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Strategy to Develop Okra (*Abelmoschus esculentus* L.) Plantation Based on Land Suitability Class and SWOT analysis

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ABSTRACT

Okra is famous as super food sources that prevent diabetes and reduce cholesterol. To meet the increasing demand for okra, it is necessary to develop plantation for okra cultivation. In this sense, land suitability analysis for okra plantation is needed as base information to develop the plantation development strategies. This study aimed to identify the okra plantation development strategies in Jember Regency. The strategies involved the technology recommendations needed to improve land conditions. Land suitability evaluation parameters were analyzed using ArcGIS software. The results of the analysis were used to determine internal and external factors in the SWOT (strengths, weaknesses, opportunities, and threats) analysis to determine the technology needed. Results showed that suitable area for okra plantation was divided into class S1 (highly suitable) of 56.85%, and class S2 (moderately suitable) 43.15% of the area. Moreover, based on SWOT analysis the proposed technology strategies for 7 sub districts were in the quadrant II, meaning had weaknesses. Increasing compost as fertilizer was recommended to increase N, K, and P in the soil as well as to increase soil solum. In addition, irrigation and drainage system was proposed to solve problems regarding rainfall. Recommendation to reduce sloping area included terracing development.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is a flowering plant belonging to the *Malvaceae* family. It is distributed and cultivated across Africa, America, Europe, and Asia. Although okra is not indigenous to Indonesia, the country has become a significant center for okra cultivation diversity. Okra has gained popularity among the public due to its beneficial properties. According to Hattaya *et al.* (2019), consuming okra is beneficial for health as it can help prevent diabetes, lower cholesterol levels, reduce the risk of heart disease, enhance lactation, alleviate constipation, provide essential vitamins, and maintain healthy skin. Almost all parts of the okra plant, including the leaves, shoots, flowers, pods, and seeds, can be utilized.

Okra is primarily distributed in regions with tropical and subtropical climates (Hafizh & Banu, 2019). This plant has high market value and is an export commodity. In 2017, only about 30% of locally marketed okra was sold domestically, while 70% of the total production of around 1500 tons/year was exported to Japan, Taiwan, Australia, and several other countries (Millah *et al.*, 2022). Every year, Japan imports approximately 4000 tons of okra from various suppliers such as China, Taiwan, and Indonesia (Afandi, 2016). However, okra is not yet widely cultivated and unable to meet market demands. Therefore, increasing the cultivation area for okra is necessary, particularly in Jember

Regency. In Jember, okra is cultivated through a partnership model with PT Mitra Tani. However, there are still opportunities to expand okra cultivation in Jember Regency to meet both national and international market demands.

Jember Regency covers an area of 3,306.69 km², with altitudes ranging from 0 to 3,330 meters above sea level, resulting in a generally tropical climate with temperatures between 15°C and 37°C (BPS, 2021). Land use in Jember Regency is dominated by agricultural activities, with agricultural land covering 46.41% of the total area. Under these environmental conditions, okra can grow well in areas with an altitude of 800 meters above sea level. Okra can grow longer in the highlands. According to Simanjuntak & Gultom (2018), okra planted in the Berastagi highlands with altitude of 1340 m above sea level, can survive and grow well until reaching the age of 4-6 months. High-quality okra have a size of 5-10 cm (Muliadi *et al*., 2019). The quality of okra is influenced by many factors, necessitating a study to determine land suitability for okra cultivation to achieve optimal results from suitable land (Rachmah *et al*., 2018).

For large-scale assessments, such as at the regency level, land evaluation can be conducted using spatial analysis with Geographic Information System (GIS) integrated into ArcGIS software (Fadila *et al*., 2021). The results of this land suitability evaluation can then be used to formulate land improvement strategies. One method involves the combination of SWOT (strengths, weaknesses, opportunities, and threats) analysis, where the internal factor analysis summary (IFAS) and external factor analysis summary (EFAS) are determined based on the land suitability evaluation conditions. The analysis results provide information and strategies for the development and improvement of land for okra cultivation in Jember Regency.

2. MATERIALS AND METHODS

This study was conducted from January to July 2023 at the Environmental Control and Conservation Engineering Laboratory, Agricultural Engineering Study Program, Faculty of Agricultural Technology, University of Jember. The tools used included a laptop, Microsoft Office Excel 2010 software, Microsoft Office Word 2010 software, Microsoft Visio 2007 software, and ArcGIS 10.3 software. The materials used included climatology data such as air temperature from 2003-2022 obtained from the BMKG website, rainfall data from 2003-2022 at 79 rain stations in Jember Regency obtained from the Public Works and Spatial Planning Office (Jember Regency), soil data from the 1960 Exploratory Soil Map of Java and Madura verified with physical and chemical soil characteristics measurements in 2022, soil fertility data, altitude and slope data from a 30m x 30m Digital Elevation Model (DEM) obtained from the USGS in 2022, and land use maps from the Rupa Bumi Indonesia (RBI) for Jember Regency obtained from the Ina Geoportal.

Land suitability evaluation was conducted using the matching method, comparing land characteristics with okra growth conditions (Fadila *et al*., 2021). Suitability maps were created by overlaying layers and conducting a SWOT analysis to determine land improvement strategies. Land capability classes and dominant classes for each land characteristic were determined through weighting and rating based on interviews with three key competent individuals in okra cultivation and plant engineering. The interview results were used to determine land suitability classes (Maulana & Rudiarto, 2015). The weights were determined as shown in Table 1, where S1 (very suitable) is rated 4, S2 (suitable) is rated 3, S3 (marginally suitable) is rated 2, and N (not suitable) is rated 1 (Ritung *et al*., 2011). The total weight of the 11 parameters was then matched with the class range to form a land suitability map for okra plants in Jember Regency. The parameters include air temperature, annual rainfall, soil texture, soil depth/solum, organic C, CEC, soil pH, soil N, P, K, and slope. The land suitability map creation procedure is shown in Figure 1.

Table 1. Calculation of land suitability class classification (Fadila *et al*., 2021)

Class	Weight	Parameter	a	b	c	d
N	1	11	11	5.5	16.5	5.5-16.5
S3	2	11	22	5.5	27.5	16.5-27.5
S2	3	11	33	5.5	38.5	27.5-38.5
S1	4	11	44	5.5	49.5	38.5-49.5

Note: a: weight multiplied by the number of parameters; b: distance between two weights; c: total of a and b; d: value range between land suitability classes

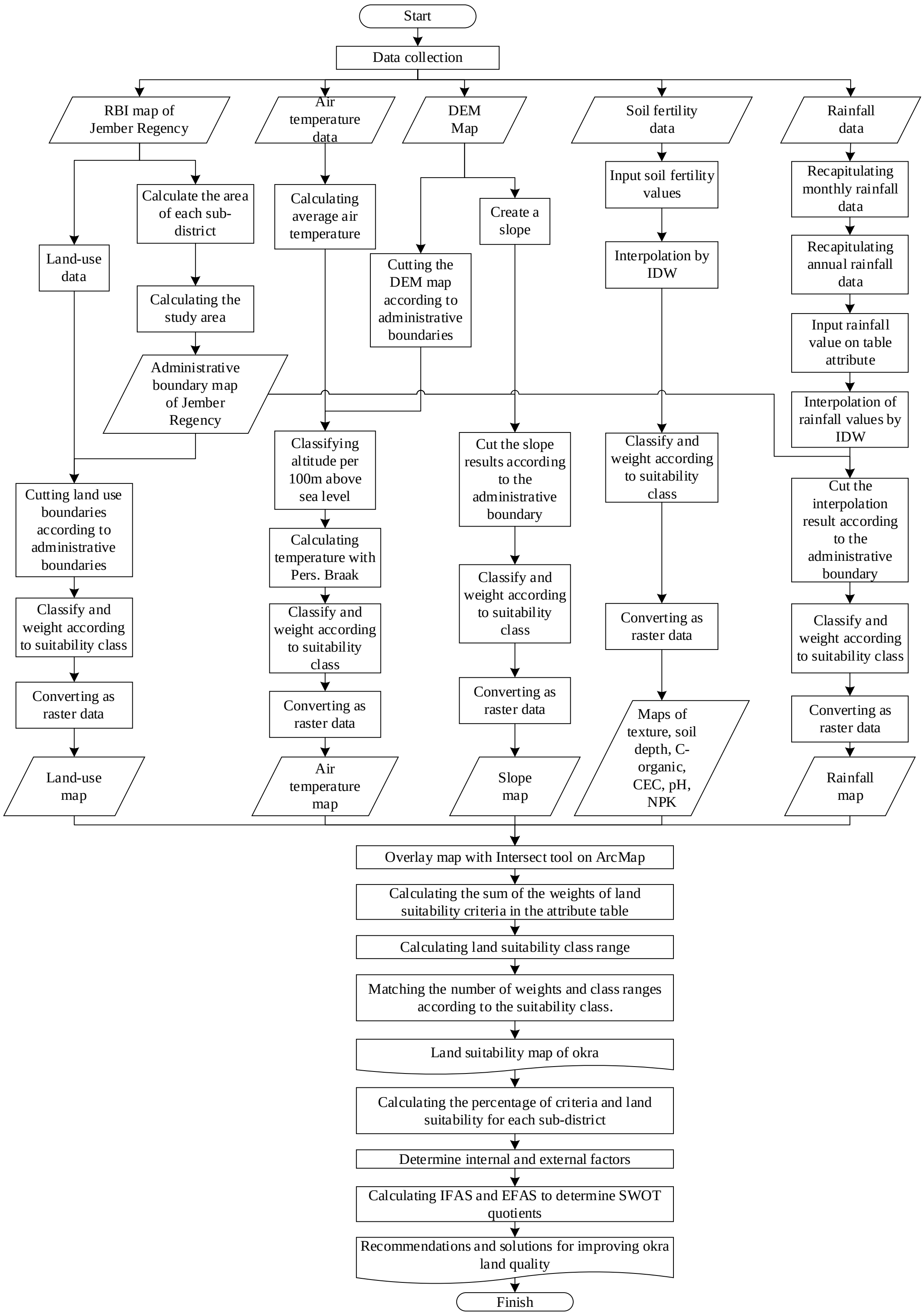


Figure 1. Research flow diagram

Following the matching method, land parameter analysis with weighting determination was conducted. Weighting was based on the results of interviews with experts from PT Mitra Tani, including the field production manager and agronomy lecturers from the Faculty of Agriculture, University of Jember. Weighting was done by formulating IFAS and EFAS with limiting factors as shown in Table 2. Weighting was based on the importance level of a factor in relation to strengths and weaknesses, starting from 1.0 (most important) to 0.0 (not important). The rating was based on the magnitude of the impact of a factor on strengths and weaknesses, ranging from 4 to 1 (Fadila *et al*., 2021).

Table 2. Determination of IFAS and EFAS

SWOT Factor	Suitability Class	Criteria
S	S1	> 50%
W	S3	≥ 50%
O	S1	≥ 50%
	or S2	≥ 50%
T	S3	> 50%
	or N	> 50%

Internal (IFAS) and external (EFAS) factors were used to determine the position of each land on the SWOT space matrix quadrant as shown in Figure 2. Strategies for land improvement or development for okra cultivation was then determined. An area is included in the S quadrant (strength) if more than 50% of the area has IFAS in the S1 category (suitable). If an area has IFAS in the S3 category of more than or equal to 50%, then the area is included in quadrant II (W) or has weakness factors. An area with criteria S1 or S2 of more than and equal to 50% will be included in quadrant III (O) or has opportunities. Conversely, if an area is included in the S3 or N suitability class of more than 50% of the total area, then the area will be in quadrant IV (T) or has threats.

The S-O (strength-opportunities) strategy is implemented by utilizing all strengths and opportunities. The S-T (strength-threat) strategy is implemented by leveraging strengths to anticipate existing threats. The W-O (weakness-opportunities) strategy is implemented by utilizing opportunities to minimize existing weaknesses. Last, the W-T (weakness-threat) strategy is implemented by minimizing weaknesses and avoiding threats. The development strategy may include directing suggestions for improvements to address land suitability issues for okra classified as S2, S3 to be improved into S1. Improvements can be based on observation to the parameters requiring enhancement.

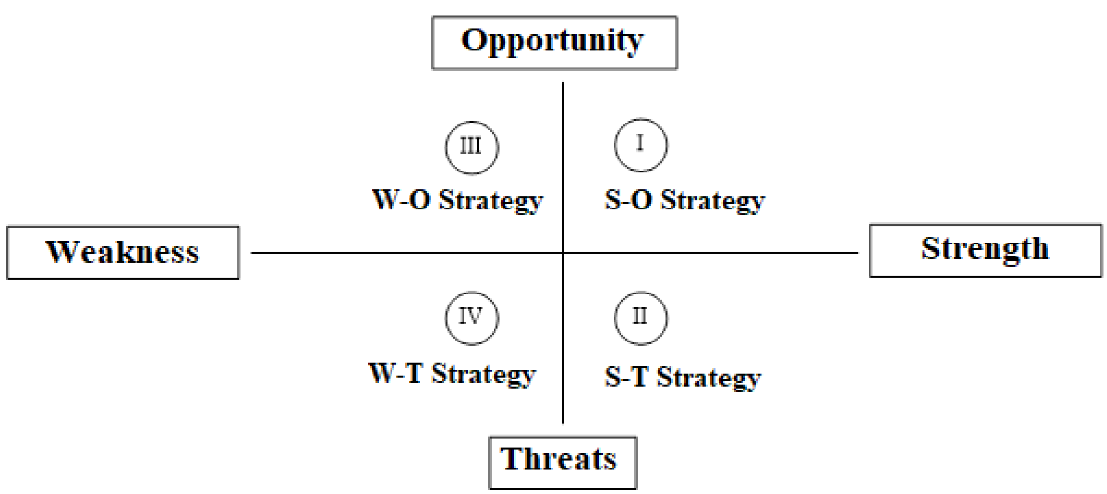


Figure 2. Space matrix of SWOT analysis

3. RESULTS AND DISCUSSION

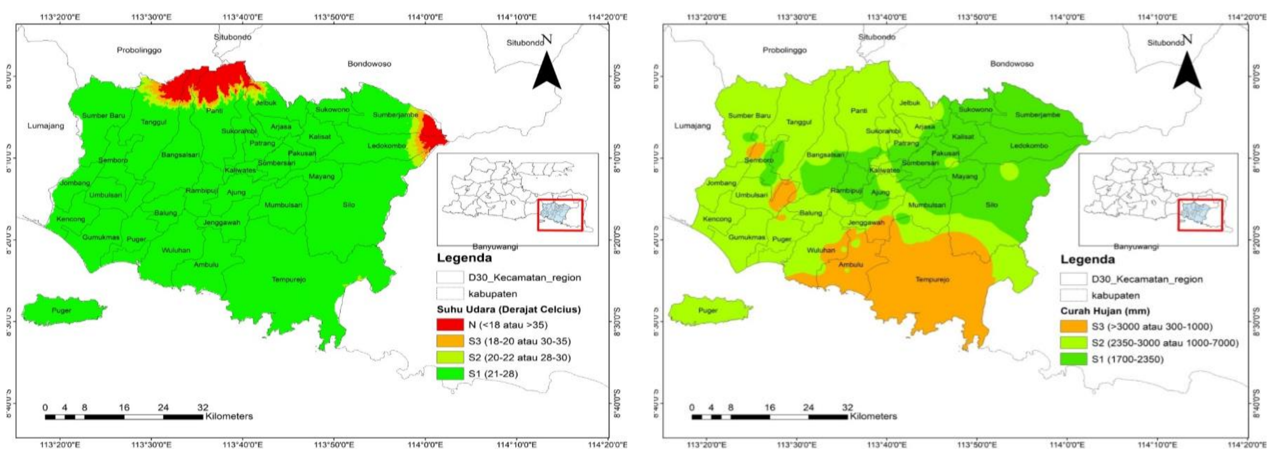
3.1. Potential Natural Resources and Land Suitability

a. Air Temperature

The optimal air temperature suitable for okra plants is between 21-28°C. Although okra can be grown in dry and hot conditions exceeding its optimum temperature, the yield will not be maximal. Conversely, if okra is planted at temperatures below 17°C, it will not germinate (Zulhaedar & Mardiana, 2016). The analysis showed that 92.87% of the area in Jember Regency has a temperature suitable for okra cultivation, as presented in Table 3 and the evaluation map in Figure 3a.

Table 3. Air temperature suitability classes

Criterion	Temperature (°C)	Description	Area (Ha)	Area (%)
S1	21-28	Very suitable (S1)	304,294.60	92.87
S2	20-22 28-30	Moderately suitable (S2)	6,591	2.01
S3	18-20 30-35	Marginally suitable (S3)	4,400.76	1.34
N	<18	Not suitable (>1500m asl) (N)	12,370.80	3.78



(a) (b)

Figure 3. Land suitability map: (a) Air temperature, and (b) Annual rainfall.

Table 4. Annual rainfall suitability classes

Criterion	Rainfall (mm/year)	Description	Area (Ha)	Area (%)
S1	1700-2350	Very suitable	101,540.88	30.66
S2	2350-3000 1000-1700	Moderately suitable	162,644.49	49.11
S3	>3000 300-1000	Marginally suitable	67,022.55	20.24

b. Rainfall

Rainfall affects water availability and land drainage systems. Optimal growth of okra occurs at rainfall levels between 1700-2350 mm. Low rainfall reduces water availability in the soil for okra, resulting in suboptimal production.

Conversely, high rainfall can cause waterlogging, leading to stress for okra plants (Gunawardhana & Silva, 2011). The analysis showed that 49.11% of the area falls under the S2 class, indicating limitations that can be mitigated by farmers through the construction of drainage systems and daily watering. Rainfall suitability analysis was determined using IDW interpolation, utilizing centroid data representing certain regions (Sari *et al*., 2021). The land suitability evaluation results are shown in Table 4 and the evaluation map in Figure 3b.

c. Soil Texture

Soil texture plays a crucial role in water absorption, nutrient development, and soil erosion sensitivity. For okra, a suitable soil texture is sandy loam or sandy clay loam (Suryani, 2014) because these textures have high cation exchange capacity (CEC). In Jember Regency, 50.90% of the area falls under the S1 class for soil texture. The evaluation results are shown in Table 5 and the evaluation map in Figure 4a.

Table 5. Soil texture suitability classes

Criterion	Soil Texture	Description	Area (Ha)	Area (%)
S1	Sandy loam, Sandy clay loam	Very suitable	168,569.82	50.90
S2	Loam, Clay	Moderately suitable	133,438.41	40.29
S3	Sand, Sandy clay	Marginally suitable	29,199.69	8.82

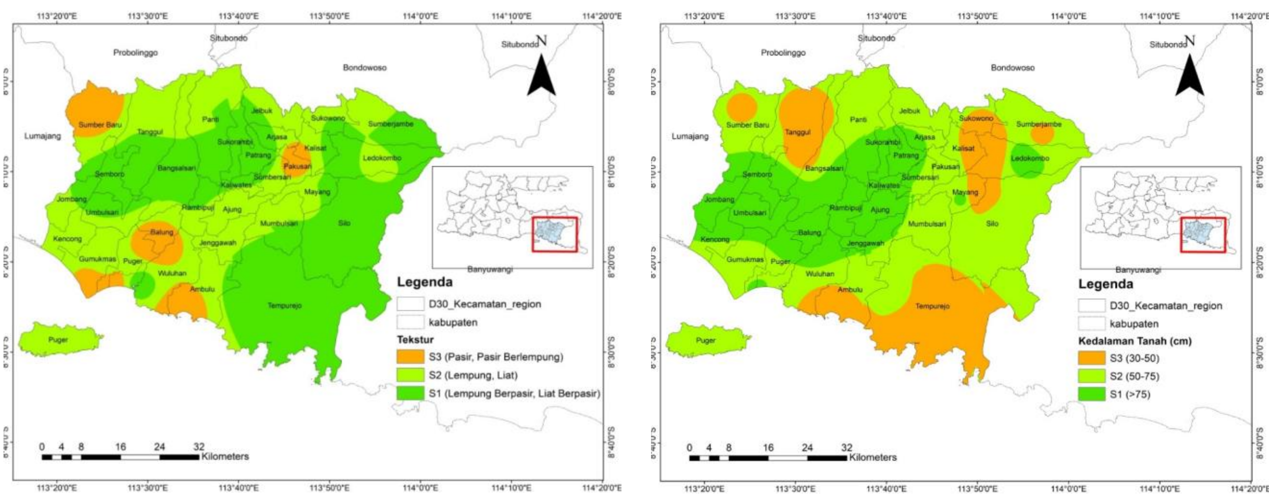


Figure 4. Land suitability map: (a) Soil texture, and (b) Soil depth.

d. Soil Depth (Soil Solum)

Soil depth, or solum, is the root zone for plants. For okra, a soil depth of more than 75 cm is ideal, providing sufficient nutrients and support for stems that can reach up to 2 meters (Gustian *et al*., 2018). In Jember Regency, 50.08% of the land falls under the S2 class for soil depth. Adding topsoil depth can be achieved by using compost. The evaluation results are shown in Table 6 and the evaluation map in Figure 4b.

Table 6. Soil depth suitability classes

Criterion	Soil Depth (cm)	Description	Area (Ha)	Area (%)
S1	>75	Very suitable	88,594.29	26.75
S2	50-75	Moderately suitable	165,856.51	50.08
S3	30-50	Marginally suitable	76,749.03	23.17

e. Organic Carbon (C-Organik)

For okra, the ideal organic carbon level is less than 2% (Du *et al*., 2012). High organic carbon in soil indicates high mineral content, contributing to plant structure, energy, and nutrient sensitivity. In Jember Regency, all evaluated areas 331,207.92 ha or 100% fall under the S1 class with criteria of organic C >1.2%. The evaluation results are shown in the evaluation map in Figure 5a.

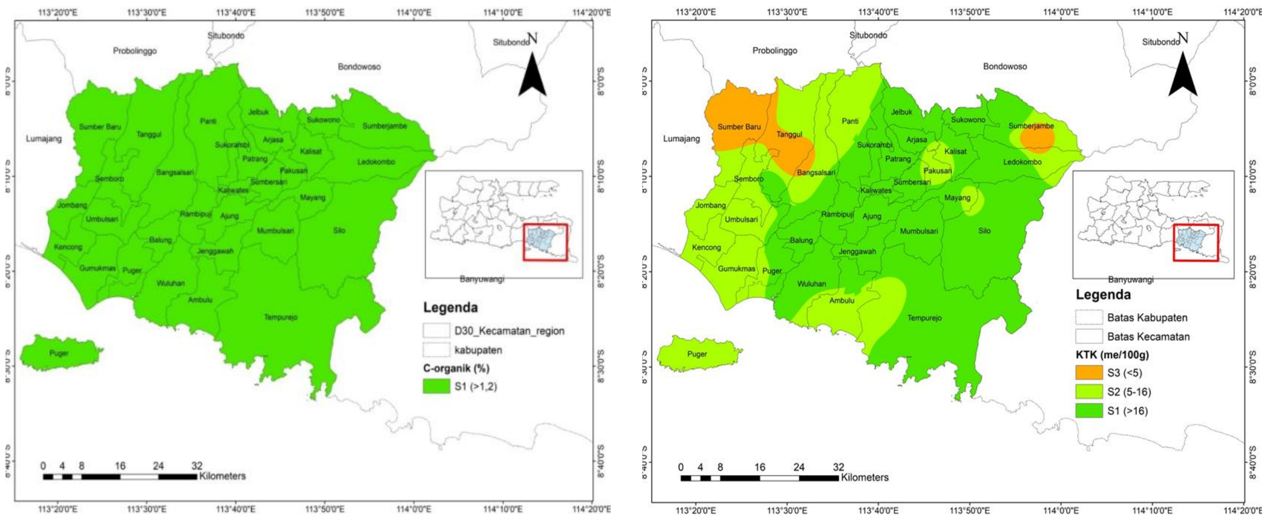


Figure 5. Land suitability map: (a) Organic carbon, and (b) Cation exchange capacity (CEC).

f. Cation Exchange Capacity (CEC)

CEC is crucial for providing nutrients and depends on soil texture (Suryani, 2014). Higher clay content increases CEC. The ideal CEC for okra is >16%, categorized as S1, covering 59.15% of the area in Jember Regency. The evaluation results are shown in Table 7 and the evaluation map in Figure 5b.

Table 7. Cation exchange capacity suitability classes

Criterion	CEC (me/100g)	Description	Area (Ha)	Area (%)
S1	>16	Very suitable	195,910.29	59.15
S2	5-16	Moderately suitable	110,946.51	33.5
S3	<5	Marginally suitable	24,351.12	7.35

g. Soil pH

Okra tolerates a soil pH of 5.5-6.2. Below pH 5.5, okra pods do not develop well (Brandenberger *et al*., 2019). In Jember Regency, the dominant pH class is S2, covering 47.07%. Soil pH improvement can be done through liming. The evaluation results are shown in Table 8 and the evaluation map in Figure 6a.

Table 8. Soil pH Suitability Classes

Criterion	Soil pH	Description	Area (Ha)	Area (%)
S1	5.5-6.2	Very suitable	26,556.39	8.02
S2	5.2-5.5 6.2-6.8	Moderately suitable	155,887.74	47.07
S3	<5.2 >6.8	Marginally suitable	148,763.79	44.92

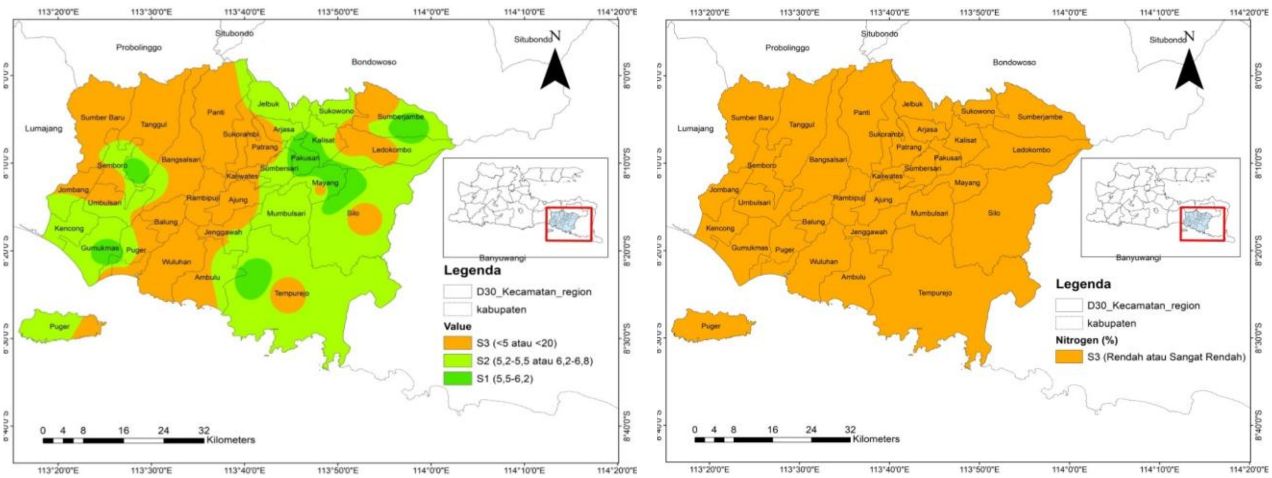


Figure 6. Land suitability map: (a) Soil pH, and (b) Soil nitrogen.

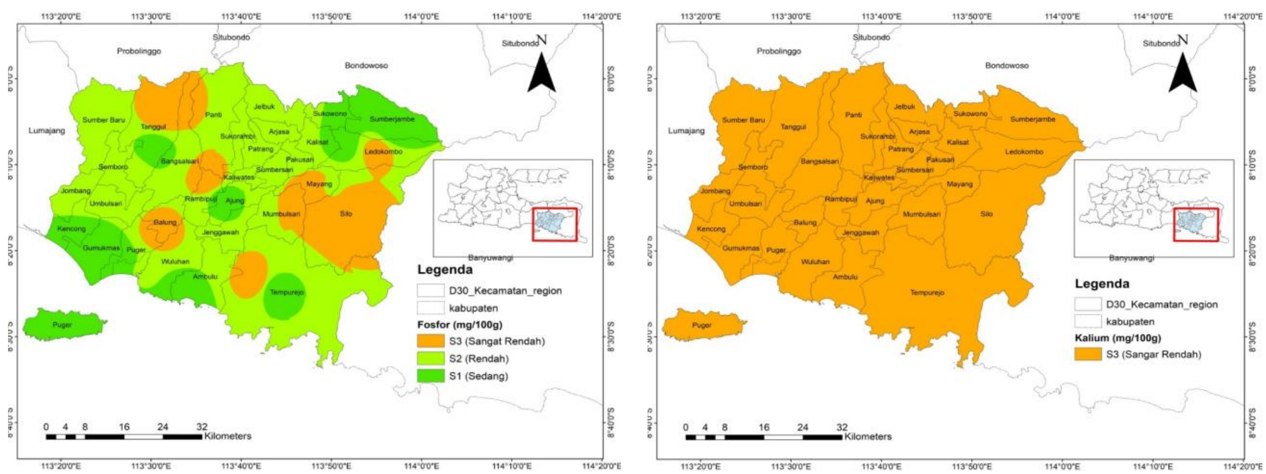


Figure 7. Land suitability map: (a) Phosphorus content, and (b) Potassium (K) content.

h. Nitrogen (N)

Nitrogen aids vegetative growth in plants (Suminar *et al*., 2018) and increases the number of fruits (pods) in okra. In Jember Regency, the overall evaluation shows that all areas 331,207.92 ha or 100% classified as marginally suitable (S3 category), indicating low or very low nitrogen. This can be improved by applying organic fertilizer (Andriyani & Patricia, 2021). The evaluation results are shown in the evaluation map (Figure 6b).

i. Phosphorus (P)

Phosphorus is essential for energy transfer within plants (Qibtyah, 2015). In Jember Regency, 56.70% of the area falls under the S2 class with low phosphorus. Low phosphorus results in brown leaf edges and can be improved with organic fertilizers. The evaluation map in Figure 7a and the evaluation results are shown in Table 9.

Table 9. Phosphorus suitability classes

Criterion	Phosphorus (mg/100g)	Description	Area (Ha)	Area (%)
S1	Medium	Very suitable	71,527.95	21.60
S2	Low	Moderately suitable	187,804.80	56.70
S3	Very low	Marginally suitable	71,875.17	21.70

j. Potassium (K)

Potassium strengthens the plant, preventing leaves, flowers, and fruits from falling off easily (Hutapea *et al*., 2014). In all Jember Regency (331,207.92 ha or 100%), potassium levels fall entirely within the S3 class, indicating very low levels due to soil erosion and leaching. This can be improved by applying adequate organic fertilizer. The evaluation results are shown in the evaluation map (Figure 7b).

k. Slope Gradient

Slope gradient affects land cultivation; steeper slopes are more prone to erosion, reducing soil fertility and topsoil (Septiaji *et al*., 2024). In Jember Regency, 38.84% of the area has slopes >15%, categorized as N (not suitable). Although challenging, such land can be made productive by considering climate, soil nutrients, irrigation, and terracing. The evaluation results are shown in Table 10 and the evaluation map in Figure 8a.

Table 10. Slope gradient suitability classes

Criterion	Slope Gradient	Description	Area (Ha)	Area (%)
S1	<3	Very suitable	109,219.95	32.99
S2	3-8	Moderately suitable	60,994.44	18.42
S3	8-15	Marginally suitable	32,260.32	9.74
N	>15	Not suitable	128,609.46	38.84

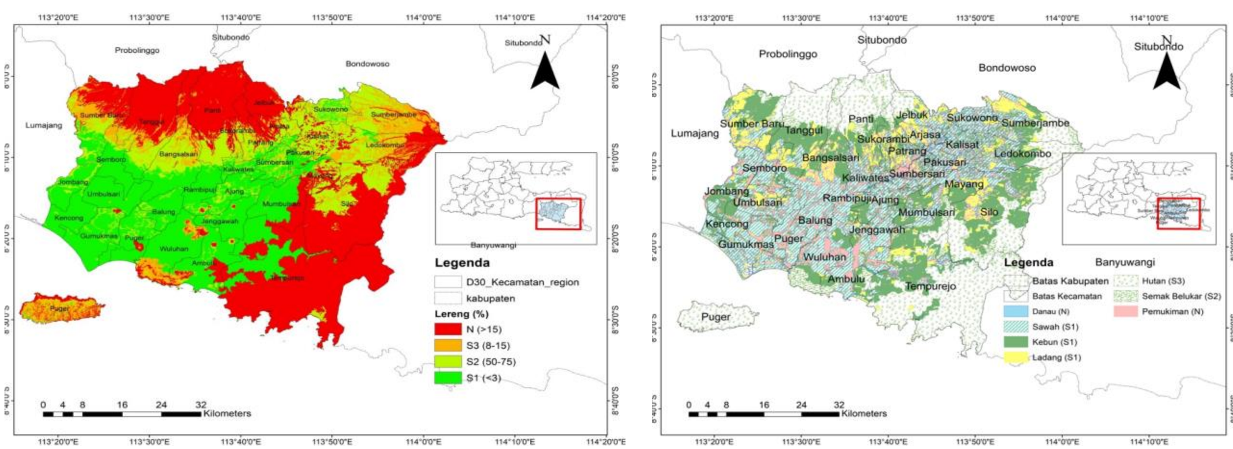


Figure 8. (a) Slope gradient suitability map, and (b) Land use map of Jember Regency.

l. Land Use Planning

Land use planning is used to ensure areas are used according to their designated functions. In Jember Regency, land use is in the S1 category including gardens, fields, and rice paddies as productive land. The S2 category includes shrub-lands, which can be developed into productive land. The S3 category includes forests, and changing their use have significant impacts, such as reducing water absorption areas and increasing the risk of landslides (Figure 8b).

3.2. Land Suitability for Okra Cultivation

The overlay analysis of all land characteristics for okra cultivation in Jember Regency revealed that 56.85% of the area falls into the S1 class, meaning it is highly suitable and can be developed into productive or cultivated land as it meets the growth criteria for okra. The S2 class, covering 43.15% of the area, can also be used as productive land but requires some improvements to address limiting factors. These improvements can be made by farmers and do not require extensive time for land preparation. The land suitability evaluation results are presented in Table 11 and the evaluation map in Figure 9.

Table 11. Land suitability classes for okra cultivation

Criterion	Land Suitability	Description	Area (Ha)	Area (%)
S1	42-54	Highly suitable	184,457.83	56.85
S2	30-42	Moderately suitable	139,981.98	43.15

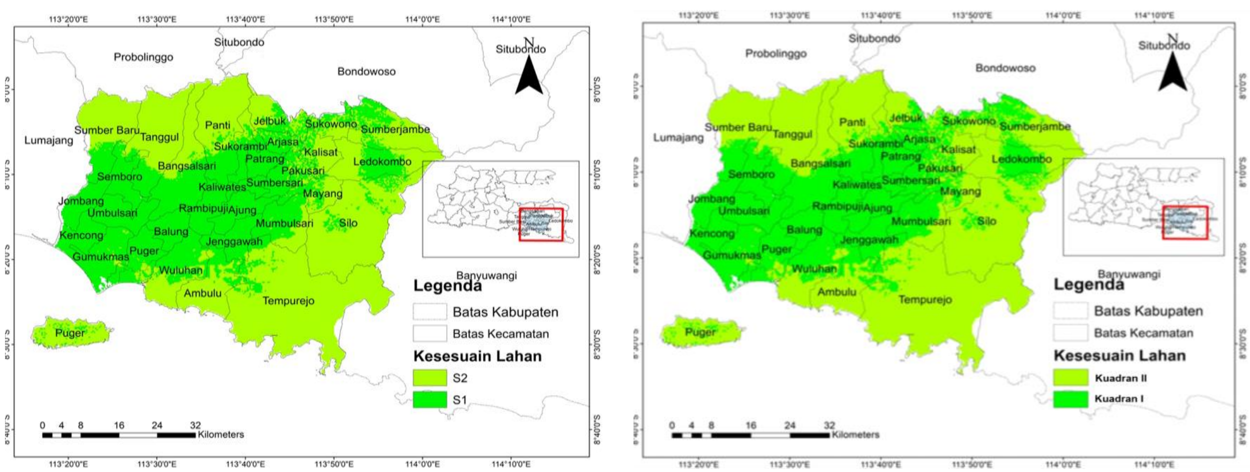


Figure 9. Land suitability classes map for okra cultivation based on: (a) land and climate parameters, and (b) SWOT analysis

3.3. Okra Cultivation Development Strategy Based on SWOT Analysis

The land suitability results for okra cultivation in Jember Regency fall into the S1 and S2 classes. The S2 class has limiting factors that need improvement. Land suitability improvement requires strategic analysis. The SWOT analysis used includes IFAS and EFAS factors. IFAS factors consist of soil texture, soil depth, organic carbon, CEC, nitrogen, phosphorus, potassium, soil pH, and slope gradient. EFAS factors include rainfall and air temperature. This analysis involves calculating the weight and range for each characteristic, resulting in a SWOT score that determines the quadrant position. This analysis is conducted for each sub-district in Jember Regency. The SWOT analysis results for 31 sub-districts are presented in Table 12.

The SWOT analysis results between IFAS and EFAS show that 27 sub-districts fall into quadrant I, while 4 sub-districts (Ambulu, Balung, Patrang, and Sumberbaru) fall into quadrant II. For the sub-districts in quadrant I, which are already classified as S1 (highly suitable), no land improvement is needed. Land improvement is only required for sub-districts in quadrant II, which are still classified as S2 (moderately suitable). In quadrant II, the limiting factors that need to be addressed include the high annual rainfall, which can be mitigated by developing irrigation and drainage systems. Another factor is the high slope gradient in some sub-districts, which increases erosion risk and requires terracing for okra cultivation; however, this is an expensive technology. Other limiting factors include unsuitable soil physical and chemical properties, such as low N and K content throughout the study area, low P levels, inappropriate soil pH, and thin topsoil layers in some areas. The recommended technology includes using more compost as a fertilizer.

Table 15. SWOT analysis results for okra cultivation land suitability

No	Sub-district	Criteria				Value		Quadrant
		S	W	O	T	IFAS	EFAS	
1	Ajung	1.69	1.32	2.53	1.23	0.37	1.3	I
2	Ambulu	2.19	0.89	1.26	2.49	1.30	-1.23	II
3	Arjasa	2.25	0.87	1.33	0.00	1.38	1.33	I
4	Balung	1.92	1.71	1.33	2.40	0.21	-1.07	II
5	Bangsalsari	1.97	1.14	2.76	0.86	0.83	1.90	I
6	Gumukmas	2.24	0.77	3.67	0.00	1.47	3.67	I
7	Jelbuk	2.28	0.81	2.62	0.95	1.47	1.67	I
8	Jenggawah	1.97	1.10	1.33	0.00	0.87	1.33	I
9	Jombang	2.16	0.89	1.67	0.00	1.27	1.67	I
10	Kalisat	2.04	1.07	3.67	0.00	0.97	3.67	I
11	Kaliwates	1.97	1.06	2.53	1.23	0.91	1.30	I
12	Kencong	1.92	1.13	3.67	0.00	0.79	3.67	I
13	Ledokombo	1.78	1.32	1.37	1.08	0.46	0.29	I
14	Mayang	1.99	1.10	2.53	1.23	0.89	1.30	I
15	Mumbulsari	2.23	0.85	2.53	1.23	1.38	1.30	I
16	Pakusari	1.82	1.52	2.53	1.23	0.30	1.30	I
17	Panti	2.22	0.89	2.12	1.44	1.21	0.68	I
18	Patrang	1.82	1.26	1.21	1.3	0.56	-0.09	II
19	Puger	2.44	0.63	3.69	0.00	1.81	3.69	I
20	Rambipuji	2.28	0.77	2.53	1.23	1.51	1.30	I
21	Semboro	2.09	1.02	3.78	0.00	1.07	3.78	I
22	Silo	2.05	1.06	2.34	1.33	0.99	1.01	I
23	Sukorambi	1.72	1.37	1.00	0.82	0.35	0.18	I
24	Sukowono	2.06	1.01	3.67	0.00	1.05	3.67	I
25	Sumberbaru	1.92	1.22	1.10	2.68	0.70	-1.58	II
26	Sumberjambe	1.90	1.21	3.16	0.36	0.69	2.80	I
27	Sumbersari	2.43	0.70	3.67	0.00	1.73	3.67	I
28	Tanggul	1.88	1.21	1.2	0.95	0.67	0.25	I
29	Tempurejo	1.66	1.42	1.93	1.88	0.24	0.05	I
30	Umbulsari	2.11	1.03	3.78	0.00	1.08	3.78	I
31	Wuluhan	2.30	0.82	3.69	0.00	1.48	3.69	I

4. CONCLUSION

1. The land suitability evaluation for okra cultivation in Jember Regency shows that 56.85% of the area is classified as S1 (highly suitable), while the remaining 43.15% is classified as S2 (moderately suitable) due to factors such as low rainfall in some areas, low nutrient content (particularly N, K, and P), and high slope values in certain regions.
2. The okra cultivation development strategy in Jember Regency, based on SWOT analysis, places it in quadrant II (Ambulu, Balung, Patrang, and Sumberbaru sub-districts). The recommended technologies for land improvement in quadrant II include developing irrigation systems to meet water needs, using compost instead of chemical fertilizers to improve soil nutrients, and constructing terraces in steep areas, although terracing is not recommended due to the high investment required.

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