

The Role of Cropping System on Horticultural Farming Production and Income in the Bromo Region

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Abstract. Ngadisari Village, a leading horticultural center in the Bromo highlands, is known for its potato, leek, and cabbage cultivation by the Tengger community. Farmers commonly use two systems: potato monoculture and intercropping with leeks or cabbage, which affect production and income. This study analyzes the role of the cropping system, specifically comparing monoculture and intercropping in influencing the production and income of potato farming in the Bromo region. Data from 50 potato farmers, selected via snowball sampling, were analyzed using a Cobb-Douglas production function and multiple linear regression. Results show that land area, seed quantity, and cropping system have a significant influence on production. Meanwhile, production costs and cropping system are the key determinants of farmer income. These findings highlight that the choice of cropping system is crucial for the economic performance of potato farming. The research offers a practical, evidence-based guide for farmers to select optimal systems to maximize income. Furthermore, it provides valuable insights for government policies aimed at enhancing agricultural productivity and supporting the economic stability of highland communities.

1 Introduction

The horticulture subsector contributes 1.55% to Indonesia's Gross Domestic Product (GDP), ranking fourth in the agricultural sector [1]. One of the horticultural commodities with high economic value is potatoes. East Java is the province with the highest potato production in Indonesia, with an average production of 339,367.8 tons per year in the last five years.

Although there was a decrease in production of 8.4% in 2021 due to the Covid-19 pandemic and land conversion, the trend of potato production continues to increase. Probolinggo Regency, as part of East Java, has great potential in potato development due to its supportive natural conditions, namely highlands with an altitude of 1,000-1,300 meters

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above sea level and suitable temperatures [2]. Based on data from BPS East Java (2023), the district ranks second in potato production with an average production of 560,545 tons during 2021-2022.

One of the leading areas in potato production is Ngadisari Village in Sukapura Sub-district, which is located in the Bromo Tengger Semeru highland area. The village's agricultural potential is supported by data from BPS Sukapura Sub-district (2018), which notes that 30.56% of the population work as horticultural farmers, making potatoes the main commodity [3]. Farmers in this village apply two cropping systems, namely monoculture and intercropping (with leeks or cabbage), where the intercropping system takes advantage of the difference in harvest age between crops. This strategy provides two advantages: efficient use of production inputs and additional income opportunities before the potato harvest.

However, the use of the same inputs for two different crops in an intercropping system may result in potatoes not receiving optimal inputs, which has an impact on decreased productivity. On the other hand, cost efficiency is an advantage as one input is used for two commodities. Therefore, it is important to assess the differences in production and income between monoculture and intercropping systems. Previous studies have examined the agronomic constraints of input competition and the general sustainable intensification benefits of intercropping [4,5]. There remains a paucity of empirical research specifically quantifying the simultaneous economic trade-offs between production determinants and income formation within the unique agro-ecological context of the Bromo Tengger highlands. Unlike prior research that often treats cropping systems solely as a technical variable, this study offers novelty by integrating a comparative analysis of the Cobb-Douglas production function with income determinants. This approach allows for a clearer identification of how the specific choice between monoculture and intercropping systems directly alters the economic structure and profitability for smallholder farmers in high-altitude volcanic regions. This study aims to analyze the role of the cropping system, specifically comparing monoculture and intercropping in influencing the production and income of potato farming in the Bromo region.

2 Methods

This research was conducted purposively in Ngadisari village, Sukapura sub-district, Probolinggo district, which is known as a center for horticultural production, especially potatoes. This area was chosen because farmers practiced monoculture and intercropping (potatoes with leeks or cabbage), making it relevant to study their farming strategies [3]. The research method used was descriptive quantitative and analytical, with a sample size of 50 potato farmers determined using snowball sampling technique. The data collected consisted of primary and secondary data. Primary data were obtained through direct observation and interviews, including information on production, land area, input costs, income, experience, education, and cropping systems. Secondary data was obtained from various agencies such as BPS, Ministry of Agriculture, and subdistrict offices.

Data analysis was conducted using two approaches. First, to determine the factors affecting potato production and the effect of cropping systems, regression analysis with the Cobb-Douglas production function model was used. Second, to analyze the income and the effect of cropping systems on farmers' income, multiple linear regression analysis was used. The dummy variables used are monoculture = 0; intercropping = 1. The tolerable error rate is 5%. Statistical testing is done through the F test (simultaneous), coefficient of determination and t test (partial). In addition, classical assumption tests were carried out including: multicollinearity test, heteroscedasticity test, autocorrelation test, and normality test. The Cobb-Douglas production function equation can be written as follows
The Cobb-Douglas production function equation can be written as follows.

$$Y = b_0 X_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} e^{b_6 D} \tag{1}$$

To facilitate the estimation, the equation is converted into a multiple linear form by logarithmizing it so that the equation becomes:

$$\ln(Y) = \ln b_0 + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 D \tag{2}$$

Dependent variable Y = Potato farm production (kg), b_i = Regression coefficient, X_1 = Land area (ha), X_2 = Labor (HOK), X_3 = Quantity of seed (kg), X_4 = Quantity of fertilizer (kg), X_5 = Quantity of pesticide (liter), and D = Dummy variable (cropping system).

Factors affecting farm income were analyzed using multiple linear regression analysis, through the following equation.

$$Y = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 D + e \tag{3}$$

Where, Variable Y is potato farming income (Rp/ha), X_1 = farmer education (years), X_2 = farming experience (years), X_3 = production costs (Rp/ha), D = Dummy variable (cropping system).

3 Results and Discussion

3.1 Respond characteristic

The research site is Ngadisari Village, Sukapura Sub-district, Probolinggo Regency, which is a highland area at an altitude of 1,800 meters above sea level within the Bromo Tengger Semeru National Park zone. The village with a total area of 775 hectares is dominated by agricultural land in the form of fields/moorland covering 456 hectares or 58.8% of the total area [6]. This dominance of moorland emphasizes the characteristics of the village's agricultural system as dryland (rainfed) agriculture, where farmers rely heavily on rainfall for irrigation. Agricultural activities are the main livelihood for most of the 1,447 residents of Ngadisari Village. The leading horticultural commodities cultivated on the sandy soil type include potatoes, cabbage, and leeks. Local farmers apply two main cropping systems: monoculture (especially potatoes) and intercropping. Intercropping, which combines the main crop (potatoes) with secondary crops (leeks or cabbage), is a strategy to increase farm income [3]. The characteristics of respondents in the study are presented in Table 1.

Table 1. Characteristics of potato farmer respondents in the Bromo Region.

General Characteristics	Range	Total (Farmer)	Average
Land Area (ha)	≤ 0.5	8	1.8
	>0.5 – 3.5	39	
	>3.5	3	
Total		50	
Farmer Age (years)	25-44	29	42
	45-54	18	
	>55	3	
Total		50	
Farming Experience (years)	11 – 20	7	24
	21 – 30	30	
	31 – 40	13	
Total		50	
Education (years)	Elementary and Junior High School	27	Junior High School
	Senior High School	18	
	Bachelor's Degree	5	
Total		50	
Cropping System	Monoculture	19	Intercropping
	Intercropping	31	
Total		50	

Source: Authors' identification, 2025

3.2 Production analysis of potato farming in Bromo Region

The use of factors affecting the production of potato farming in Bromo Region analyzed includes land area (X_1), labor (X_2), the quantity of seeds (X_3), the quantity of fertilizer (X_4), the quantity of pesticides (X_5), and dummy (D) in the form of monoculture with a value of zero and intercropping with a value of one. Data on the average use of production factors for potato farming in Bromo Region are presented in Table 2.

Table 2. Average use of potato farm production factors in Bromo Region.

No.	Description	Cropping System	
		Monoculture	Intercropping
1	Land area (ha)	2.62	1.60
2	Average productivity (kg/ha)	23,283.00	30,569.00
3	Average use of production factors		
	a. Quantity of seeds (kg/ha)	4,305.00	2,330.00
	b. Quantity of fertilizers (kg/ha)	607.00	548.00
	c. Quantity of pesticides (liters/ha)	59.00	50.00
	d. Labor (HOK/ha)	51.53	43.48

Source: Authors' computation, 2025

Based on Table 2, potato farming with a monoculture cropping system produces lower productivity than potato farming with an intercropping system. The difference in productivity between the two is 7,286 kg/ha, higher in the intercropping system. This occurs because at the same planting time and with the same land area, it is not only used for potato cultivation

but also for leek and cabbage cultivation, in other words, the land area is used for cultivation of more than one type of crop [7,8].

The potato production function was analyzed using the exponential function (cobb-douglas) approach. The regression model used has passed the classical assumption test, so it can be concluded that the model is statistically valid and able to explain the relationship between production factors and potato farm production [9–11]. The results of the potato production function analysis in Bromo Region are presented in Table 3.

Table 3. Production factor analysis of potato farming in Bromo Region.

Coefficient Table					
Model	Regression Coefficient (b _i)	t-statistic	Significance	Tolerance	VIF
Constant	8.733	5.016	0.000***		
Land area (ha)	0.658	3.443	0.002***	0.172	5.825
Labor (HOK)	-0.055	-0.187	0.853 ^{ns}	0.555	1.801
Quantity of seeds (kg/ha)	0.334	1.425	0.000***	0.108	9.241
Quantity of fertilizers (kg/ha)	-0.121	-0.760	0.455 ^{ns}	0.183	5.475
Quantity of pesticides (liter/ha)	-0.015	-0.111	0.913 ^{ns}	0.201	4.974
Cropping system	0.182	1.680	0.000***	0.585	1.711
ANOVA Table					
F-statistic = 15.093					
Sig. = 0.000					
R ² = 0.745					

Note. *** = $\alpha < 0.01$, ** = $\alpha < 0.05$, * = $\alpha < 0.10$, ^{ns} = not significant

Source: Authors' computation, 2025

Based on Table 3, the calculated F-statistic is 15.093 and the significance value of 0.000 is smaller than α (0.05) in the ANOVA table, meaning that production factors jointly or simultaneously have a real effect on potato farm production in Bromo Region at a 95% confidence interval. Adjusted (R²) is 0.745 or 74.5%. This value means that 74.5% of the variation in potato farm production in Bromo Region can be explained by the variation in production factors used in the model. The remaining 25.5% is explained by other variables outside the model. Based on the analysis, the Cobb-Douglas production function model of potato farming in Bromo Region can be estimated with the following equation.

$$Y = (\text{Exp } 8,733) X_1^{0,658} X_2^{-0,055} X_3^{0,334} X_4^{-0,121} X_5^{-0,015} D^{0,182} \tag{4}$$

$$Y = 6,204 X_1^{0,658} X_2^{-0,055} X_3^{0,334} X_4^{-0,121} X_5^{-0,015} D^{0,182} \tag{5}$$

Table 3 shows that the independent variables that partially have a significant effect (sig. < $\alpha = 0.05$) on the production of potato farming in Bromo Region are land area, number of seeds, and cropping system between monoculture and intercropping. The results of the analysis show that the land area variable has a real and positive effect on potato production, with elasticity at the rational production stage [12]. This indicates that an increase in land area significantly increases production. In contrast, the variables of labor, quantity of fertilizer, and quantity of pesticide have no significant effect and have negative coefficients. This indicates that excessive or inefficient use of these three inputs can reduce production, especially if they are not in accordance with the principles of proper use (5T concept). The

variable number of seeds has a positive and significant effect on production. This means that the use of quality seeds and the right quantity can increase the productivity of potato farming. The cropping system dummy variable shows that intercropping significantly increases production compared to monoculture. This is due to intercropping with other crops, namely leeks and cabbage, when the potatoes are still small. As soon as the potato starts to grow beyond 3 months, the cabbage or leeks are harvested [13]. Therefore, the intercropping system does not interfere with potato farming and even has higher production than monoculture.

3.3 Analysis of potato farming income in Bromo Region

Potato farmer income is calculated by subtracting potato farm receipts from all costs incurred. Revenue is uniformed in the calculation of revenue per hectare of land area. Data on revenue, costs and income per hectare are presented in Table 4.

Table 4. Average production costs and income of potato farming in Bromo Region.

No.	Description	Cropping System	
		Monoculture	Intercropping
1	Average land area (ha)	2.62	1.60
2	Average productivity (kg/ha)	23,283.00	30,569.00
3	Average income (Rp/ha)	143,571,661.00	156,859,679.00
	Average production costs (Rp/ha)		
	a. Variable costs	40,175,730.00	36,695,927.00
	1. Seed costs (Rp/ha)	34,493,464.00	30,701,370.00
	2. Labor costs (Rp/ha)	1,711,012.00	2,696,213.00
	3. Fertilizer costs (Rp/ha)	1,522,403.00	1,375,361.00
	4. Pesticide costs (Rp/ha)	2,448,852.00	1,922,983.00
	b. Fixed costs (Rp/ha)	519,494.00	503,415.00
4	Average income (Rp/ha)	102,876,436.00	119,660,337.00

Source: Authors' computation, 2025

Based on Table 4, the average acceptance of potato farming in Bromo Region with monoculture planting system of Rp143,571,661 is lower than potato farming with intercropping planting system of Rp156,859,679. The difference in revenue between monoculture potato farming and intercropping potato farming is Rp13,288,018. Production costs of monoculture potato farming in Bromo Region are higher than intercropping potato farming. This is because the costs used for intercropping are able to finance the cultivation of two different types of plants. This means that potato farming in Bromo Region by applying intercropping cropping systems can minimize production costs because the inputs used can simultaneously meet the needs of two different types of plants, namely potatoes and leeks or cabbage. The behavior of horticultural farmers in the Bromo region does not distinguish the allocation of inputs in intercropping and monoculture cropping systems, only a little need for additional labor to plant, care for, and harvest crops other than potatoes (cabbage or leeks) [14].

The income from intercropping potato farming in Bromo Region generates greater income compared to monoculture potato farming with a difference of IDR 16,783,901. This is in accordance with the theory that by applying intercropping cropping systems, farmers can obtain additional income before the potato harvest. Thus, farmers not only earn income from potato crops but also from leeks or cabbage because leeks and cabbage can be harvested before the potato harvest period, which is at the age of 90-105 HST.

Factors thought to influence potato farming income in Bromo Region include farmer education (X_1), farming experience (X_2), production costs (X_3), and dummy cropping systems (D), which were analyzed using multiple linear regression with IBM SPSS Statistics 25. Table 5 below shows the results of the analysis of the simultaneous effect, R^2 value, and partial effect of factors influencing potato farming income in Bromo Region.

Table 5. Factor analysis of potato farming income in Bromo Region.

Coefficient Table					
Model	Regression Coefficient (b_i)	t-statistic	Significance	Tolerance	VIF
Constant	68,673,369.77	1.873	0.073*		
Farmer education	494,179.50	0.340	0.737 ^{ns}	0.801	1.248
Farming experience	239,622.90	0.360	0.722 ^{ns}	0.863	1.159
Production cost	1,120	2.342	0.027**	0.901	1.110
Cropping system	19,973,183.02	2.241	0.034**	0.905	1.105
ANOVA Table					
F-statistic = 2.606					
Sig. = 0.000					
$R^2 = 0.535$					

Note. *** = $\alpha < 0.01$, ** = $\alpha < 0.05$, * = $\alpha < 0.10$, ^{ns} = not significant

Source: Authors' computation, 2025

Based on Table 5, the calculated F-statistic is 2.606 and the significance value is 0.000, which is smaller than α (0.05) in the ANOVA table. Thus, the factors that influence income together have a significant effect on potato farm income in Bromo Region at the 95% confidence interval. Adjusted (R^2) is 0.535 or 53.5%. This value means that 53.5% of the variation in potato farm income in Bromo Region can be explained by variations in income factors such as farmer education, farming experience, production costs, and intercropping and monoculture cropping systems used in the model. The remaining 46.5% is explained by other variables outside the model. Based on the results of the analysis in Table 5, the regression equation to show the relationship between factors affecting income and potato farming income in the village is as follows.

$$Y = 68.673.369,77 + 494.179,50X_1 + 239.622,90X_2 + 1.120X_3^{**} + 19.973.183,02D^{**}(4)$$

The equation shows that without income factors such as farming experience, farmer education, labor costs, seed costs, fertilizer costs, pesticide costs, and intercropping and monoculture cropping systems, the potato income generated in Bromo Region is Rp68,673,369.77. The farmer education variable has a regression coefficient of Rp494,179.50 with a significance value of 0.737 (> 0.05), so it has no real effect on income. This is because most farmers understand that farming doesn't require a high level of formal education, as skills are acquired through generations. Field conditions indicate that approximately 43.33% of farmers have a formal education of elementary or junior high school. This result is in line with research which also found a positive but insignificant influence between education and farmers' income.

The farming experience variable has a regression coefficient of Rp239,622.90 with a significance value of 0.722 (> 0.05), indicating that farming experience has no significant effect on income. Although most farmers have 21-30 years of experience, changes in market conditions, environment, and technology make old experience less relevant. Lack of farmer

participation in farming training also results in limited new knowledge that can increase productivity and income [12]. In contrast, the production cost variable has a significant effect on income, with a regression coefficient of 1.120 and a significance value of 0.027 (<0.05). This indicates that any increase in production costs by Rp1 can increase income by Rp1.120. Production costs include variable costs (seeds, fertilizers, pesticides, labor) and fixed costs (equipment and depreciation).

The cropping system dummy variable also had a significant effect on income with a coefficient of Rp19,973,183.02 and a significance value of 0.034 (<0.05). Farmers who apply intercropping cropping system earn higher income than monoculture system. The intercropping system allows efficient use of inputs and provides additional income from other crops such as leeks or cabbage, which can be harvested earlier. This cost efficiency and additional income make intercropping more profitable for potato farmers in Bromo Region. Overall, the results of the analysis show that improving production cost efficiency and implementing intercropping systems are the main factors that can increase potato farming income in Bromo Region, while farmer education and experience have not been significant determinants.

4 Conclusions and Suggestions

Based on the results of the analysis of the potato production function with the Cobb-Douglas function approach in Bromo Region, the variables of land area, number of seeds, and cropping system have a significant and positive effect on increasing production. Thus, increasing potato farming production in Bromo Region can be achieved through optimizing land use, selecting quality seeds, and implementing intercropping systems. Based on the results of the analysis of factors affecting potato farming income in Bromo Region, it can be concluded that the variables of production costs and planting systems have a significant effect on farmers' income. Meanwhile, farmer education and farming experience have no significant effect. The intercropping system also has a positive effect because it can increase the efficiency of input use and generate additional income from other crops such as leeks or cabbage.

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Data availability statement. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contribution. Yuli Hariyati (conceptualized the research framework, supervised the overall study, and revised the final manuscript), Vina Yunita Ria (contributed to data analysis, interpretation, and preparation of the discussion section), Diva Aura Jasmine Handia (was responsible for field coordination and data collection), Ebban Bagus Kuntadi (managed data validation and visualization for descriptive analysis), Ariq Dewi Maharani (participated in literature review and preparation of the results section), M. Rondhi (provided methodological guidance and critical revision of the manuscript), Ankardiansyah Pandu Pradana (assisted in data interpretation, refinement of the theoretical framework, and final proofreading of the article).

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