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Research Article

Reallocation of the use of chemical fertilizers and pesticides to increase the income of vegetable farmers and prevent land degradation

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Abstract

The study, which aimed to analyze the use of chemical fertilizers and pesticides using the Cobb-Douglas production function approach and their reallocation to increase the income of vegetable farmers and prevent land degradation, was conducted in Sumberejo Village, Batu City, Indonesia. Data were collected from 138 pakcoy (*Brassica rapa*), celery (*Apium graveolens*), and red chili (*Capsicum annuum*) farmers through interviews using a questionnaire. The relationship between input and output was analyzed by regression with the Cobb-Douglas production function. Data validity, reliability, and classical assumption tests were performed to ensure the goodness of fit regression model. Furthermore, the F test and t-test were applied to analyze production response to chemical fertilizers and pesticides. This study revealed that the modeled regression equation is appropriate, where R^2 = 0.827-0.933. Vegetable production gives a different response to the use of chemical fertilizers (TSP, Urea, and NPK) and pesticides. Increasing this chemical in pakcoy and celery farming is possible, but it needs to be considered because it has no significant effect on increasing production. The productivity of these two types of plants is relatively high. Farmers need to compare the costs of adding these inputs to additional income and the possibility of land degradation. Chemical fertilizers and pesticides have been excessive in red chili farming, so productivity is very low. There are indications that the land has been degraded, but to be sure, a study is needed on the chemical content of the vegetable fields in Sumberejo Village and the optimal use of chemical fertilizers and pesticides.

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Introduction

Farmers' income will continue declining because their arable land area is smaller. This limited natural resource encourages farmers to use it intensively by using chemical production factors to increase crop production to meet family needs. They do not realize that intensification will eventually lead to unhealthy land, which can lead to land degradation. Degraded land has an impact on reducing agricultural productivity so that it can reduce farmer income (Sitorus and Pravitasari, 2017). Land damage is caused by various forces, including biophysical and socioeconomic factors (Lestariningsih et al., 2018), excessive pesticide application (Joko et al., 2017), and erosion, which, according to Ambarwulan et al. (2021) is the main cause in agriculture in tropical climates. Therefore, the land of vegetable farming has the potential to be damaged because the use of chemical fertilizers and pesticides in vegetable cultivation causes the organic content in the soil to decrease. In this case, farmers must be wise in using appropriate chemical fertilizers and pesticides according to plant needs.

Farmers in various countries worldwide widely cultivated vegetables because these commodities contribute significantly to human health. In addition, vegetable production provides a promising economic opportunity for reducing rural poverty and unemployment in developing countries and is a key component of farm diversification strategies (Schreinemachers et al., 2018). In Indonesia, farmers grow various types of high-quality vegetables that have the potential to generate foreign exchange for the country. It will positively affect the trade balance (Pudjiastuti and Kembauw, 2018).

One of the vegetable centers in Indonesia is Batu City, which is also known as an agropolitan city. The land is fertile because it comes from sediments from the mountains surrounding it, namely Mount Panderman, Mount Arjuna, and Mount Welirang. However, rainwater runoff easily erodes this fertile soil layer because the topography includes highlands (altitude 700-1700 meters above sea level) and slopes. In addition, the very rapid development since the city became an autonomous administrative city on October 17, 2001, has created a large-scale conversion of agricultural land. As a result, the area for cultivating vegetables is also getting smaller. To increase their income on increasingly limited land, farmers generally choose intensification through the use of chemical fertilizers and pesticides so that their vegetable production will increase.

Types of vegetables commonly grown by farmers in Batu City (especially in Sumberejo Village) are pakcoy (*Brassica rapa*), celery (*Apium graveolens*), and red chili (*Capsicum annuum*). Technically, vegetable land that has the potential to be degraded can be detected using a production function approach. The soil in Sumberejo Village belongs to Dystrandepts, Humitropepts, Hydrandepts, and Ustropepts that belong to the order of Inceptisol. Dystrandepts have a base saturation of <60%, rather thick to thick solum, and well drainage. Humitropepts have high organic matter, blackish top layer, fine to medium texture, slightly acidic to neutral soil reaction, and relatively fertile. Hydrandepts have rather low fertility with a high water content (Soil Survey Staff, 2014). Improper management of Inceptisol soil for agriculture will cause the plants to become less productive (Bhupenchandra et al., 2022). Decrease in soil carrying capacity can occur as a result of a decrease in soil fertility, soil acidity, and the intensive use of chemical fertilizers and pesticides

In the context of vegetable production, the Cobb-Douglas production function is commonly used to analyze the relationship between input factors and output. This function can show the response (elasticity) of production to chemical fertilizers and pesticides applied by farmers, as well as technical efficiency. The coefficient of the production function and the two parameters can be used to identify inputs (chemical fertilizers and pesticides) that can be added or over-applied. Excessive use of chemicals (or additions can be made but not significantly affect production), the amount of use must be reduced. Meanwhile, the potential for future development can be estimated by a return to scale. This parameter can be a guideline for farmers in allocating inputs in their farming in the next growing season.

No research has highlighted the allocation of input in vegetable farming, especially pakcoy, celery, and red chili, related to land degradation. However, technical efficiency that shows the relationship between the input and output of several agricultural commodities, such as vegetables in Africa, has been studied by Rajendran et al. (2015) and Rijal and Bhatta. (2022), maize in Ghana (Adzawla and Alhassan, 2021), and in Malawi (Jolex, 2022; Mgomezulu et al., 2022). These studies used the Cobb-Douglas production function and found technical inefficiencies in cultivating agricultural commodities. According to Khatri et al. (2011) and Shrestha et al. (2022), resource use efficiency differs between types of vegetables. Other researchers mentioned factors that significantly contribute to input use efficiency, namely plant productivity (Okello et al., 2019), farmers' educational background, farm size, water availability, the application of manure, and poor drainage systems (Karimov, 2014).

This study aimed to analyze the reallocation of chemical fertilizers and pesticides in Indonesian vegetable farming to increase farmers' income and prevent land degradation using the Cobb-Douglas production function approach.

Materials and Methods

This research was conducted in Sumberejo Village, Batu City (Figure 1). The village is known as a center for vegetables in Batu City, especially celery (*Apium graveolens*), red chili (*Capsicum annuum)*, and pakcoy (*Brassica rapa*). Conventional farming is the main choice for farmers in this village because the processing techniques are easier. Plant fertilizers and medicines are also available at the farm shop. However, conventional farming systems negatively impact farmers and the environment, such as decreasing soil quality caused by excessive pesticide applications. The use of pesticides also causes the vegetables produced to be less healthy.

Primary data were collected from farmers who cultivate these three types of vegetables. Samples were selected by simple random sampling from 350 farmers growing vegetables in monoculture. Farmers are homogeneous based on the land area because the maximum scale of vegetable farming is only 0.5 hectares.

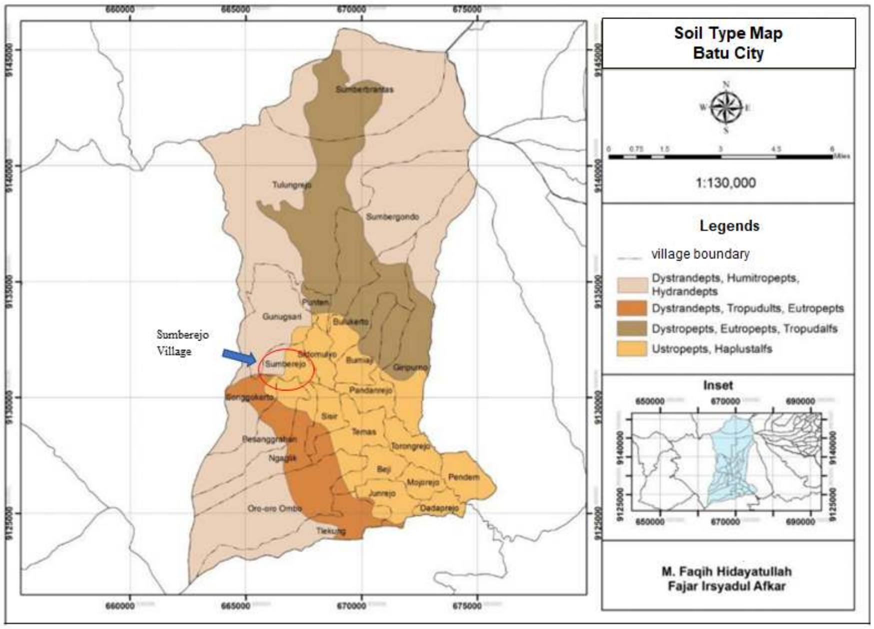

Figure 1. Map of the location of Sumberejo Village, Batu District, Batu City.
Source: Hidayatullah and Afkar (2023).

The number of samples is determined using the Slovin formula:

$$n = \frac{N}{1+N \cdot e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where, n = number of samples; N = total population; and e = desired level of accuracy.

The number of samples obtained through this formula were 45 mustard greens farmers, 45 celery farmers, and 48 red chili farmers, so the total respondents were 138 farmers. Interviews with farmers were conducted using a questionnaire at home during their free time or on the farm while working. This questionnaire was tested for its validity and reliability (Table 1) to ensure the accuracy of the data collected.

Table 1. Results of data validity and reliability tests.

Variable	Corrected Item-Total Correlation (r count)		
	Pakcoy (n = 45)	Celery (n =45)	Red chili (n = 48)
Yield (kg)	0.731	0.940	0.911
Land area (m^2)	0.827	0.923	0.932
Seed (g)	0.792	0.515	0.921
Manure (kg)	0.541	0.870	0.467
TSP fertilizer (kg)	0.674	0.760	0.454
NPK fertilizer (kg)	0.574	0.569	0.624
Urea fertilizer (kg)	0.608	0.790	0.557
Labor (man-days)	0.563	0.872	0.378
Pesticide (mL)	0.529	0.704	0.311
r-table (43; 0.05)	0.248	0.248	
r-table (46; 0.05)			0.240
Cronbach's Alpha	0.885	0.627	0.678

Questions raised to farmers included land area, number of seeds, manure, TSP fertilizer, NPK fertilizer, urea fertilizer, labor, pesticides, and production. Land area was measured in hectares. The number of seeds was measured in grams per vegetable growing season. The amount of manure, TSP, NPK, and urea applied was measured in kilograms of fertilizer per vegetable growing season. The labor involved in all activities ranging from land preparation, seeding, planting, fertilizing, irrigation, weeding, eradicating pests and plant diseases, and harvesting was measured in working days. Pesticides were measured in milliliters of the volume of pesticides used to eliminate pests and diseases of vegetables during one growing season. Vegetable production was measured in kg per growing season (the sum of directly sold yields, stored for sale, stored for seed, given to relatives, and self-consumed). A questionnaire is declared valid if r-count > r-table and is called reliable if Chronbach's alpha > 0.60. Thus, the results of the validity and reliability tests in Table 1 show that the questionnaire used as the research instrument was valid and reliable.

Data that have been collected were edited in the field, then tabulated, processed, and analyzed regression. The relationship between input and output in vegetable farming was estimated by the Cobb-Douglas production function, which is written mathematically as:

$$Y_i = b_{0i}X_{1i}^{b_{1i}}X_{2i}^{b_{2i}}X_{3i}^{b_{3i}}X_{4i}^{b_{4i}}X_{5i}^{b_{5i}}X_{6i}^{b_{6i}}X_{7i}^{b_{7i}}X_{8i}^{b_{8i}} \quad i = 1,2,3 \ \ldots \quad (2)$$

where: Yi = yield of each type of vegetable (kg) where Y_1 = pakcoy yield, Y_2 = celery yield, Y_3 = red chili yield; b_{0i} = constant; b_{ji} = regression coefficient of each production factor (j=1,2, …, 8); X_{1i} = land area (ha);

X_{2i} = seed (gr); X_{3i} = manure (kg); X_{4i} = TSP fertilizer (kg); X_{5i} = NPK fertilizer (kg); X_{6i} = urea fertilizer (kg); X_{7i} = labor (man-days); X_{8i} = pesticide (mL).

The model was first transformed into multiple linear functions in natural logarithmic:

$$\ln Y_i=\ln b_{oi}+b_{1i}\ln X_{1i}+b_{2i}\ln X_{2i}+b_{3i}\ln X_{3i}+b_{4i}\ln X_{4i}+ b_{5i}\ln X_{5i}+b_{6i}\ln X_{6i}+b_{7i}\ln X_{7i}+b_{8i}\ln X_{8i} \quad \ldots\ldots (3)$$

A classical assumption test was conducted to show that the regression model is a good estimator. Cobb Douglas production function for each type of vegetable is obtained by retransforming the estimated multiple linear regression function. Technical efficiency is formulated as:

$$TE = \frac{MPPxi}{APPxi} = \frac{\Delta Y/AXi}{Y/Xi} = bji \quad \ldots\ldots\ldots.. (4)$$

where: TE = technical efficiency; MPPxji = marginal physical product for input ji; APPxji = average product for input ji.

Justification: If TE = 1, then the production factor is technically efficient. If TE>1, then the production factor is not technically efficient. If TE<1, then the production factor is technically inefficient. It can be an indicator of efficiency in the short term. RTS, as an indicator of long-term efficiency, is the sum of the regression coefficients of all factors of production. These parameters are classified into (1) increasing return to scale, if $\sum_{i=1}^{j}$ bji >1, (2) constant return to scale, if $\sum_{i=1}^{j}$ bji = 1, and (3) decreasing return to scale, if $\sum_{i=1}^{j}$ bji <1.

Results and Discussion

Characteristics of vegetable farmers

Farmers in Sumberejo Village generally cultivate various types of vegetables in wetlands. Types of vegetables that are widely cultivated include pakcoy, celery, and red chili. The characteristics of farmers of the three types of vegetables are presented in Figure 2. Most (89-100%) of vegetable farmers are productive age, and (87-94%) are male. However, the findings of Missiame et al. (2021) showed that even though there is a technological gap between male and female farmers, it turns out that the farming they manage is still technically inefficient. The majority (90-98%) of farmers have a high school education and below, but with relatively long farming experience (>10 years) and only cultivate vegetables on limited land (≤ 0.5 ha). Rahaman and Abdulai (2022) stated that farmer education affects farm input use and output. Meanwhile, according to Josephson and Ricker-Gilbert (2020), the smallholder farmer faces considerable risk and uncertainty in the relationship between market failure and crop choice.

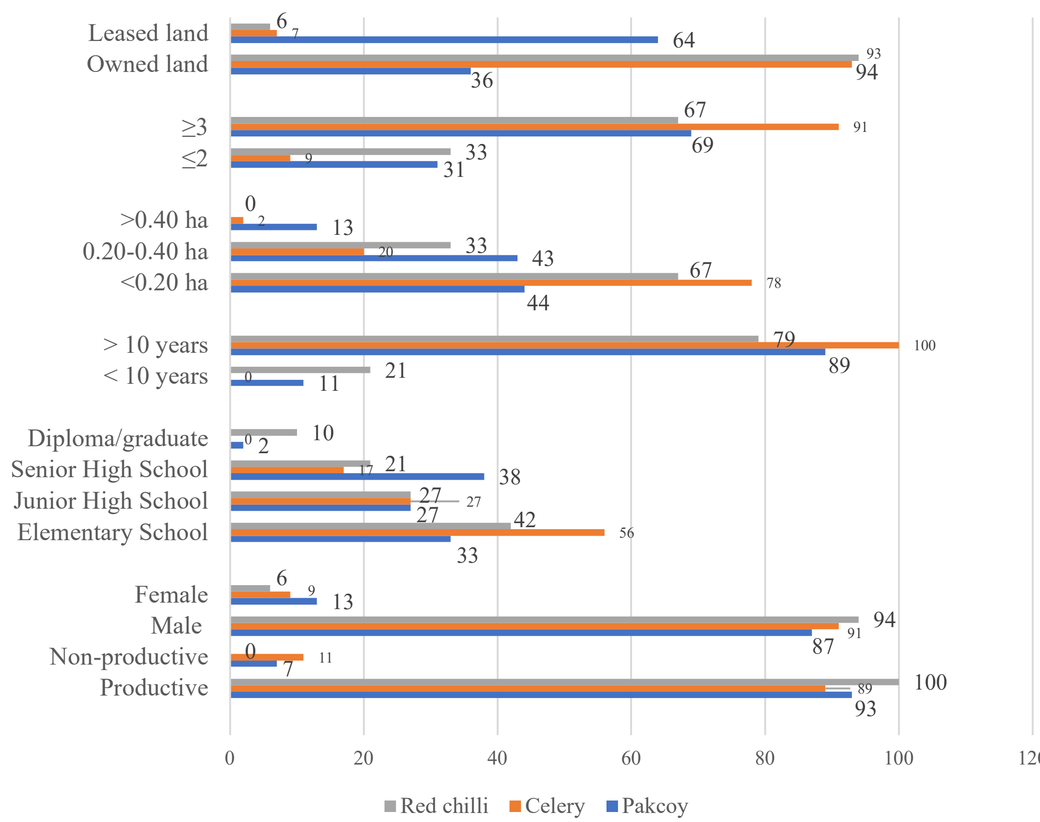

Figure 2. Characteristics of vegetable farmers.

In addition, 67-91% of vegetable farmers have large family members (>3 people). Most of these three types of vegetables (93-94%) are cultivated on their own land, except for pakcoys, 64% of which are grown on leased land.

Cobb-Douglas production function estimation for vegetables

Farmers in the research location generally cultivate vegetables on very limited land. Their land area ranges from 0.03-0.50 ha with an average of 0.14 ha, indicating a very small area of cultivated vegetable farmers in Sumberejo Village (Figure 3). Only a few farmers have arable land of 0.30-0.50 ha. Generally, farmers cultivate vegetables only in an area of 0.13-0.15 ha. Several previous research results revealed that small-scale farming is generally inefficient, even though the level of technology is different. Farmers are required to meet large household needs because of the burden on large family members, so they manage very limited land intensively. This is indicated by the variation in the amount of input used according to the area of land cultivated and the types of vegetables chosen (Table 2).

Because this study focused more on detecting the possibility of land degradation, the discussion focused more on chemical fertilizers and pesticides. Chemical fertilizers (TSP, NPK, and Urea) are most widely applied in pakcoy farming and the least used in red chili farming. This shows that there is a different orientation of farmers in farming, considering that the price of pakcoy is lower than that of celery and red chili. Farmers plant pakcoy with the intention of maximizing production (income), while red chili farming is intended to maximize profits. Celery farmers maximize production through the use of very high pesticides (about 20 liters), compared to pakcoy (about 2.5 liters) and red chili (only 0.2 liters). This data shows clearly that the intensification of vegetable farming in Sumberejo Village is still centered on the use of chemicals when farmers want to achieve maximum production. This farmer's behavior can lead to unhealthy cultivated land, which can lead to land degradation in the future if they do not make changes.

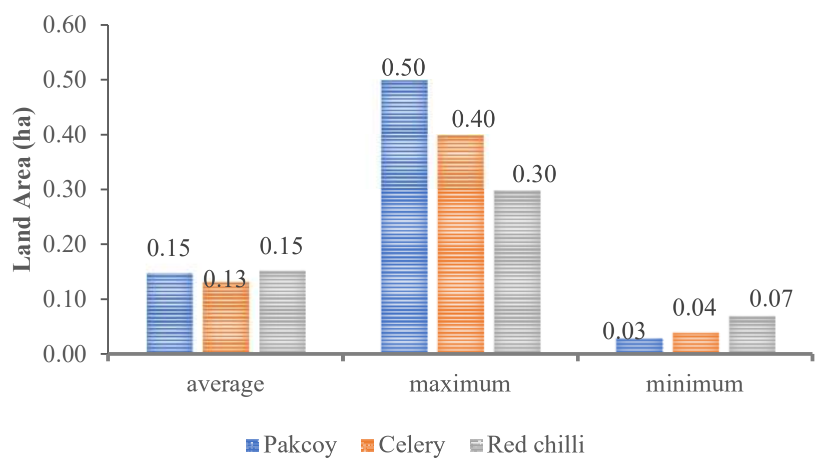

Figure 3. Distribution of vegetable farmers.

Table 2. Allocation of input use in vegetable farming per hectare.

Variables	Pakcoy (n = 45)			Celery (n = 45)			Red chili (n = 48)		
	Avrg	Max	Min	Avrg	Max	Min	Avrg	Max	Min
Yield (kg)	21,524	58,000	9,167	49,935	75,000	32,143	4,364	7,000	2,500
Seed (g)	810	1,250	500	1,461	2,000	800	2,159	3,000	1,667
Manure (kg)	4,306	12,500	950	4,337	12,000	1,200	1,655	3,000	667
TSP fertilizer (kg)	1,572	6,000	229	1,009	2,400	400	712	2,000	300
NPK fertilizer (kg)	1,461	3,375	333	766	2,400	160	605	1,000	280
Urea fertilizer (kg)	1,426	5,000	188	1,167	4,000	250	307	571	100
Labor (man-days)	3,437	10,400	1,010	9,472	15,820	2,807	1,449	3,500	400
Pesticide (mL)	2,469	7,500	625	20,194	50,480	3,500	220	875	67

Notes: Avrg = average, Max = maximum, Min = minimum.

To find out how chemical inputs affect production, it can be seen from the results of regression analysis of Cobb Douglas production function (Table 3). The estimation results of this function fulfill the goodness of fit model because the coefficient of determination (R^2) is close to 1 (0.827-0.933). That is, the inputs used by farmers can explain variations in vegetable production by 83-93%. In more concise words, the variables selected in the Cobb-Douglas production function can represent the relationship between the input and output of the types of vegetables. The questionnaire has been tested for validity and reliability to produce accurate data and fulfill classic assumptions (data is normally distributed, with no multicollinearity and heteroscedasticity), indicating that the regression model is in a good category. The results of the analysis showed that only land area affects the yield of pakcoy and celery, while red chili yield is influenced by land area and number of seeds. Other inputs, especially chemical fertilizers and pesticides, have no significant effect on vegetable production. Vegetables in Sumberejo Village are indeed cultivated on very small land. Farmers usually buy red chili seeds at farm shops because, with certified seeds, they hope to get a high income from the yield of this commodity.

Table 3. Relationship between input and output in pakcoy, celery, and red chili farming.

Variables	**Pakcoy (Y_1)**			**Celery (Y_2)**			**Red chili (Y_3)**		
	RC	**sig.**	**EF**	**RC**	**sig.**	**EF**	**RC**	**sig.**	**EF**
Constant	1.866			0.947			0.296		
Land area (X_{1i})	**1.014	0.000	e	**0.985	0.000	ne	**0.842	0.000	ne
Seed (X_{2i})	-0.195	0.495	ne	0.052	0.471	ne	**0.430	0.001	ne
Manure (X_{3i})	0.021	0.836	ne	0.046	0.413	ne	0.040	0.735	ne
TSP fertilizer (X_{4i})	0.048	0.768	ne	0.097	0.241	ne	-0.137	0.300	ne
NPK fertilizer (X_{5i})	0.184	0.359	ne	0.079	0.324	ne	-0.125	0.239	ne
Urea fertilizer (X_{6i})	0.111	0.526	ne	0.092	0.314	ne	0.021	0.790	ne
Labor (X_{7i})	-0.413	0.057	ne	0.055	0.617	ne	0.063	0.692	ne
Pesticide (X_{8i})	0.251	0.142	ne	0.040	0.521	ne	-0.131	0.270	ne
R^2	0.827			0.933			0.897		
Sig. F	0.000			0.000			0.000		

Notes: RC = regression coefficient, EF = efficiency, sig. = significance, ** = highly significant (sig.< 0.01); e = efficient, ne = inefficient.

The reason is that red chili prices are higher than other vegetables, even though the fluctuations are also greater. However, farmers plant red chili in smaller areas to minimize the risk of loss when red chili prices fall. Almost all factors of production are used inefficiently in vegetable farming, except for the land area in pakcoy farming. Seeds and labor were inefficient production factors in pakcoy cultivation, TSP fertilizers, NPK fertilizers, and pesticides in red chili farming. Farmers have to reduce the amount of this input. Meanwhile, the amount of other inputs must be increased, especially land area and seeds. Red chili farming is very intensive in using chemicals (TSP fertilizers, NPK fertilizers, and pesticides) because farmers want to increase their yield.

According to Table 3, Cobb Douglas production function for the vegetables (Y_1 = pakcoy yield; Y_2 = celery yield; Y_3 = red chili yield) can be written mathematically as follows:

$$Y_1=1.866X_{11}^{1.014}X_{21}^{-.195}X_{31}^{.021}X_{41}^{.048}X_{51}^{.184}X_{61}^{.111}X_{71}^{-.413}X_{81}^{.251} \quad (5)$$

$$Y_2= 0.947X_{12}^{.985}X_{22}^{.052}X_{32}^{.046}X_{42}^{.097}X_{52}^{.079}X_{62}^{.092}X_{72}^{.055}X_{82}^{.040} \quad (6)$$

$$Y_3=0.296X_{13}^{.842}X_{23}^{.430}X_{33}^{.040}X_{43}^{-.137}X_{53}^{-.125}X_{63}^{.021}X_{73}^{.063}X_{83}^{-.131} \quad (7)$$

The sum of the production function exponents shows a return to scale (Table 4). It can be a signal for vegetable farmers to manage their farming in the following season. In the long term, farmers can change their return to scale by expanding the planting area and improving a combination of chemical fertilizers and pesticides that have the potential to degrade their land.

Table 4. Estimated return to scale of vegetables.

Description	**Pakcoy**	**Celery**	**Red chili**
Return to scale figures	1.021	1.446	1.003
Justification	Increasing return to scale	Increasing return to scale	Increasing return to scale
Implication	If all inputs are increased by one time, the output will increase by 1.021 times.	If all inputs are increased by one time, the output will increase by 1.446 times.	If all inputs are increased by one time, the output will increase by 1.003 times.

Increasing return to scale (IRTS) means that vegetable farming has the potential to use more efficient production factors, capacity to accumulate capital for land expansion, and to be a source of profit and attractive to other farmers. IRTS of these vegetables is similar to the results of studies on yam plants in

Nigeria (Izekor and Alufohai, 2015), tomatoes (Subedi et al., 2020), and vegetables in Nepal (Rijal and Bhatta, 2022). According to Jabbar (1977), within the Cobb-Douglas production function, the determination of optimum scale requires the production elasticity of each factor input to be less than unity, i.e., all the factors are variable, and the marginal productivity of each factor is declining. It can happen only when at least one factor is fixed. Scale relationship may then be presented in the form of a two-factor production function implying a proportionality relationship between one factor as a fixed factor and all the other factors as an aggregate homogeneous variable. Increasing returns may prevail over a wide range of output if substantial unused capacity in production exists; decreasing returns will prevail when production capacity is reached, and negative returns will ensue as size expands beyond production limit. An optimizing farmer would be expected to operate within the range of diminishing returns to scale.

By incorporating research from diverse contexts and geographical settings, this narrative strengthens its argumentative framework and demonstrates the consistency of findings across different regions (Schreinemachers et al., 2017). Further research and analysis are required to explore the underlying factors contributing to observed returns to scale and their implications for agricultural policy and practice.

Farmer income and land degradation

The fertile soil conditions due to volcanic eruptions make the agricultural land in Sumberejo Village very suitable for growing vegetables. However, the conversion of agricultural land has reduced the scale of farmers' businesses. Small farmers have limited capital, so the income earned from their farming is also small. Because most of the income is used for consumption, the income allowance for reinvestment in farming is also low. It is what makes it difficult to develop small-scale farming. So that their income does not decrease, the farmers in Sumberejo Village are trying to keep their vegetable yield increasing through the intensive allocation of TSP, Urea, NPK fertilizers, and pesticides.

Farmers assume that the chemicals applied to their fields will be able to produce vegetables in a minimum quantity equal to the yield in the previous growing season. Generally, they grow vegetables in monoculture with an intensity of planting three times per year. This cropping pattern is possible because enough water is available, although water sources in this area are also beginning to decrease. There is a tendency for farmers to increase the use of chemical fertilizers and pesticides in vegetable cultivation, especially those that are highly commercial. It was revealed by the results of this study that chemical fertilizers and pesticides were applied excessively in red chili farming. The relationship between the amount of fertilizers and pesticides with yield and income is presented in Table 5. Most chemical fertilizers are used in pakcoy farming, and most pesticides are applied in celery. The use of these chemicals can be increased in both types of vegetables, but the effect was insignificant. Therefore, farmers should reduce the amount of fertilizers and pesticides, even though the productivity of these plants was above the standard, namely 20 tons/ha for pakcoy and 30 tons/ha for celery. High productivity was achieved because farmers put relatively large amounts of organic matter (manure) into the soil. The highest income is obtained by celery farmers. On the other hand, red chili farming has experienced a decline in productivity because it is much lower than the standard of 8-10 tons.

Table 5. Relationship between chemical fertilizers, pesticides, production, and income per hectare

Variables	Pakcoy	Celery	Red chili
TSP fertilizer (kg)	1,571.8	1,008.9	7,12.4
NPK fertilizer (kg)	1,460.7	765.9	604.9
Urea fertilizer (kg)	1,426.4	1,167.4	307.1
Pesticide (mL)	2,469.2	20,193.7	219.5
Yield (kg)	2,1524	4,9935	4,364
Revenue (US$)	2,152	16,645	7,273

There are indications that red chili land has been degraded because productivity has fallen by around 50%, and the analysis results in Table 3 show that the use of chemical inputs has the potential to reduce production. Farmers must reduce chemicals and add organic matter to the soil. The data shows that the manure applied in red chili farming is much less than pakcoy and celery. It also indicates that the goal of red chili farmers is to maximize profits.

The production functions of different vegetables demonstrate variations in the efficiency of production factors. Some input factors show effectiveness in increasing output, while others exhibit inefficiencies. These inefficiencies can affect productivity and resource management (Izekor and Alufohai, 2015; Mariyono, 2017; Subedi et al., 2020). Furthermore, small-scale vegetable farmers face limited capital challenges, hindering their development and sustainability (Bahta and Owusu-Sekyere, 2019). This indicates that the optimal scale of vegetable production may vary depending on the context and available resources. The results of returns to scale analysis in vegetable production align with and complement existing research findings. Zhang et al. (2020) conducted a study focusing on vegetable producers and technological change in China. They found evidence supporting the presence of increasing returns to scale in vegetable farming, affirming the notion that economies of scale can be achieved through the proper allocation of resources and technology adoption.

Farmers' efforts to increase production and income, if done continuously, will cause their land to be degraded. Farmers need to highlight the following: (1) The use of chemical fertilizers and pesticides is still possible in pakcoy and celery farming, but it does not have a significant effect. This indicates that there is no point in increasing the amount of this input because it will not increase production. Farmers must compare the opportunity cost of adding chemicals to the chance of land degradation in the future. (2) The application of chemicals in red chili farming is excessive. In addition to reducing farmers' income, adding chemical fertilizers and pesticides can lead to faster land degradation than other vegetable commodities. It is necessary to study the condition of farmers' land in this region to confirm this.

Based on the results of this study and supported by a previous study by Jaya et al. (2014) and Maftu'ah et al. (2014), it can be identified several ways to prevent the degradation of vegetable land. These efforts include (1) implementing conservation farming patterns such as agroforestry, intercropping, and integrated farming, (2) implementing eco-friendly organic farming patterns, and (3) increasing the role and participation of farmer institutions.

Conclusion

Farmers have not been proportional in applying chemical fertilizers and pesticides in vegetable farming, so they have to reallocate them. Pakcoy and celery farmers can still increase the use of chemical fertilizers and pesticides in their farming, but it must be done carefully to prevent land degradation. The productivity of these two types of vegetables is still high and can potentially increase return to scale to increase farmers' income. Meanwhile, red chili farmers must reduce the application of chemical fertilizers and pesticides because the amounts are excessive. The productivity of red chili that is below standard indicates that land degradation has occurred. However, a more in-depth study of the chemical content in vegetable fields is needed to strengthen this finding. The government, through agricultural extension workers, needs to facilitate farmers to be wiser in applying chemical fertilizers and pesticides on their land. A study to needed is a comparison between the costs of adding chemical inputs, additional yield (income), and opportunities for land degradation.

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