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Regional Case Study

Analysis of Soil Fertility and Sustainability of Shallot Intensive Farming: Case study of Brebes

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Abstract

Larangan District is one of the shallot-producing areas that the government prioritizes for agricultural intensification. The high intensity of agriculture in Larangan District causes soil fertility and sustainability disparities. This research evaluates soil fertility and the sustainability of shallot farming intensification activities in Larangan District, Brebes Regency. Soil fertility evaluation used two different approaches: Base Cation Saturation Ratio (BCSR), which referred to Koppitke & Menzies research in 2007 and assessment through a combination of soil chemical properties, as referred to Soil Research Center of Indonesia. Sustainability analysis was carried out using the Rapid Appraisal for Farming (RAP-Farm) approach with a multi-aspect sustainability analysis method, with a total of 6 aspects (ecological, economic, social, institutional, technological, and logistics, and infrastructure) with 36 factors. The results of the research show that Larangan District has a moderate soil fertility status, with a nutrient unbalance from cation ratio analysis. Sustainability status shows a less sustainable status with aspects that have values below the limit, namely ecology, economics, and technology.

Keywords: Fertility evaluation; sustainability analysis; multiaspect sustainability analysis; rapid appraisal for farming

1 Introduction

Population growth and food availability are two factors that have a dynamic relationship. The concept of food security has been widely launched to maintain balance and sufficiency in the food sector (Reddy et al., 2016). Agricultural intensification is one of the methods applied in Indonesia to support food security through efficient land management to obtain maximum agricultural production results (Food Agriculture Organization 2004). Agricultural intensification is intended to maintain the sustainability of Indonesia's food stocks as stipulated in the regulation of the Minister of Agriculture of the Republic of Indonesia Number 56/PERMENTAN/RC.040/11/2016 concerning guidelines for the development of agricultural areas, to maintain food security in line with the growing population (Struik & Kuyper 2017; Ministry of Agriculture 2016).

In Indonesia, one of the areas that has become one of the locations for agricultural intensification is Brebes Regency, which is an area focused on meeting the stock of shallot commodities in Indonesia (Aminda et al., 2024). In 2023, shallot production in Brebes Regency reached 2,890,000 Quintal, with the highest production location being Larangan District with 773,240 Quintal (National Bureau of Statistics Indonesia 2024). Larangan sub-district as one of the sub-districts that has intensive shallot farming activities every year has encouraged the acceleration and increase in production. However, if seen from the other side, the acceleration of shallot commodity production has increased the use of pesticides and inorganic fertilizers. Previous research found that pesticide use for agricultural fields amounts 500 to 1,588 liter per hectare with regular spraying every 3 to 4 days, which affected residual accumulation that bond nutrient movement (Susilawati et al. 2018). In addition, the decline in the use of organic fertilizers as one of the aspects that can accelerate soil fertility is increasingly massive. Therefore, a decrease in soil fertility began to occur in Brebes Regency with unbalanced nutrient conditions and soil fertility status (Badrudin et al., 2022; Muliana et al., 2018). Under these conditions, potential measures are needed to evaluate agricultural intensification activities through evaluating soil fertility every 3-5 years, especially soil nutrients as well as evaluating technological improvements, socio-economic balance, targeted distribution, and sustainable institutions (Fraser et al., 2016; USDA 2009).

Soil Fertility analysis has been carried out in previous research by Sumarni et al. (2012), which found that P levels were very high at 165 mg/100g and K levels were high at 49 mg/100g. The research shows that the soil in Brebes Regency has experienced accumulation of P and K nutrients. In addition, the analysis of the sustainability of shallot farming in previous research was conducted by Siregar et al., (2024) who found that the analysis of the sustainability of shallot farming carried out in Simanindo, Samosir Regency, has a fairly sustainable status with development priorities in the form of increasing income, increasing suitability and land potential, increasing the type of shallot technology, and increasing farmer groups. Previous research has shown that soil fertility analysis and identification of priority factors are needed to develop interventions for sustainable onion farming activities.

The problem of ecosystem carrying capacity, increasing population with the fulfillment of national shallot commodity supply in Larangan District, should follow the regulations made by the Brebes Regency Government as stated in articles 15 and 16 of the Regent Regulation of Brebes Regency in 2021 which states that agricultural intensification must be accompanied by ecological, socio-economic, technological and infrastructure improvements (Legal Documentation and Information Network of Brebes Regency 2021). Therefore, sustainability and soil fertility analysis is needed to evaluate and reference interventions to maintain productivity while maintaining the resource base in shallot commodity agriculture (Fauzi 2019). In addition, Erbaugh et al. (2019) stated that local scale analysis is necessary for evaluation and monitoring for measurable sustainability goals. Therefore, to obtain the results of a comprehensive sustainability assessment related to shallot farming intensification activities in Larangan Sub-district, Brebes Regency, fertility analysis and sustainability based on the analysis of 6 aspects of sustainability, namely ecological, economic, social, technological, institutional, and logistical infrastructure aspects. This study aims to determine the status of soil fertility and sustainability of each related aspect as well as sustainability leverage variables as a reference for development interventions for agricultural intensification activities in Larangan District, Brebes Regency, Central Java.

2 Methods

2.1. Study Area

This research was conducted in Larangan Subdistrict, Brebes Regency from November 2024 to December 2024. Soil samples were taken from 5 villages include Pamulihan, Kamal, Sitanggal, Rengaspendawa, and Larangan, that have the main income from shallots (Central Bureau of Statistics 2024). The study area of this research can be seen in Figure 1.

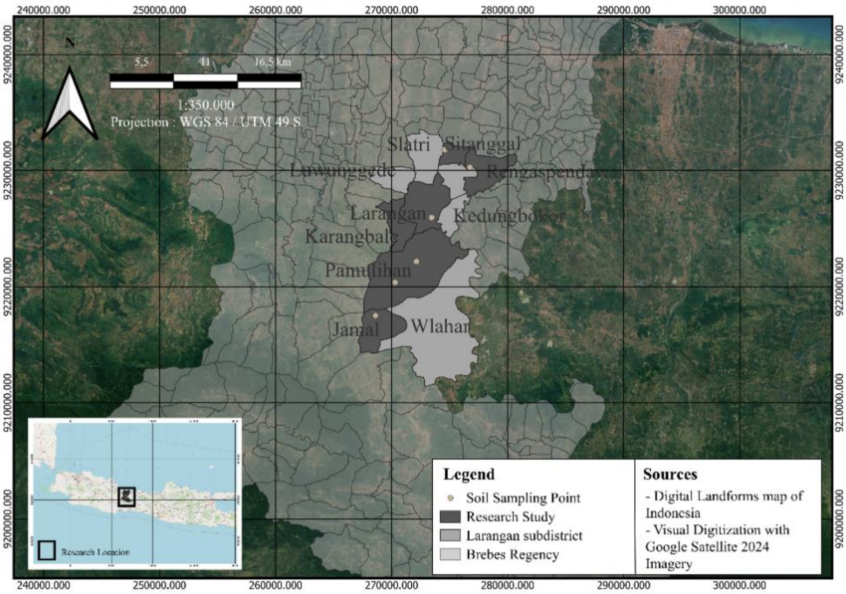

Figure 1. Map of research sites

2.1.1 Method of Analysis

2.1.1.1. Soil Fertility Evaluation

Soil fertility evaluation was conducted using a soil analysis approach based on soil chemical properties. Soil fertility assessment was conducted through two approaches, namely through an approach based on a combination of soil chemical properties by the Soil Research Center (1983) in Eviati & Sulaeman (2009) and soil nutrient balance analysis with base cation comparison approach based on the base cation saturation ratio (BCSR). Data on soil fertility assessment is part of the fertility data obtained from data previously studied by the author in Nadalia et al. (2024). The standards used in soil fertility assessment can be seen in Soil Research Center (1995).

Furthermore, soil nutrient balance for fertility evaluation in this study was carried out with a cation approach analyzed using the Base Cation Saturation Ratio (BCSR) method. The BCSR method is a comparative analysis of base cation ratio test that displays the range of exchangeable cation ratios (Vieweger et al., 2017). The BCSR method refers to the ideal ratio values of Kopittke & Menzies (2007), namely Ca:Mg 6.5:1, Ca:K 13:1, and Mg:K 2:1.

2.1.1.2. Sustainability Analysis

Sustainability analysis was conducted by scoring the aspects and factors determined. This research used Rapid Appraisal for Farm (Rap-Farm) with the determination of research respondents was carried out by purposive sampling by considering the direct role or key person on the sustainability of agricultural intensification of shallot commodities in Larangan, Brebes. The key persons taken by 7 different institution including the Agriculture and Food Security Office of Brebes District, the Agricultural Extension Agency of Larangan District, Academics, Farmer Group Associations, the Brebes Shallot Association, the Brebes Andalan Fishermen Farmers Association, and the Agricultural Census of the Central Bureau of Statistics of Larangan District.

This research uses a modeling approach, Multi-aspect Sustainability Analysis (MSA). The MSA analysis was conducted using Exsimpro software which is a development of previous tools, namely RAPFISH (Firmansyah 2022). This analysis will measure the sustainability of aspects related to agricultural intensification of shallot commodities in Larangan, Brebes. The analysis is carried out by measuring the sustainability of each aspect studied through factors in each aspect of sustainability and assessing based on actual data through field observations, discussions with experts, and literature review.

Each attribute was assessed and categorized based on the sustainability status value interval. The sustainability value interval refers to sustainability status value that can be seen in Firmansyah (2022).

The factors analyzed in this study are a collection tailored to the aspects measured. The aspects measured in this study are ecological, economic, social, institutional, technological, and logistical and infrastructure aspects which is the key aspects of sustainable agricultural development (Asiyat et al. 2024). Factors that are attributes of sustainability analysis criteria can be seen in Table 1.

Table 1. Attributes of sustainability analysis criteria

Aspect	Factor
Ecology	1. Soil Fertility
	2. Soil erosion hazard level
	3. Rainfall suitability for shallots
	4. Intensity of inorganic fertilization
	5. Intensity of organic fertilization
	6. Shallot pest and disease control
	7. Pest and disease resistance level
Economy	1. Farmer income
	2. Access to marketing of agricultural products
	3. Farmer's capital capability
	4. Profit from shallot farming
	5. Fertilizer and pesticide subsidy rates
Social	1. Frequency of related conflicts
	2. Ownership status of land used
	3. Time allocation used for agriculture activity
	4. Farmer's motivation for farming
	5. Farmer's motivation in pursuing education
	6. Level of regeneration of farmers
	7. Farmer's understanding of the impact of farming with excess chemicals
Institutional	1. Availability of government budget for shallots
	2. Capitalization institutions
	3. Farmer participation in training
	4. Presence of intermediary trades or middleman
	5. Presence and frequency of agricultural extension services
	6. Existence of farmer groups
Technology	1. Access to developments in agricultural science and technology
	2. Implementation of land and water conservation
	3. Farmer's level of mastery and understanding of cultivation technology
	4. Level of technology application in cultivation
	5. Level of application of harvest and post-harvest technology
	6. Level of application of land preparation technology
Logistic and Infrastructure	1. Irrigation channels to shallot fields
	2. Storage warehousing system
	3. Transportation network to the shallot fields
	4. Marketing distribution network
	5. Existence of agricultural cooperatives

After obtaining the score data, the next step is to apply it in Eximpro software with the MSA program to get more value, sensitivity leverage, and sustainability status. MSA program is developing program from multidimensional scaling (MDS) system for occur the sustainability status, MSA offer holistic approach that relevant with reseach and institutional need. Sustainability status is measured using the status value ordinate, which shows the mapping of conditions based on the coordinated status value in general. The ordinate is divided into bad, unlogic, important, urgent, good, and priority referring to Firmansyah (2022).

In addition, the sensitivity value can be seen in the Leverage factor value on the variable leverage sensitivity graph. This function describes the key factors that are most affected by changes in either the individual aspects or their aggregate status. The key factor value is taken from the highest value of the sum of the maximum sensitivity value added to the sensitivity value. The formula for this function is as following equation (1)-(3):

$$L = S_M + S_V \quad (1)$$

$$S_M = \frac{1}{Gfn} \quad (2)$$

$$S_V = (Gfn - Mofn) \times S_M \quad (3)$$

Description:

L = *leverage factor value*
S_M = maximum value
S_V = sensitivity value
Mo = modus value of factor
G = Highest score value
f = *factor value*

3. Result and Discussion

The results of this study are divided into two parts, namely the results of soil fertility analysis and the results of sustainability analysis. Soil fertility results show the results of two approaches, namely based on the category of soil chemical properties and cation ratio. The sustainability analysis shows the results of the leverage analysis and the sustainability status analysis. The results and discussion of this research are as follows.

3.1. Soil Fertility Analysis

3.1.1. Fertility Evaluation Based on a Combination of Soil Chemical Properties

The results of the soil fertility evaluation at 5 villages in Larangan Subdistrict as a whole have a medium status. The tendency of intensive land management carried out by farmers in the form of intensive use of inorganic fertilizers and pesticides, not applying organic matter returns to the soil, flooding, and dominant clay soil types rich in colloids are factors that hinder soil fertility status so that it has a moderate fertility status. Farmer's habits are supported by data showing that P and K extracted by HCl 25% have very high values, and C-organic and N-total are relatively low. The results of the analysis of soil chemical properties and status, as well as the assessment of soil fertility status can be seen in Table 2 and its explanation as follows

Table 2. Result of soil fertility evaluation

Village (Type of Soil)	pH H_2O 1:5	Organic C (%)	Total N (%)	HCl 25% (mg/100g)		CEC (cmol(+)/kg)	BS (%)	Fertility Status
				P_2O_5	K_2O			
Pamulihan (Typic Eutrudepts)	8.0 (SA)	1.0 (L)	0.1 (L)	127.5 (VH)	103.7 (VH)	41.7 (VH)	172.8 (VH)	Moderate
Larangan (TypicEndoaquepts)	7.5 (N)	1.0 (L)	0.1 (L)	169.3 (VH)	65.5 (VH)	46.0 (VH)	108.0 (VH)	Moderate
Kamal (Typic Eutrudepts)	7.8 (SA)	1.7 (L)	0.17 (L)	284.4 (VH)	140.3 (VH)	48.9 (VH)	159.9 (VH)	Moderate
Sitanggal (Typic Endoaquepts)	6.8 (N)	1.5 (L)	0.11 (L)	100.4 (VH)	45.6 (H)	52.5 (VH)	102.9 (VH)	Moderate

Village (Type of Soil)	pH H_2O 1:5	Organic C (%)	Total N (%)	HCl 25% (mg/100g)		CEC (cmol(+)/kg)	BS (%)	Fertility Status
				P_2O_5	K_2O			
Rengaspendawa (Typic Endoaquepts)	7.0 (N)	1.4 (L)	0.11 (L)	122.0 (VH)	62.4 (VH)	43.1 (VH)	111.4 (VH)	Moderate

**Description: CEC (Cation Exchange Capacity); BS (Base Saturation); VH (Very High); H (High); L (Low); VL (Very Low); SA (Slightly Acid); N (Neutral).*

Based on the analyzed soil chemical properties, the soil acidity status (pH) has a range of slightly alkaline to normal with a value of 7.0 to 8.0. Areas with slightly alkaline pH are Kamal and Pamulihan which have Typic Eutrudepts soil types that have a base saturation of more than 60%. The soil develops from clay, sand and limestone rocks that have low Al saturation, so the pH is slightly alkaline. While areas with a pH that tends to be neutral are locations with soil types in the Typic Endoaquepts subgroup category, this soil type is dominated by clay deposits to calcareous sandstone and marl that have high Ca and exchangeable Mg values that have implications for the relative amount of basic cations to cation exchange capacity that affects the balance of ions in the soil solution and pH (Pinatih et al., 2015).

Organic C and Total of N analyzed at the soil sampling location have an overall low status with a range of C-organic of 1% to 1.5%, and N-Total of 0.1 to 0.17%. This is following the research of Patti et al. (2013), which found that C and N values have a relationship that is nitrogen fixation carried out by microbes in the soil. The tendency of land cultivation that does not return biomass to the soil, and the massive use of inorganic fertilizers and synthetic pesticides in shallot farms, causes low C and N values in the soil because it affects the population and activity of soil microbes that have the role of decomposing organic matter. In addition, uprooting during harvesting transports soil C-organics into the air, which has implications for soil C and N status (Pahalvi et al., 2021).

P2O5 extracted by HCl 25% at the soil sampling sites in Larangan subdistrict showed a range of values from 100.4 mg/100g to 284.4 mg/100g. The overall status of P2O5 HCl 25% at the soil sampling sites is very high. Fertilization is done using triple super phosphate (TSP) which is applied 3 times in one planting period. In addition, the soil in Larangan sub-district is alkaline to normal in acidity, with high Ca levels. This can result in the P content in the soil being bound or adsorbed to form Ca-P and Mg-P. This happens because Ca and Mg have a strong positive charge on soil particles, while P has a negative charge, so it is attracted to Mg and Ca (Pohan et al., 2016).

K2O extracted by HCl 25% in the soil sampling locations in Larangan Subdistrict has values from high to very high with values of 45.6 mg/100g to 140.3 mg/100g. The availability of K in the soil is regulated by the dynamics of potassium in the soil which includes sorption and release. Intensive fertilizer application and excessive doses than recommended cause an increase in nutrient concentration in the soil solution, so that some K is absorbed by the soil containing 2:1 clay minerals into an unavailable form (Nursyamsi et al., 2007). In addition, the difference in numbers that occurred in Sitanggal Village was caused by soil leaching due to daily watering, causing the release of K. This is in accordance with the research of Mendes et al. (2016), which states that K nutrients in the soil are easily leached due to their transfer to soil solution and percolation.

Cation Exchange Capacity (CEC) at the soil sampling sites in Larangan sub-district ranges from 41.7 cmol(+)/kg to 52.5 cmol(+)/kg with a very high CEC status. The soil texture at each soil sampling location has a klei to dusty klei texture. Clay has a large surface area and is negatively charged. Soils with high clay have a greater number of soil colloids than other textures, thus affecting the CEC value in Larangan Subdistrict. This is in accordance with research conducted by Hartono (2024), which states that the CEC value increases according to the increase in clay content determined by soil clay minerals.

Base Saturation (BS) at the soil sampling sites in Larangan Sub-district ranges from 102.9% to 172.8% and is very high. Land management with inundation and rainfed systems in Larangan Sub-district affect the level of soil BS to be high (Kabala and Labaz 2018). The dominance of soil types with the Inceptisol order, which has a parent material of klei deposits to calcareous sandstone and marl in Larangan

Sub-district, has a high value of base cations in the soil colloids. This causes very high soil BS (Puja and Atmaja 2018).

3.1.2. Fertility Evaluation Based on Base Cation Saturation Comparison

BCSR analysis shows that the cation saturation value at the soil sampling location dominates Ca cations followed by Mg and K cations. Ca saturation has a higher value in Pamulihan and Kamal areas which have higher altitudes than other areas, different land management, and different soil types than other points, namely Typic Eutrudepts. Mg and K values have lower values than Ca due to the dominance of cation exchange complexes in the soil due to Ca saturation (Kasno et al., 2021). Analysis data of base saturation and cation ratio can be seen in Table 3.

Table 3. Results of fertility analysis based on BCSR

Village	Base Cation (%)			Cation Rasio		
	Ca	Mg	K	Ca/Mg	Ca/K	Mg/K
Pamulihan	158.92	11.29	2.05	14.08	77.67	5.52
Larangan	90.24	15.96	1.31	5.65	68.62	12.14
Kamal	145.62	4.91	4.77	29.66	30.50	1.03
Sitanggal	83.27	17.47	0.56	4.77	147.62	30.97
Rengaspendawa	90.79	18.56	1.40	4.89	64.66	13.21

In the table 3, the cation ratio shows the level of antagonistic and synergistic ions that affect the absorption of minerals by plant roots (Zalewska et al., 2017). The cation ratio shows that the Ca/Mg value in Pamulihan Village, and Kamal Village has a ratio value above the predetermined cation, while the Ca/Mg ratio in Larangan Village, Sitanggal Village, and Rengaspendawa Village has a ratio below the predetermined ratio. The overall Ca/K ratio is above the predetermined ideal ratio. Mg/K ratios in all soil sampling locations except Kamal Village, had ratios higher than the predetermined ratios, while Kamal had ratios lower than the predetermined ratios. The massive use of K fertilizer by farmers over a long period of time and the non-addition of Mg fertilizer, decreases the value of Mg, and suppresses the value of exchangeable K in the soil which has a lower valence cation than Mg (Gransee & Fuhrs 2013). This indicates that a cation imbalance is detected that can affect the effectiveness of cation exchange due to antagonism and mutual suppression. This can be detrimental to plants because it will affect the growth and movement of nutrients to the plant (Pulunggono et al., 2022).

3.2. Sustainability Analysis

The MSA analysis performed shows varying results. The sensitivity graph of the leverage variable shows the leverage factor, the leverage factor is selected through the highest sensitivity value which is a combination of the maximum sensitive value plus the sensitive value. In addition, the sustainability status graph is also presented. In the graph, the sustainability value is shown on the X-axis, while the Y-axis shows the future condition of the aspect. The explanation of the leverage factor analysis and sustainability status values is as follows.

3.2.1. Ecological Aspect

In the ecological aspect measured from 7 factors related to ecological sustainability in the intensification of shallot farming in Larangan District shows the results of the MSA analysis of 40,43 on the X-axis which means that the ecological aspect has a less sustainable status. While the value for future conditions is shown on the Y-axis which has a value of 35,2 which indicates that there is a possibility of a worse downturn. Because of that, the ecological aspect has urgency and requires greater policy intervention. The graph of leverage factors and sustainability status of ecological aspect can be seen in Figure 2.

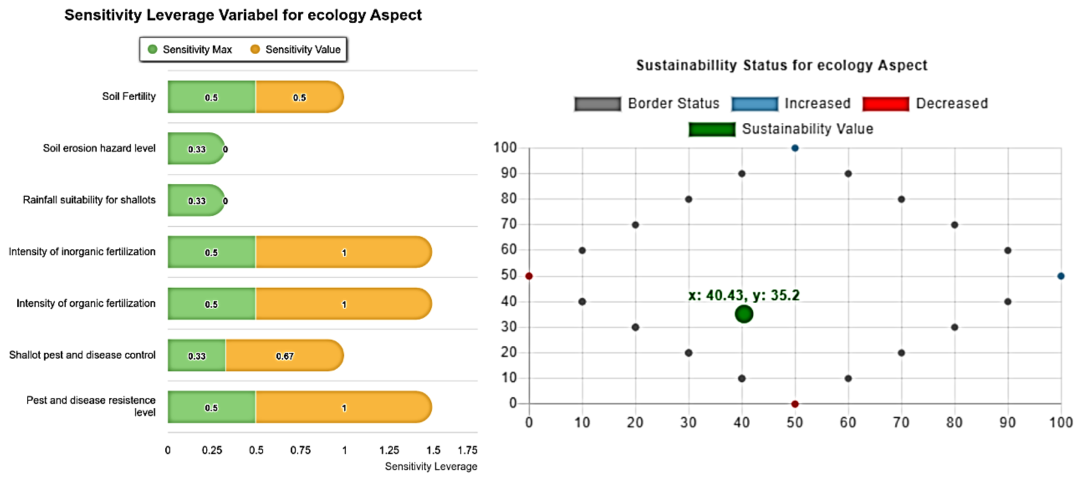

Figure 2. Graph of leverage factors and sustainability status of ecological aspects

In the figure 1, It can be seen that the 3 leverage factors that have the highest dominance in ecological aspects are pest and disease resistance, organic fertilization intensity, and inorganic fertilizer intensity. The three factors have the same value of 1.5 where the sensitive value is 1.0 (orange) and the maximum sensitivity value is 0.5 (green). The three sensitive factors are related to the unwise process of accelerating and maintaining the crop. The use of chemicals in pesticides and inorganic fertilizers causes pests and diseases to adapt to new conditions (Furlong et al., 2013). In addition, inorganic fertilizers that are applied intensively cause the binding of P nutrients and the absorption of K nutrients, so the efficiency of fertilizers absorbed into plants is not effective (Ibrahim et al., 2022). Onion farming activities in Larangan Subdistrict are also followed by a lack of organic fertilizer application, thus reducing C-organic values. Organic matter that is not returned to the soil causes less effective soil improvement, because of the function of organic matter in improving the physical and chemical properties of the soil (Wang et al., 2019). The factor in this aspect is also supported by the soil analysis that has been carried out which shows the low value of organic C and the high value of P and K that exctracted by HCl 25%.

3.2.2. Economical Aspect

Economical aspect is measured through 5 sustainability factors related to the economy of shallot farming intensification activities in Larangan Sub-district, in the form of income capitalization, and subsidies. In the economic aspect, the results of the MSA analysis show that the economic status of intensive agriculture in Larangan Sub-district has a value of 45 with a less sustainable status. Conditions in the future have a value of 55 which means there is a possibility of an increase in the future. The graph of leverage factors and sustainability status of economical aspect can be seen in Figure 3.

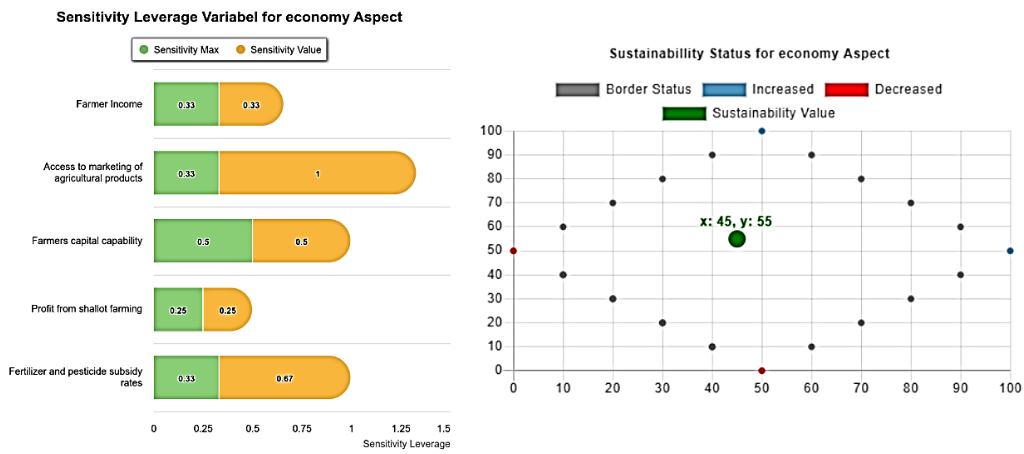

Figure 3. Graph of economic leverage factors and sustainability status

In the economic aspect of the leverage sensitivity graph, it can be seen that the first 3 leverage factors in the economic aspect are farmer's marketing access with a value of 1.33 with a sensitivity value of 1.0, and maximum sensitivity of 0.33. The second leverage factor is the ability of farmers' capital which has a value of 1.0 with a maximum sensitivity value of 0.5 and a sensitivity value of 0.5. The third leverage factor is the level of fertilizer and pesticide subsidies, which has a value of 1.0 with a sensitivity value of 0.67 and a maximum sensitivity value of 0.33. The tendency of shallot farmers in Larangan sub-district who still sell to middlemen with a bonded system that sells before the harvest period at a low price. This is because the market is relatively far from the land (Sanakh et al., 2020). This marketing problem provides uncertainty to farmers because it is not uncommon for farmers to experience losses due to uncertain price fluctuations. In addition, the capital factor is related to the easy accessibility of farmers to financial conditions to start a farming business in Larangan Subdistrict using the People's Business Credit program which has an annual interest rate of 6%. The uncertainty of prices obtained by farmers during the harvest period does not guarantee the return of capital loans on time. Thus, it is necessary to increase farmer's capital, which is a key factor in increasing farmer's income (Febryanto et al., 2024). The next factor is related to the subsidy program by the government. In its activities, access to fertilizer that requires the use of a farmer card makes it difficult for farmers to access subsidized fertilizer. The low knowledge of farmers regarding the making of farmer cards and the long printing time of farmer cards cause obstacles for farmers so that they do not take subsidized fertilizers and end up stacked at agricultural kiosks.

3.2.3. Social Aspect

The social aspect was analyzed based on 7 factors related to the social situation in Larangan Sub-district. The analyzed factors start from the social state of farmers, the level of understanding, and the level of regeneration of farmers. The results of the analysis on social aspects show that the sustainability status has a value of 57.14 which means it has a sustainable status, while the conditions in the future have a value of 67.86 which means there is a possibility of better improvement, because of that sustainability on this aspect needs to be maintained. The graph of the leverage factor and sustainability status can be seen in Figure 4.

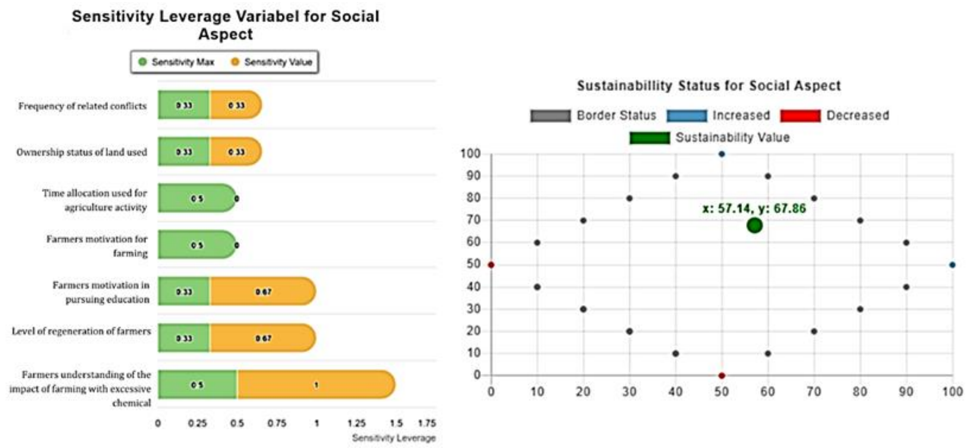

Figure 4. Graph of social aspect leverage factor and sustainability status

In the social aspect, leverage factors that can improve the social level of shallot farmers in Larangan Subdistrict are the first level of understanding of the impact of agriculture with excessive chemicals which has a total sensitivity value of 1.5 with a maximum sensitivity of 0.5 and a sensitivity value of 1.0. The second leverage factor is the motivation of farmers in formal education with a total sensitivity value of 1.0 with maximum sensitivity value of 0.33 with a sensitivity value of 0.67. The third sensitivity factor is the level of regeneration of farmers who manage the land with a total sensitivity of 1.0 with maximum sensitivity of 0.33 and a sensitivity value of 0.67. Regarding its activities, the intensification of shallot farming socially has a high value but still has factors that threaten the stability of farming activities. The high use of inorganic fertilizers occurs due to farmer's lack of knowledge about the regulated dose of fertilizer. In addition, the lack of quality and quantity of qualified human resources related to sustainable agriculture will affect coordination in the implementation of government activities (Nasrullah & Ovitasari 2021). Furthermore, the motivation of farmers to obtain both formal and informal education in Kecamatan Larangan is dominated only up to elementary and junior high school which is continued by hereditary knowledge. This factor affects land management because management should adapt to existing conditions, as well as technological adaptations in land management that can increase farmer's income in Larangan District (Mariyono et al., 2021). In addition to education, the regeneration level of farmers in Larangan Subdistrict is still dominated by the age of more than 40 years to 70 years. The younger generation who enter the productive age tend to leave farmland and choose industrial labor jobs, both domestically and abroad. This happens because the younger generation wants to obtain a higher economic status, get a fixed salary, and social status.

3.2.4. Institutional Aspect

Institutional aspect was analyzed by the value of sustainability status that based on the state of the institution which is composed of 6 factors in the form of transparency of cooperation between the government and the sub-district, agricultural organizations, training, and capital provider institutions. In the institutional aspect, the MSA analysis shows a value of 55.5 with a sustainable status, while the future condition has a value of 70.83 which means there is a possibility of better improvement, because of that, this condition needs to be maintained. The graph of leverage factors and sustainability status can be seen in Figure 5.

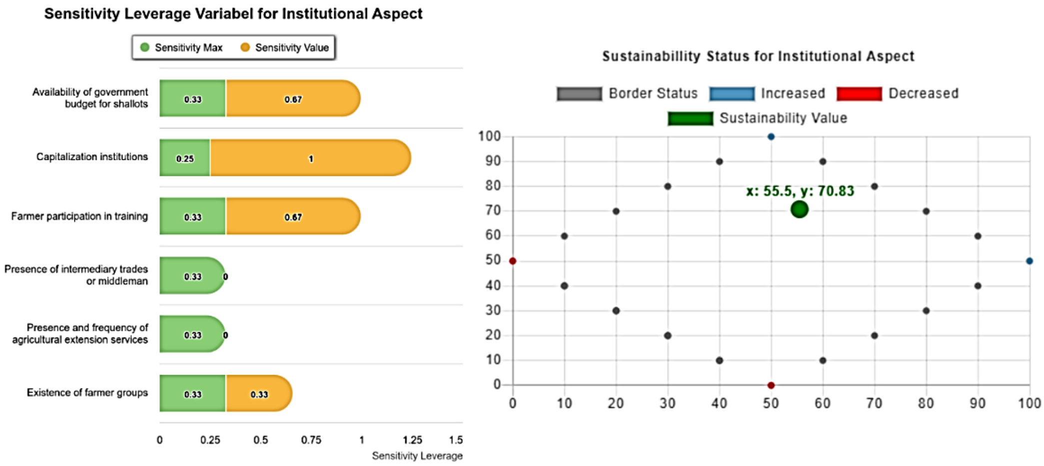

Figure 5. Graph of institutional aspect leverage factor and sustainability status

In the institutional aspect the first lever factor to maintain the institutional condition of shallot farming in Larangan Subdistrict is the dominant institution used to start shallot farming which has a total value of 1.25 with a maximum sensitivity of 0.25 and a sensitivity value of 1.0. The second leverage factor is the availability and smooth distribution of the local government budget for shallots with a total value of 1.0 with a maximum sensitivity value of 0.33 and a sensitivity value of 0.67. The third leverage factor is the participation of farmers in training which has a total value of 1.0 with a maximum sensitivity value of 0.33 and a sensitivity value of 0.67. The tendency of shallot farmers in Larangan Sub-district to borrow from institutions in the form of banks provides uncertainty about interest rates and inflation rates (Amanullah et al., 2020). In addition, the equitable distribution of the budget has not been equally touched by all farmers in Larangan Subdistrict. The subsidy, which is only focused on fertilizers, continues to expand farming capital, both from seeds, pesticides, irrigation, and land rent, so further evaluation is needed regarding this issue. In addition, the low participation of farmers in training shows the low participation in institutions in the form of capacity building and capabilities of farmers (Jamaluddin et al., 2023). The availability of agricultural extension officers who take care of 1-3 people per village, requires extension officers to work extra to educate farmers. This has implications for other aspects such as the economy and ecology of shallot farmers in the Larangan sub-district.

3.2.5. Technological Aspect

This aspect is analyzed based on 6 factors. These factors are related to the development of agricultural science and technology from before planting to post-harvest. The results show that the sustainability value is 41.67, which means it is less sustainable, while the future condition has a value of 63.09, which means that there is a possibility of better improvement, but need to take action to maintain decreasing sustainability. The graph of the leverage factors and sustainability status can be seen in Figure 6.

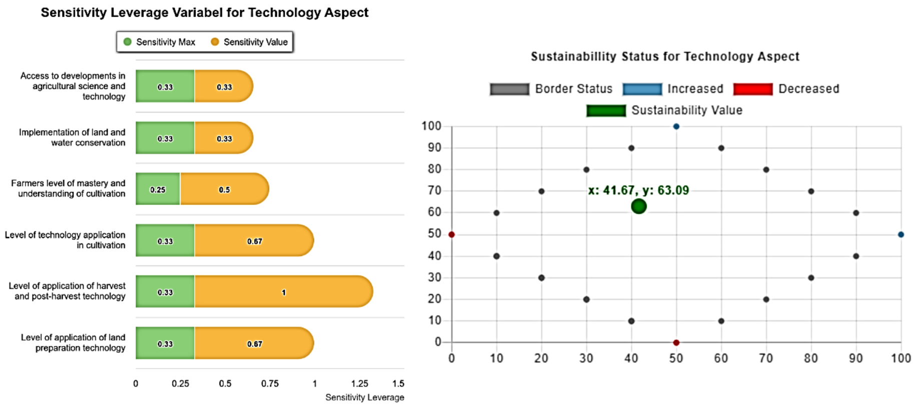

Figure 6. Graph of technology aspect leverage factor and sustainability status

The first leverage factor in the technological aspect is the level of application of harvest and post-harvest technology which has a value of 1.33 with a maximum sensitivity of 0.33 and a sensitivity value of 1.0. The second leverage factor is the level of technology application in cultivation which has a total value of 1.0 with a maximum sensitivity of 0.33 and a sensitivity value of 0.67. The third leverage factor is the level of technology application and land preparation methodology, which has a value of 1.0 with a maximum sensitivity value of 0.33 and a sensitivity value of 0.67. The three leverage factors are related to existing technologies in land preparation to post-harvest. Based on scores from key people and field observations, the use of technology has entered several villages in Larangan sub-district, but it is still uneven and dominated by conventional methods. The use of technology is still limited to land preparation in the form of cultivators and pesticide sprayers. The use of technology should be developed in agriculture, to increase efficiency, maintain quality, and save labor expenses. Following the research of Assad et al. (2013), which states that by improving one component of cultivation technology, shallot productivity can be increased. In addition, economic improvement is in line with technological improvement, so that agricultural actors can implement technology in the form of superior cultivars that have high yield power, sustainable cultivation techniques, and farm mechanization (Ulfa et al., 2018).

3.2.6. Logistic and Infrastucture Aspect

This aspect is composed of 5 factors related to logistics and infrastructure ranging from irrigation, warehousing systems, transportation networks, and marketing distribution, as well as the availability of agricultural cooperative facilities. The results of the MSA analysis show a value of 53.4, which is quite sustainable, with future conditions having a value of 65 which mean, there is a possibility of better improvement, so this condition needs to be maintained. The graph of leverage factors and sustainability status can be seen in Figure 7.

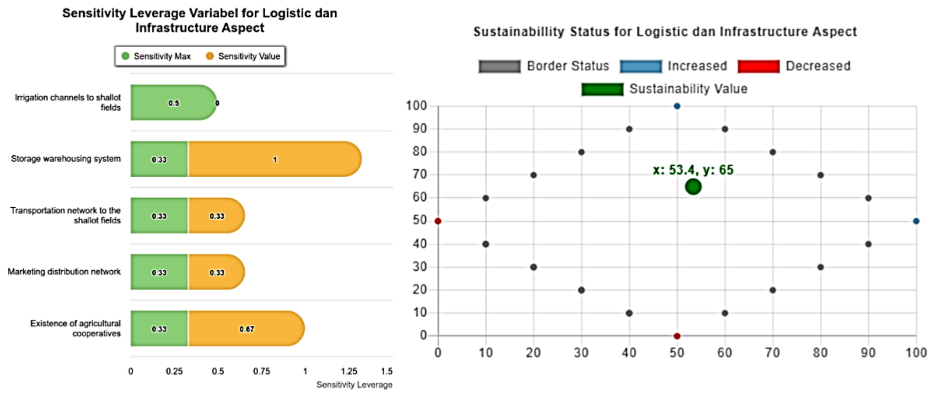

Figure 7. Graph of logistic and infrastucture leverage factor and sustainability status

In the logistics and infrastructure aspect, leveraging factors to maintain and develop logistics and infrastructure conditions, namely the first is the existence of a storage warehousing system which has a total value of 1.33 with a maximum sensitivity of 0.33 and a sensitivity value of 1.0. The second leverage factor is the existence of agricultural cooperatives, which have a total value of 1.0 with a maximum sensitivity of 0.33 and a sensitivity value of 0.67. The third leverage factor is the marketing distribution network with a total value of 0.66 a maximum sensitivity value of 0.33 and a sensitivity value of 0.33. The leverage factors are related to warehousing, facilitation of agricultural cooperatives, and marketing distribution. Based on field observations and key person answers, the situation related to the analyzed leverage factors is that agriculture in Kecamatan Larangan still uses conventional methods to store crops and seeds, this should be developed through the integration of warehouses equipped with Controlled Atmosphere Storage (CAS) with a warehouse receipt system to maintain price stability (Zidny et al., 2024). In addition, the abandonment of cooperatives in Larangan sub-district requires further intervention, as cooperatives function to increase income, provide employment, and manage the marketing of production (Kristiana et al., 2024). In addition, low marketing distribution networks reduce farmers' ability to sell directly to the market and get higher prices, so they sell to middlemen at lower prices than the market (Ma et al., 2024). This requires further adaptation of both market sales and agricultural activities for higher profits (Liu et al., 2019).

3.2.7. Multiaspect Analysis and Validation

The analysis provides a sustainability index for each aspect measured with a range of 0-100%, where values >50% are given a sustainable index. The results of the analysis of the 6 aspects measured in this study, for each aspect, can be seen it is found that aspects that have a less sustainable status are technological, ecological, and economic aspects. Meanwhile, logistics and infrastructure, institutional, and social aspects have a sustainable status. The overall multi-aspect status of sustainability can be seen in Table 4.

Table 4. Sustainability index value and validation status of sustainability analysis

Aspect	Sustainability Index (%)	Validation (%)	Sustainability Status
Ecology	40.43	0.57	Low Sustainable
Economy	45.00	1.00	Low Sustainable
Social	57.14	1.14	Sustainable
Institutional	55.50	2.50	Sustainable
Logistic and Infrastucture	53.40	0.40	Sustainable
Technology	41.67	1.33	Low Sustainable
Multiaspect	**48.86**	**1.18**	**Low Sustainable**

**Note: Sustainability status standard by Firmansyah (2022).*

In the table above, it can be seen that the sustainability index value for intensive land management in Larangan Sub-district has a value of 48,86% with a less sustainable status. The overall validation result is 1.18%, which means that the data can be validated because it is by the minimum requirement of 5%. Therefore, increasing the sustainability status requires strategic intervention or policy treatment in each of the leverage factors in each aspect. The intervention will form a sustainability strategy scenario to optimize land management in shallot farming intensification activities in Larangan District, Brebes Regency. The scenario that can be done is by increasing the value of the leverage factor that has the highest sensitivity value in each aspect and the factor score value that is at the value of 0 or bad. The improvement is done by increasing farmers' understanding of the impact of excess chemicals, increasing market access for agricultural products, improving the intensity of pesticide use, stabilizing the use of inorganic fertilizers, optimizing the function of the capital agency, improving the warehousing system, and improving harvest and post-harvest technology.

4. Conclusions

Larangan is one of the areas that runs the onion farming intensification program with massive fertilization and pesticide use. The research conducted found that the results of nutrient balance analysis were categorized as less balanced, despite having moderate soil fertility status. This is due to the low value of organic carbon and the unbalanced cation ratio in the soil. Based on the evaluation of sustainability status, Larangan is divided into two statuses, namely low sustainable in ecological, economic and technological aspects, and sustainable in social, institutional, and logistical and infrastructure aspects. On a multi-aspect basis, the status of sustainability in Larangan is categorized as low sustainable. Ecological aspects with low sustainable status require policies that must take precedence over other aspects because they have the potential to decline in the future, followed by economic and technological aspects that have low sustainable status but have the potential to increase in the future. The main leverage factors to improve multi-aspect sustainability in ecological aspects include the intensity of organic and inorganic fertilization, and resistance to pests and plant diseases. On the economic aspect, access to agricultural product markets, farmer's capital capacity, and fertilizer and pesticide subsidies. On the technological aspect, it concerns the level of technology application in activities related to harvest, post-harvest, cultivation, and land preparation.

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