreed-upon planting season, which is May - July due to lower rainfall than other months. This is because planting during the rainy season increases the probability of land flooding, resulting in crop failure. From May to July, the average rainfall in Gunungkidul was 218.1 - 35.5 mm [55] which is following the optimal needs for shallot growth. Furthermore, the number of land block possessed will influence the magnitude of the danger. The more pieces of land held, the more complex the upkeep that must be done, resulting in varying risk levels.

Based on the regression analysis results of the Just and Pope risk model (Table 3.3), the *Adjusted* R^2 value was 0.6917 with a significant F probability, indicating that the independent variables of the model might jointly explain the dependent variable. Previously, when estimating production risk using the Cobb Douglas model, classical assumption testing was performed, and the results of the normality, autocorrelation, and heteroscedasticity tests were greater than alpha 10%, indicating that the model's errors were normally distributed, there was no correlation between one observation and another, and the regression model's residual variance was constant. Furthermore, multicollinearity testing indicates no linear relationship between the independent variables, with a correlation coefficient of less than one and a VIF value is <5.

Table 3.3. Factor Affecting the Risk Level of Shallot Production in Kapanewon Wonosari, Gunungkidul Regencey, Daerah Istimewa Yogyakarta, 2023

Variable	*ExpSign*	*Coefficient*	*Std. Error*	*t-stat*	*Prob.*
C	+	-1.20519^{Ns}	2,1670	-0.56	0.580
Ln Land Area (X_1)	+	0.30736^{Ns}	0,1901	1.62	0.114
Ln Seedling (X_2)	+	-0.326152^{Ns}	0,2196	-1.49	0.145
Ln Fertilizer cost (X_3)	-	-0.033429^{Ns}	0,0677	-0.49	0.624
Ln Pesticide cost (X_4)	+	0.133997*	0,0728	1.84	0.073
Ln Labor and Machinery cost (X_5)	+	0.0837879^{Ns}	0,1201	0.70	0.489
Ln Farm Experience (X_6)	-	-0.1271357*	0,0695	-1.83	0.075
Dummy Planting Frequency (X_7)	+	0.9472635**	0,3401	2.79	0.008
Dummy Main Growing Season (DX_8)	-	-1.62915***	0,1949	-8.36	0.000
Dummy Number of blocks (DX_9)	-	0.026992^{Ns}	0,1909	0.14	0.888
Number of Obs					50
R-Squared					0.7483
Adj R-Squared					0.6917
Prob > F					0.0000

Where:
* : significance at the error level 10% (α=0,10)
** : significance at the error level 5% (α=0,05)
*** : significance at the error level 1% (α=0,01)
^{NS} : non significance

Just and Pope's production risk model estimates that an increase in pesticide costs can increase production risk. This aligns with research [56] and [57]. According to the interview data, 98% of farmers used chemical pesticides under various trademarks as a preventive or risk mitigation measure. Chemical pesticides were allocated based on farmers' perceptions of their effectiveness in controlling pests and plant diseases, and the dose was increased whenever an attack occurred. This condition allocated resources and expenses inefficiently, increasing the danger as pests develop to become more resistant [27]. The long-term impact also causes negative externalities for the environment and health [58] and [57].

The difference in the frequency of planting shallots has a beneficial effect, resulting in a difference in the magnitude of the production risk for farmers who plant more than once by up to 2.579 kg compared to planting once. This aligns with a some study that because planting many times during the rainy season (off-season) increases the risk of production loss due to incompatibility between weather conditions and shallot growing requirements [30,59]. Farmers who cultivate more than once a year typically do not work a second job and rely only on shallot cultivation for their source of income.

Farm experience has a negative influence so that the more farmers have experience, the lower the amount of risk. Farmers with more experience and abilities can read opportunities and are less willing to take chances, allowing them to mitigate risks effectively [30]. Farmers in the research location have an average experience of 18.1 years, with 56% falling between the ages of 10 and 30.

According to the findings of this study, the difference in the main growing season has a negative effect, meaning that farmers who plant outside of the main season face a lower risk than farmers who plant during the main growing season. The major growing season is the planting season, which is the benchmark and is accepted by farmers when planting shallots in the research area. As many as 90% of farmers plant simultaneously during the main growing season, so if one land is affected by the attack, the spread to other land will be rapid. Planting season dummy has a negative and significant effect on production risk. Some pests and diseases that target shallots are polyphagous, which means that the infestation can spread to other crops that are intercropped [59,60].

4 Conclusion

The production risk level of shallot farming in the karst mountains of Kapanewon Wonosari, Gunungkidul, has a coefficient of variation (CV) value of 0.685, indicating a high level of risk. Weather changes, insect attacks (particularly armyworms and gerandong), and moler plant disease attacks all pose significant risks. According to the Just and Pope model estimation, pesticide cost and planting frequency more than once a year, can increase production risk. However, farm experience and planting outside of the main planting season can lower the risks associated with shallot production.

The findings of this study are significant for policymakers involved in extension improvements. Policymakers should consider these findings to enable shallot farmers to adopt preventive and risk mitigation strategies. These strategies may include strengthening farmer institutions and providing resources on pesticide allocation at appropriate dosage and target levels. Given the high level of production risk, farmers should consider utilizing insurance as a means to mitigate risks. Additionally, farmers may benefit from assessing the frequency of planting and determining the optimal planting season for shallot farming.

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