Caraka Tani: Journal of Sustainable Agriculture, 41(3), 468-490, 2026
URL: https://jurnal.uns.ac.id/carakatani/article/view/119340
DOI: http://dx.doi.org/10.20961/carakatani.v41i3.119340
ISSN 2613-9456 (Print) 2599-2570 (Online)

Spatial Assessment of Land Suitability, Regional Hierarchy, and SAW-Based Multi-Criteria Analysis for Pepper-Based Agrotourism Planning: A Case Study of Membalong Sub-District, Indonesia

Satrio Adi Wicaksono[1], Andrea Emma Pravitasari[2,3*] and Bambang Sulistyantara[4]

[1]Regional Planning Science Study Program, Postgraduate School, IPB University, Bogor, Indonesia; [2]Regional Development Planning Division, Department of Soil Science and Land Resources, IPB University, Bogor, Indonesia; [3]Center for Regional System Analysis, Planning, and Development (CRESTPENT), IPB University, Bogor, Indonesia; [4]Department of Landscape Architecture, IPB University, Bogor, Indonesia

[*]*Corresponding author:* andreaemma@apps.ipb.ac.id

Abstract

Pepper is a spice commodity whose existence is increasingly threatened. At the same time, tourism diversification is needed to strengthen the attractiveness of Belitung Regency, and agrotourism planning serves as a strategic approach to support this effort. This study aimed to identify and determine priority areas for agrotourism planning based on the pepper commodity. A total of 19 pepper plantations were identified in Membalong Sub-district, with Simpang Rusa Village having the largest number, at 6 plantations. The study area was dominated by the S3 (marginally suitable) land suitability class, while Lassar Village had the largest area of land available for pepper plantation development. The regional hierarchy was classified into 3 levels, with Pulau Seliu, Padang Kandis, and Gunung Riting Villages at the first level, and Perpat and Mentigi Villages at the second level. Spatial analysis revealed a mismatch between agricultural potential and tourism infrastructure. Villages with pepper plantation resources lacked adequate infrastructure readiness, while villages with better tourism infrastructure did not have pepper plantations. Based on the Simple Additive Weighting (SAW) analysis, Simpang Rusa Village was designated as the highest priority area for pepper-based agrotourism development. This result designates that Simpang Rusa possesses the greatest potential for future pepper-based agrotourism development in Membalong Sub-district. This study demonstrates that integrating land suitability assessment, land availability analysis, regional hierarchy analysis, and multi-criteria decision-making can support pepper-based agrotourism planning. These findings provide a spatial base for implementing the Belitung Regency Tourism Development Master Plan (RIPPARKAB).

Keywords: agrotourism area planning; GIS based-planning; land availability analysis; multi-criteria decision analysis (MCDA); regional infrastructure hierarchy

Cite this as: Wicaksono, S. A., Pravitasari, A. E., & Sulistyantara, B. (2026). Spatial Assessment of Land Suitability, Regional Hierarchy, and SAW-Based Multi-Criteria Analysis for Pepper-Based Agrotourism Planning: A Case Study of Membalong Sub-District, Indonesia. *Caraka Tani: Journal of Sustainable Agriculture*, *41*(3), 468-490. doi: http://dx.doi.org/10.20961/carakatani.v41i3.119340

INTRODUCTION

Indonesia is recognized as the world's second-largest producer of pepper after Vietnam, with the Bangka Belitung Islands Province and Lampung as its principal production centers (Amorita et al., 2021; Azahari et al., 2021; Mahdi and Suprehatin, 2021). Pepper (*Piper nigrum* L.) is a highly valued spice commodity that plays a strategic role in sustaining both international and national trade (Alif et al., 2018; Agricultural Data and Information System Center, 2022). In the Bangka

[*] *Received for publication May 19, 2026*
Accepted after corrections July 15, 2026

Belitung Islands Province, pepper cultivation has persisted since the colonial era and continues to symbolize the region's cultural and economic identity (Panggabean et al., 2016).

In recent years, pepper productivity in Belitung Regency has declined significantly. According to the Statistics Agency of Belitung Regency (2025), production decreased from 6,294.04 tons in 2020 to 5,721.48 tons in 2022, and further decreased to 4,321.86 tons in 2024. Conversely, oil palm production increased progressively from 4,699 tons in 2018 to 13,946.37 tons in 2024. The area of pepper plantations also decreased from 9,525 ha in 2019 to 4,321.86 ha in 2024, while oil palm expanded to 7,204.7 ha. This mirrors a broader trend of land conversion and increasing pressure on traditional commodities across tropical regions, driven by agricultural expansion and global economic demands (Winkler et al., 2021; Miranda et al., 2024). The decline is primarily credited to land conversion, particularly illegal tin mining, which has further degraded soil quality (Daras and Pranowo, 2009; Bagwan et al., 2023; Supriatna et al., 2026).

Alongside the plantation sector, tourism plays a vital role in Indonesia's national development and foreign exchange earnings (Zulgani et al., 2023). Belitung Island, consisting of Belitung and East Belitung Regencies, has identified tourism as the cornerstone of regional economic growth (Zukhri et al., 2021). In recent years, tourist arrivals in Belitung Regency have fluctuated, reaching a peak of 452,890 in 2018, but declining sharply from 2019 to 2020 due to the COVID-19 pandemic (Statistics Agency of Belitung Regency, 2025).

Tourism in Belitung Regency is governed by Regional Regulation No. 12 of 2015 concerning the Tourism Development Master Plan (RIPPARKAB), which designates Membalong Sub-district as an agrotourism development area with pepper as the leading commodity. In developing countries, tourism is recognized as a strategic instrument for economic growth, employment generation, and poverty alleviation (Croes and Vanegas, 2008; Khan et al., 2020; Rogerson and Rogerson, 2020). Diversification of tourism products and activities is essential to strengthen resilience and improve economic performance (Solarin et al., 2024). Accordingly, diversification strategies are pivotal to enhancing destination competitiveness and advancing adaptive sustainable tourism (Kim and Lee, 2018; Winchenbach et al., 2022).

Agrotourism represents a tourism model that integrates farming activities as attractions while functioning as an educational platform and a means of preserving local traditions (Utama, 2011). Its development raises community awareness of land conservation, mitigates degradation, and strengthens the appeal of agricultural landscapes (Palit et al., 2017; Jonni et al., 2024). In addition to economic contributions, agrotourism promotes sustainable agricultural practices (Sriyadi et al., 2021; Wartini et al., 2022).

Among spice crops, pepper stands out as a key commodity with substantial potential to advance agriculture and tourism in Belitung Regency, particularly in Membalong Sub-district. In recent years, agrotourism has been increasingly acknowledged as a strategic instrument to advance adaptive sustainable tourism, reinforce rural economic resilience, and diversify household income (Ammirato et al., 2020; Sangnak et al., 2025; Turtureanu et al., 2025). This strategy resonates with contemporary tourism development trends that emphasize local potential and region-specific resource utilization (Dwyer, 2023). This integration highlights pepper's dual contribution, reinforcing its position as an economic pillar and a cultural heritage legacy.

Research on spice-based agrotourism, particularly pepper, has remained relatively limited, with most studies focusing on production, crop management, commodity improvement, and biotechnology. Although several studies have applied land suitability analysis and multi-criteria methods to support regional planning, research integrating pepper resource potential, land evaluation, and tourism-supporting infrastructure within a single spatial framework for agrotourism planning remains rare. This condition indicates a research gap, especially regarding the integration of biophysical aspects, regional infrastructure, and decision-making in comprehensive agrotourism planning, particularly in small island regions (Sawaludin et al., 2026). In line with this, recent advances have demonstrated the increasing use of Geographic Information System (GIS)-based land suitability analysis and multi-criteria methods in regional planning. These approaches integrate biophysical and socio-economic parameters into the decision-making process (Tercan and Dereli, 2020; Wotlolan et al., 2021; Ustriyana et al., 2025).

Therefore, this study offers an integrated GIS-based approach that combines land suitability assessment, land availability analysis, scalogram-based regional hierarchy analysis, and the Simple Additive Weighting (SAW) method to identify priority areas for pepper agrotourism development in Membalong Sub-district. This approach contributes scientifically by developing an analytical framework that integrates biophysical aspects, regional infrastructure, and multi-criteria decision-making in agrotourism planning. Based on these gaps and fundamentals, the objectives of this study were: (1) to identify the spatial distribution of pepper plantations; (2) to evaluate land suitability and availability for pepper cultivation; (3) to analyze regional development based on tourism infrastructure; and (4) to formulate planning recommendations for agrotourism areas. The findings are expected to serve as a basis for policy formulation in pepper-based agrotourism development in Membalong Sub-district, Belitung Regency.

MATERIALS AND METHOD

Research area and research data

This research was conducted from June to July 2024 in Membalong Sub-district, Belitung Regency, Bangka Belitung Islands Province, covering 11 villages: Bantan, Simpang Rusa, Lassar, Perpat, Kembiri, Membalong, Mentigi, Gunung Riting, Tanjung Rusa, Padang Kandis, and Pulau Seliu (Figure 1). Primary data were collected through field surveys to identify the spatial distribution of pepper plantations, while secondary data included administrative and spatial maps, land cover, village potential data, climatic data (temperature and rainfall), soil maps, and relevant literature. Data analysis was conducted using GPS Avenza Maps and software tools such as Microsoft Office, QGIS 3.32.0, and ArcGIS Pro.

Research method

Identifying the spread of pepper plantations

This stage aimed to identify the extent and spatial distribution of pepper plantations in Membalong Sub-district. Field surveys were conducted with the support of the Belitung Regency Department of Food Security and Agriculture (DKPP) to locate productive pepper plantations and collect geographic coordinates using Avenza Maps. The identified plantation locations were subsequently verified through visual interpretation of high-resolution Google Earth Pro imagery and processed using QGIS and ArcGIS Pro. This study did not employ statistical sampling; instead, plantation identification was conducted through a comprehensive field inventory and spatial verification process. Only plantation sites whose boundaries could be clearly delineated, either directly in the field or through image interpretation, were included in the spatial analysis. Through this procedure, a total of 19 productive pepper plantation sites were successfully delineated and mapped.

Analysis of land suitability and availability of pepper plantation

Land suitability and availability assessments for agriculture and plantation development have been extensively applied in prior research.

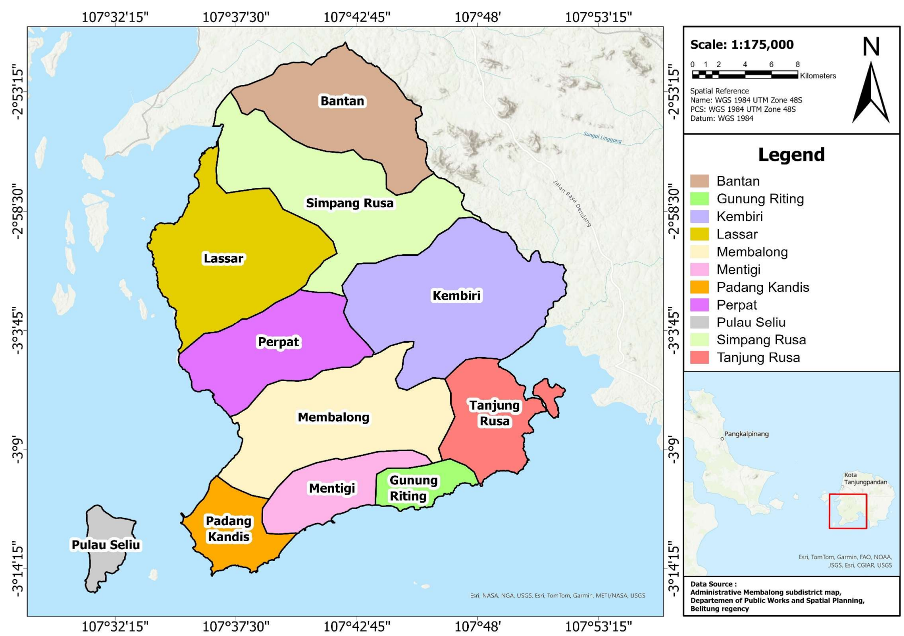

Figure 1. Map of research locations in Membalong Sub-district

They are employed as an opening step to improve pepper production before cultivation practices are implemented (Zolekar and Bhagat, 2015; Singha and Swain, 2016; Yalew et al., 2016; Mesgaran et al., 2017; Amini et al., 2020; Taghizadeh-Mehrjardi et al., 2020; Pravitasari et al., 2023). A sustainable and adaptive evaluation of land suitability enables the assessment of land potential, identification of limiting factors, and protection of soil quality for pepper cultivation, thereby supporting long-term agricultural productivity (Mujiyo et al., 2020; Anshar et al., 2022; Mohammed et al., 2025).

Fundamentally, this stage encompasses comparing the requirements of intended land use with the inherent characteristics or qualities of the land (Hardjowigeno and Widiatmaka, 2007). Land suitability analysis was conducted using soil map units matched with the criteria for pepper commodities established by the Center for Testing of Agricultural Land Resources Instruments. Additional supporting data, including administrative maps, rainfall, and slope, were also adjusted to these criteria. The results classified pepper land suitability into 4 categories: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N). The criteria for land suitability for pepper plantations are presented in Table 1.

Land availability is a key factor in identifying suitable locations and areas for food crop development (Baehaqi et al., 2010; Kammerer et al., 2024). To analyze land availability and unavailability, spatial planning maps from the Belitung Regency Department of Public Works and Housing, land cover maps from the Ministry of Forestry and Environment, and pre-processed soil map units were required. The analytical process involved overlaying these 3 maps to classify land into available and unavailable categories. Unavailable land comprises protected areas, wildlife sanctuaries, limited production forests, and land allocated for urban, residential, industrial, and mining purposes. Available land, on the other hand, consists of production forests and agricultural cultivation areas (Sitorus et al., 2012).

Analysis of regional development levels based on tourism infrastructure

The level of regional development or hierarchy is obtained through scalogram analysis, which assesses regional hierarchy based on facility availability by calculating the number and types of infrastructure in each village (Syafi'i and Santoso, 2015; Utari, 2015; Rustiadi et al., 2023). Regions with infrastructure completeness aligned with their service capacity can effectively support tourism development (Jovanovic and Ilic, 2016;

Table 1. Land suitability classes for pepper plantation

Land use requirements/land characteristics	Land suitability class			
	S1	S2	S3	N
Temperature (Tc)				
Average daily temperature	23–32	20–23	-	> 34
		32–34	-	< 20
Water availability (wa)				
Rainfall (mm)	2,000–2,500	2,500–3,000	3,000–4,000	< 1,500
			1,500–2,000	> 4,000
Oxygen availability (oa)				
Drainage	Good, Moderate	Somewhat impeded	Impeded, slightly impeded	Very impeded, rapid
Rooting media (rc)				
Texture	Moderate, slightly fine, fine	Slightly coarse	Coarse, very fine	Coarse
Soil depth (cm)	> 75	50–75	30–50	< 30
Nutrient retention (nr)				
Cation exchange capacity (cmol)	> 16	5–16	< 5	-
Base saturation (%)	> 50	35–50	< 35	-
pH H_2O	5.0–7.0	4.0–5.0	< 4.0	-
		7.0–8.0	> 8.0	-
Erosion hazard (eh)				
Slope (%)	< 8	8–15	15–30	> 30

Source: Ritung et al. (2011)

Mandic et al., 2018; Petrova et al., 2018; Adeola and Evans, 2020; Apriyanti et al., 2024; Munir et al., 2025).

According to Panuju and Rustiadi (2013), the stages of scalogram analysis consist of: (1) defining variables, (2) constructing a data matrix based on variable group A (facilities) and group B (accessibility), (3) calculating the index of variable A (facilities), (4) calculating the inverse index of variable B (accessibility), (5) determining the discriminant index weight for variable A (facilities), (6) standardizing all variable indices, and (7) establishing village hierarchy based on the availability of facilities and tourism-supporting infrastructure. The determination of regional hierarchy is presented in Table 2.

Agrotourism area planning recommendations

This stage involved preparing agrotourism planning recommendations through the SAW method, one of the most widely applied techniques in Multi-Criteria Decision Making (MCDM). The SAW method evaluates alternatives by calculating weighted scores across relevant attributes, with weights reflecting their relative importance. The cumulative score determines priority, with the highest-scoring alternative selected for development (Malczewski, 1999; Taherdoost, 2023; Naeimi et al., 2026).

The evaluated variables included the number of pepper plantations, total plantation area, S2 and S3 land suitability classes, and the Tourism Infrastructure Availability Index (TIAI). Due to differences in measurement units among the variables, standardization was applied to ensure comparability across all criteria and facilitate consistent evaluation (Vafaei et al., 2022; Malefaki et al., 2025). The standardization formula used in this study is presented as Equation 1.

$$Z_{ij} = \frac{X_{ij} - X_{min,j}}{SD_j} \quad (1)$$

Where Z_{ij} represents the standardized value of the criterion j for village i; X_{ij} is the original value of the criterion j for village i; $X_{(min,j)}$ denotes the minimum value of the criterion j; and SD_j refers to the standard deviation of the criterion j.

In this study, standardization was performed prior to weighting to address differences in measurement units and value ranges across variables, thereby enabling all criteria to be integrated into a single weighted evaluation model. Subsequently, criterion weights were determined through expert judgment. Three experts, consisting of academics and practitioners with expertise in regional development and pepper cultivation, participated in the weighting process. During the questionnaire survey, each expert was asked to allocate a total score of 100 across the 5 criteria according to their perceived importance.

The final score for each criterion was calculated as the average of the expert assessments and subsequently, then divided by 100 to convert percentage-based judgments into proportional weights that could be incorporated into the weighting procedure. This process ensured that the sum of all criterion weights equaled one. The formula used to calculate the average expert score is presented in Equation 2.

$$\bar{W}_j = \frac{\sum_{k=1}^{n} W_{jk}}{n} \quad (2)$$

Where $\bar{W}_j$ represents the average expert score for the criterion j, W_{jk} denotes the score assigned by the expert k to criterion j, and n is the number of experts involved in the assessment.

The average scores were then transformed into proportional weights using Equation 3.

$$W_j = \frac{\bar{W}_j}{100} \quad (3)$$

Where W_j represents the final weight of the criterion j, while $\bar{W}_j$ denotes the average score assigned by the experts.

To obtain the final priority score, each standardized value was multiplied by its corresponding criterion weight, and all weighted values were subsequently aggregated into a composite score. Areas with higher scores were assigned a higher priority for agrotourism

Table 2. Determination of regional hierarchy interval

Hierarchy	Interval level	Hierarchy level
Hierarchy 1	TIAI > Mean+Stdev	High
Hierarchy 2	Mean < TIAI < Mean+Stdev	Medium
Hierarchy 3	TIAI < Mean TIAI	Low

Note: TIAI = Tourism infrastructure availability index

Table 3. Data types, data source, and format data

Data	Source	Year	Format/ type	Scale/ resolution
Point and polygon of the pepper plantation	Field survey	2024	Shapefile	GPS-based
Administrative map	Department of Public Works, Belitung Regency	2024	Shapefile	1:50,000
Spatial pattern map	Department of Public Works, Belitung Regency	2024	Shapefile	1:50,000
Land cover map	Ministry of Environment and Forestry	2022	Shapefile	1:50,000
Rainfall map	CHIRPS rainfall data	2024	Shapefile	1:50,000
Temperature data	Meteorology, Climate, and Geophysics Agency	2024	Tabular	-
Soil map unit (SMU)	Center for Agricultural Land Resources Assembly and Modernization	2024	Shapefile	1:50,000
Village potential data	Statistics Agency	2021	Tabular	-

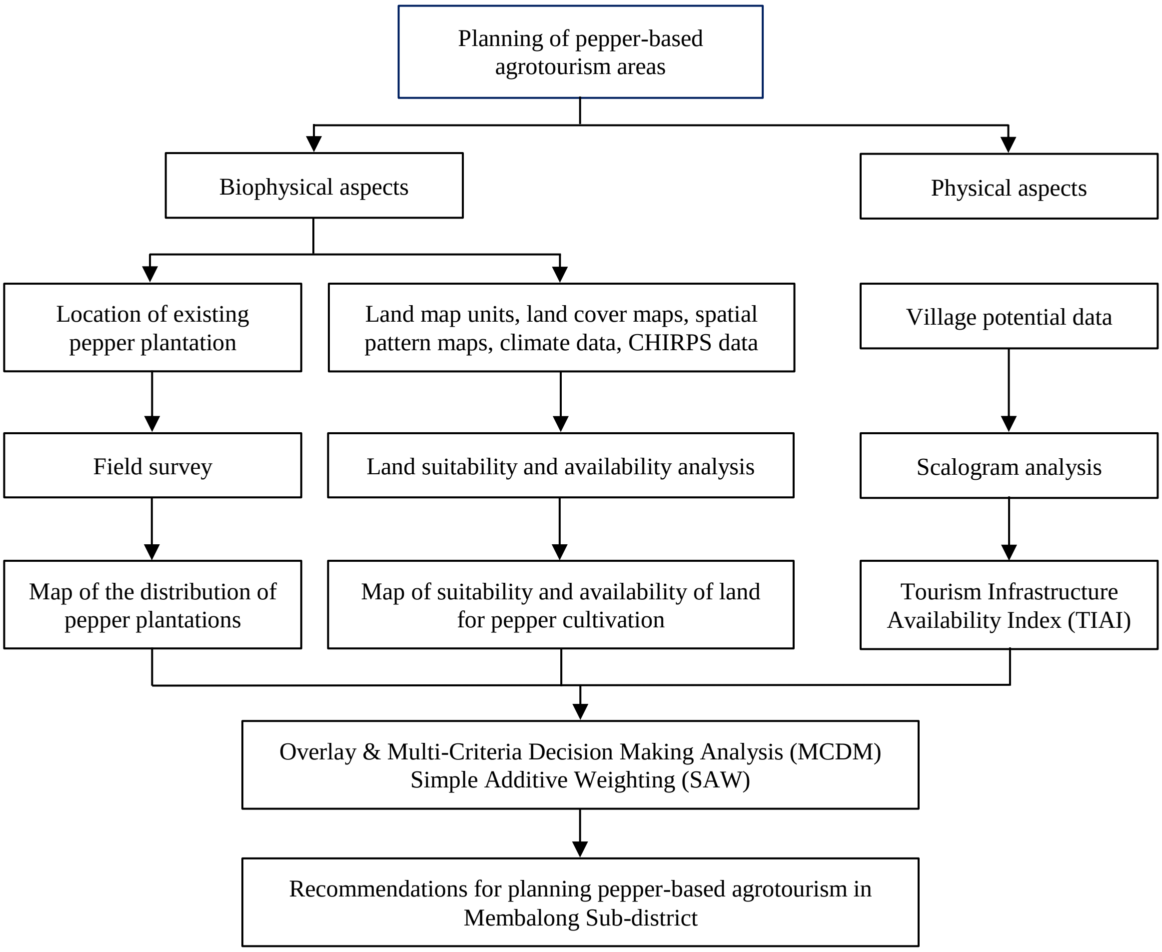

Figure 2. Research flow chart

development in Membalong Sub-district (Mardani et al., 2015). The final scoring formula is presented as Equation 4.

$$S_i = \sum_{j=1}^{m} (Z_{ij} \times w_j) \tag{4}$$

Where S_i represents the final priority score of village i, Z_{ij} is the standardized value of the criterion j for village i, W_j denotes the weight of the criterion j, and m is the total number of criteria included in the analysis.

Based on the explanation, the data types and sources are presented in Table 3 and in the research flow chart in Figure 2.

RESULTS AND DISCUSSION

Identification of pepper plantation distribution

The distribution of pepper plantations was identified through field surveys and spatial verification conducted in Membalong Sub-district, Belitung Regency. Productive pepper plantations were identified through direct field observations and subsequently verified using Google Earth Pro imagery. Only plantation sites with clearly identifiable boundaries were included in the spatial analysis. Through this process, 19 productive pepper plantation sites were successfully delineated and mapped across the study area, covering a total area of 15.75 ha. This relatively small area indicates that pepper cultivation in the study area is currently limited and may reflect a decline. These plantations are not evenly distributed across all villages, indicating that pepper cultivation is concentrated in specific locations rather than spread evenly throughout the sub-district. The distribution of pepper plantations is presented in Table 4 and Figure 3.

The limited number of plantations can be ascribed to economic and biophysical factors. Many farmers have gradually abandoned pepper cultivation due to its relatively low profitability, leading to a shift to other crops or non-agricultural sectors, such as mining, including illegal tin mining activities. This is consistent with the study by Al Zarliani et al. (2023), which highlighted that low selling prices remain a major problem for pepper farmers. In addition to economic factors, biophysical constraints also play a significant role in reducing farmers' interest in pepper cultivation. Pepper plants are highly susceptible to pests and diseases, increasing production risks and finally influencing farmers' decisions to discontinue cultivation. One of the major diseases is root rot caused by the fungus *Phytophthora capsici*, which is difficult to control and poses a significant challenge for pepper farmers (Lestari et al., 2023; Hao et al., 2025). An example of root rot in pepper plantations is presented in Figure 4.

Analysis of actual land suitability and land availability for pepper plantation

Based on the matching between soil map unit data and the criteria of actual land suitability classes for pepper commodities, Membalong

Table 4. The distribution of pepper plantations in Membalong Sub-district

No.	Village	Pepper plantation	Area (ha)
1	Bantan	0	0.00
2	Gunung Riting	0	0.00
3	Kembiri	3	1.03
4	Lassar	2	1.05
5	Membalong	1	0.55
6	Mentigi	3	5.15
7	Padang Kandis	0	0.00
8	Perpat	4	1.98
9	Pulau Seliu	0	0.00
10	Simpang Rusa	6	5.56
11	Tanjung Rusa	0	0.00
	Total	19	15.75

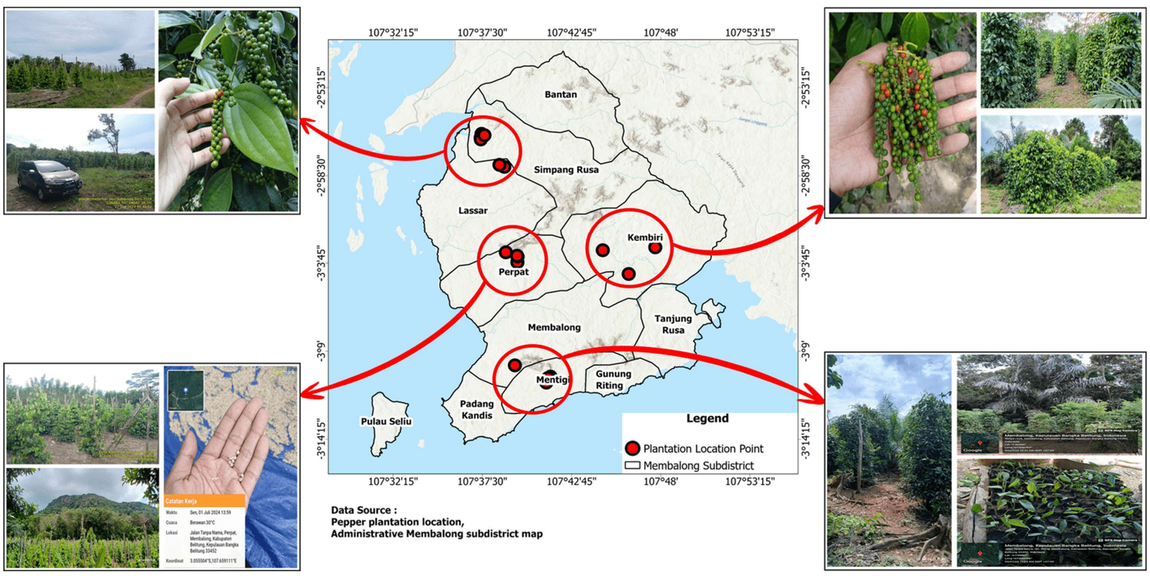

Figure 3. Map of pepper plantation distribution in Membalong Sub-district

Figure 4. The example of a pepper plantation affected by foot rot disease

Sub-district is mostly classified as S3 (marginally suitable), with a smaller portion categorized as S2 (moderately suitable). This dominance of the S3 class indicates that most of the land in the study area is constrained by certain limiting factors, reducing its optimal suitability for pepper cultivation. The results of the land suitability class matching for each village are presented in Table 5.

The S3 suitability class covers a total of 68,271.48 ha, accounting for around 75.68% of the sub-district's area. Meanwhile, the S2 class covers 1,537.67 ha, or about 1.70%; the N class (not suitable) covers 11,956.22 ha, or around 13.25%; and areas classified as no data comprise 8,447.02 ha, or approximately 9.36%. Areas designated as "no data" represent locations for which soil quality variables were unavailable, thereby preventing land suitability classification. These areas include tin mining sites, settlements, water bodies, and small offshore islands. As a result, land suitability assessment could not be conducted in these locations, highlighting a limitation of the available spatial database within the study area.

The largest S3 suitability class is located in Kembiri Village, covering 14,527.77 ha, while the smallest is found in Pulau Seliu Village, covering 13.77 ha. Despite having the smallest S3 area, Pulau Seliu records the largest S2 suitability class in the sub-district, spanning 970.00 ha. In addition, Padang Kandis Village also has the S2

Table 5. Pepper commodity land suitability class in Membalong Sub-district

No.	Village	Land suitability class (ha)				Total (ha)
		S2	S3	N	No data	
1	Bantan	0.00	7,071.33	1,193.68	1,614.41	9,879.42
2	Gunung Riting	0.00	1,775.81	401.92	26.00	2,203.73
3	Kembiri	0.00	14,527.77	497.55	91.50	15,116.82
4	Lassar	0.00	8,391.86	1,313.00	2,902.35	12,607.21
5	Membalong	0.00	10,491.66	1,232.54	998.71	12,722.92
6	Mentigi	0.00	2,959.22	555.20	981.50	4,495.93
7	Padang Kandis	567.35	2,395.42	326.04	509.70	3,798.51
8	Perpat	0.00	7,051.96	1,451.91	42.70	8,546.56
9	Pulau Seliu	970.33	13.77	622.43	18.90	1,625.43
10	Simpang Rusa	0.00	9,859.78	2,329.91	1,219.74	13,409.42
11	Tanjung Rusa	0.00	3,732.92	2,032.04	41.50	5,806.46
	Total	1,537.68	68,271.48	11,956.22	8,447.02	90,212.40
	Percentage (%)	1.70	75.68	13.25	9.36	100.00

suitability class with 567.35 ha. Within these 2 classes, several limiting factors were identified and are presented in Table 6.

Table 6 shows that the most dominant limiting factors in the sub-district were water availability (wa) and drainage conditions (oa). The S3 (marginally suitable) class was primarily constrained by water availability (wa) and drainage (oa). Areas limited by water availability (wa) covered 45,936.00 ha, representing 50.92% of the total sub-district area. In contrast, the combination of water availability (wa) and drainage (oa) accounted for 18,807.80 ha, or 20.85% of the area. These conditions were associated with annual rainfall ranging from 3,000 to 4,000 mm, which falls within the high-rainfall category, and with the lack of suitable drainage systems in many pepper plantations.

Poor drainage and high moisture levels can trigger root rot in pepper plants (Bande et al., 2015). Foot rot can be controlled by establishing an appropriate drainage system to prevent waterlogging (Wahyuno, 2009; Firdaus et al., 2022). Similar conditions have also been reported in other pepper-producing regions, where environmental factors such as soil drainage, root media, and nutrient retention pose unique challenges for pepper plantations (Mangkunegara and Firdamayanti, 2021; Danuartha et al., 2023). This indicates that the prevalence of S3-class land is not limited to Membalong Sub-district but reflects common environmental challenges across pepper-producing regions. Therefore, improving drainage systems and water management is critical to mitigating the impact of existing constraints, increasing plantation productivity, and supporting sustainable pepper development in the study area. The map of land suitability classes is presented in Figure 5.

All existing pepper plantations in Membalong Sub-district are located on land classified as suitable for pepper cultivation within the S3 (marginally suitable) class. This finding indicates that farmers continue to cultivate pepper on marginal land, suggesting either adaptive practices or limited access to higher-quality land. The relationship between land and the distribution

Table 6. The limiting factors for land suitability in the Membalong Sub-district

Class suitability	Limiting factors	Area (ha)	Percentage (%)
S2	wa, nr	382.29	0.42
	wa, nr, eh	1,155.48	1.28
S3	wa	45,936.00	50.92
	wa, eh	332.59	0.37
	wa, nr	3,195.16	3.54
	wa, oa	18,807.80	20.85
N	eh	5,867.80	6.50
	oa	1,111.85	1.23
	rc	925.94	1.03
	oa, rc	4,051.50	4.49
	No data	8,446.99	9.36
	Total	90,212.40	100.00

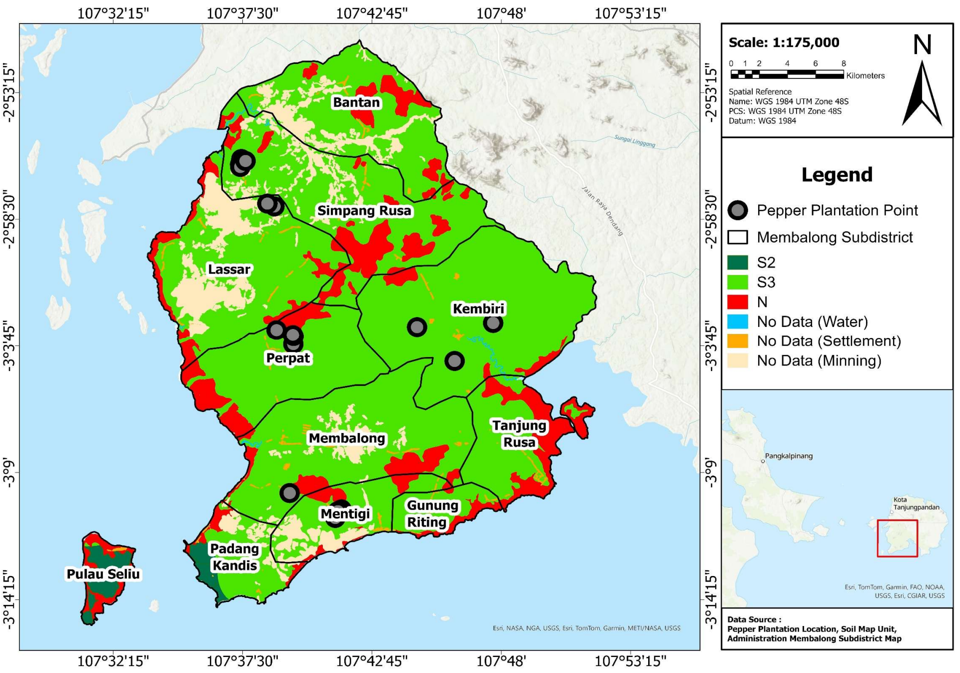

Figure 5. Map of land suitability classes in Membalong Sub-district

of pepper plantations is presented in Table 7 and Figure 6.

While the 19 plantations occupy land classified as suitable, some are not positioned within areas available for pepper cultivation. In Belitung Regency, especially Membalong Sub-district, portions of the land cover are unsuitable for pepper plantation development. The delineation of land availability for pepper cultivation in Belitung Regency follows traditional community practices. According to Riyadi (2012), land categorized as unavailable encompasses large private estates, tin mining sites, and protected forests. In contrast, land categorized as available includes shrubs, production forests, dryland farming, mixed dryland farming, and open land. This indicates that land availability is determined not only by biophysical suitability, but also by land-use regulations and existing land utilization. The proportion of land availability for pepper plantation is presented in Table 8, and the spatial distribution is illustrated in Figure 7.

Membalong Sub-district has a total area of 90,212.40 ha, of which 25,315.08 ha is available for pepper development. The largest land cover

Table 7. Relationship between pepper plantation and actual land suitability classes

Village	Pepper plantation code	Pepper plantation area (ha)	Land suitability status
Kembiri	K1	0.72	Suitable (S3)
	K2	0.17	Suitable (S3)
	K3	0.16	Suitable (S3)
Lassar	L1	0.74	Suitable (S3)
	L2	0.76	Suitable (S3)
Membalong	MB1	0.55	Suitable (S3)
Mentigi	MT1	1.05	Suitable (S3)
	MT2	0.72	Suitable (S3)
	MT3	3.38	Suitable (S3)
Perpat	P1	1.33	Suitable (S3)
	P2	0.17	Suitable (S3)
	P3	0.19	Suitable (S3)
	P4	0.27	Suitable (S3)
Simpang Rusa	SR1	0.47	Suitable (S3)
	SR2	1.15	Suitable (S3)
	SR3	1.10	Suitable (S3)
	SR4	0.85	Suitable (S3)
	SR5	1.28	Suitable (S3)
	SR6	0.72	Suitable (S3)

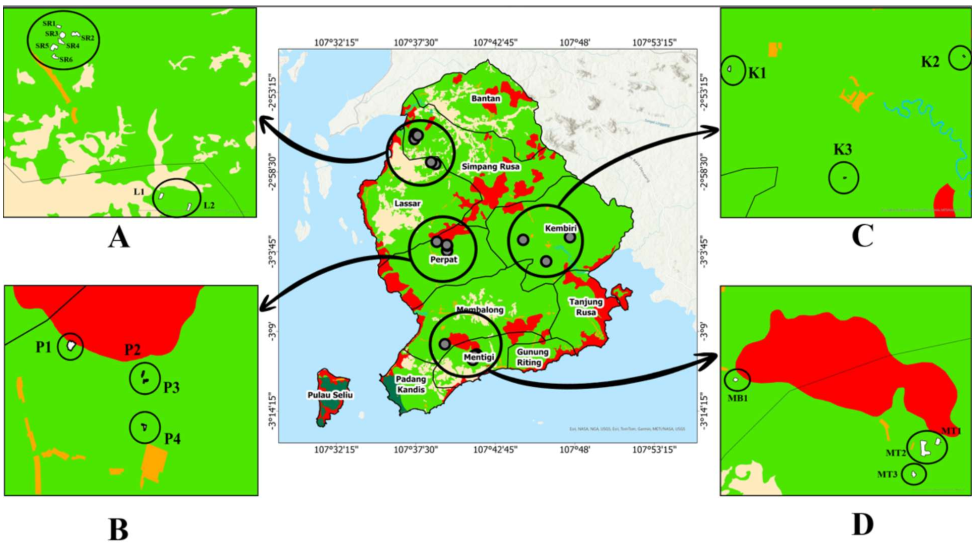

Figure 6. Land suitability based on distribution of pepper plantation (a) Simpang Rusa and Lassar; (b) Perpat; (c) Kembiri; (d) Membalong and Mentigi

type is mixed dryland farming, covering 16,590.70 ha (65.54%), while the smallest are dryland farming and open land, covering 1,128.90 ha (4.46%) and 654.00 ha (2.58%), respectively. The village with the largest available land is Lassar (4,931.10 ha), followed by Simpang Rusa (3,935.70 ha) and Bantan (3,282.60 ha). The smallest available land area is in Pulau Seliu Village (812.72 ha), as it lies outside the main island of Belitung. However, among the 19 available pepper plantations, not all are situated on land cover types appropriate for pepper cultivation. This condition reflects the presence of spatial mismatches between existing plantations and land designated as suitable and available for development. The matching between pepper plantations and appropriate land cover for pepper cultivation is presented in Table 9 and Figure 8.

Table 8. Types of land cover available for pepper plantation

No.	Village	Shrub	Dryland forest	Dryland agriculture	Mixed dryland agriculture	Open land	Total (ha)	Percentage (%)
1	Bantan	254.90	173.40	0.00	2,648.10	206.20	3,282.60	12.97
2	Gunung Riting	7.90	1.14	0.00	1,160.50	17.20	1,186.14	4.69
3	Kembiri	39.20	13.00	671.60	2,220.40	0.00	2,944.20	11.63
4	Lassar	2,968.90	128.70	296.30	1,415.00	123.20	4,931.10	19.48
5	Membalong	184.90	272.10	23.80	1,981.80	63.40	2,525.00	9.97
6	Mentigi	60.50	179.70	0.00	1,324.40	26.20	1,590.80	6.28
7	Padang Kandis	6.10	50.90	0.00	1,335.60	18.10	1,410.70	5.57
8	Perpat	685.40	125.60	0.00	874.40	166.00	1,851.40	7.31
9	Pulau Seliu	0.82	811.90	0.00	0.00	0.00	812.72	3.21
10	Simpang Rusa	672.50	202.40	137.20	2,897.90	25.70	3,935.70	15.55
11	Tanjung Rusa	65.70	38.42	0.00	732.60	8.00	844.72	3.34
	Total	4,944.22	1,997.26	1,128.90	16,590.70	654.00	25,315.20	100.00
	Percentage (%)	19.53	7.89	4.46	65.54	2.58	100.00	

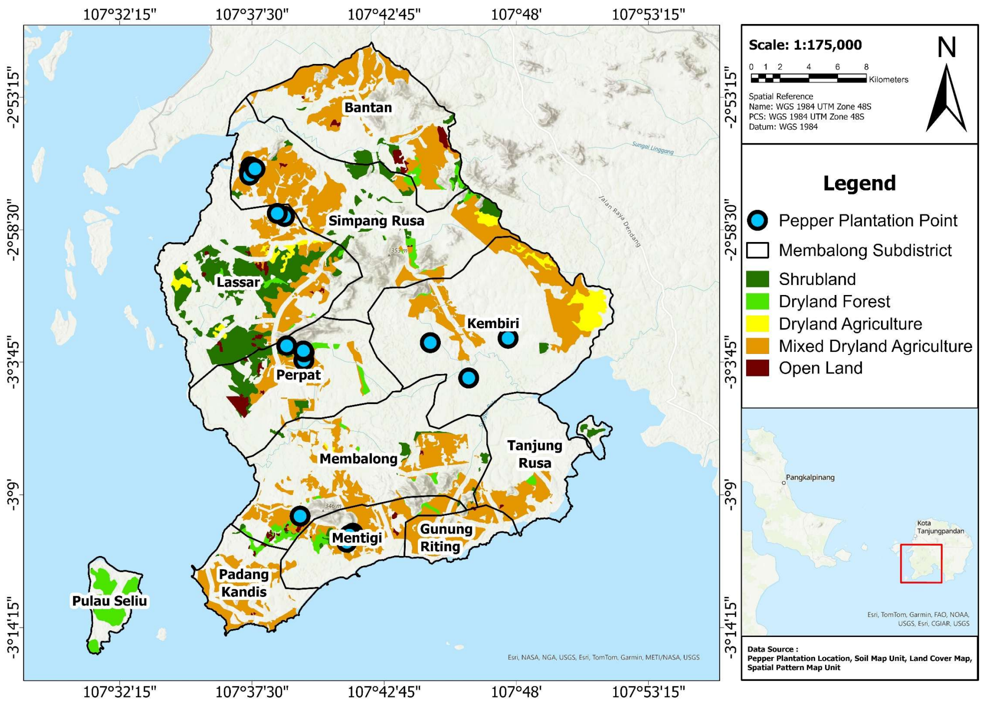

Figure 7. Map of land cover availability for pepper plantations

Table 9. The relationship between pepper plantations and the land cover available for pepper plantations

Village	Pepper plantation code	Pepper plantation area (ha)	Land suitability status	Land availability status
Kembiri	K1	0.72	Suitable (S3)	Not available
	K2	0.17	Suitable (S3)	Not available
	K3	0.16	Suitable (S3)	Not available
Lassar	L1	0.74	Suitable (S3)	Not available
	L2	0.76	Suitable (S3)	Not available
Membalong	MB1	0.55	Suitable (S3)	Available
Mentigi	MT1	1.05	Suitable (S3)	Available
	MT2	0.72	Suitable (S3)	Available
	MT3	3.38	Suitable (S3)	Available
Perpat	P1	1.33	Suitable (S3)	Available
	P2	0.17	Suitable (S3)	Available
	P3	0.19	Suitable (S3)	Available
	P4	0.27	Suitable (S3)	Available
Simpang Rusa	SR1	0.47	Suitable (S3)	Not available
	SR2	1.15	Suitable (S3)	Available
	SR3	1.10	Suitable (S3)	Available
	SR4	0.85	Suitable (S3)	Available
	SR5	1.28	Suitable (S3)	Available
	SR6	0.72	Suitable (S3)	Available

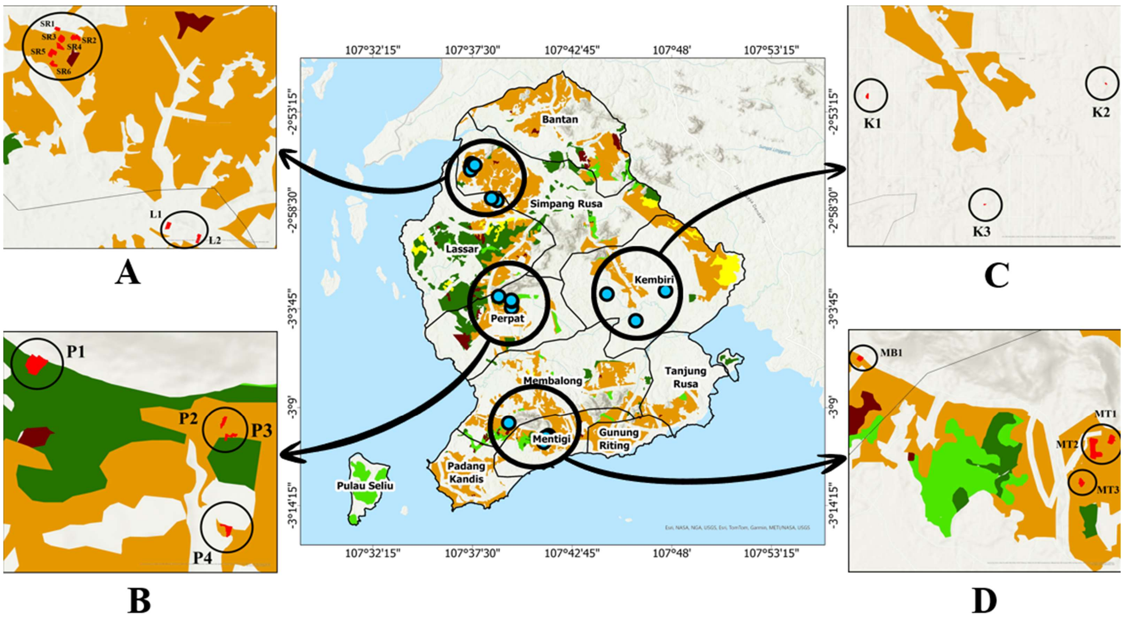

Figure 8. Land cover availability between pepper plantations (a) Simpang Rusa and Lassar; (b) Perpat; (c) Kembiri; (d) Membalong and Mentigi

Pepper plantations in Kembiri Village, Lassar Village, and one plantation in Simpang Rusa Village were classified as unsuitable for further development because they were located on land-cover types that do not support pepper cultivation. Specifically, 3 plantations in Kembiri Village were located within oil palm plantation areas, 1 plantation in Simpang Rusa Village was situated on paddy fields, and 2 plantations in Lassar Village occupied land designated for residential development. Consequently, these locations were considered unsuitable and were therefore not recommended for further expansion. In contrast, pepper plantations in Membalong, Mentigi, Perpat, and Simpang Rusa Villages were situated on compatible land-cover types and remained suitable for continued utilization. As a result, of the 19 identified and delineated plantation locations, 13 were located on suitable land and retained potential for future development.

These findings indicate that approximately 32% of the existing pepper plantations were situated on land that was either unsuitable or unavailable for further expansion. This mismatch occurred through 2 distinct processes. First, land conversion from paddy fields in Simpang Rusa Village to oil palm plantations in Kembiri Village reflects competition among agricultural commodities, as pepper cultivation has gradually been displaced by alternative land uses perceived as more economically attractive to local communities. Second, land allocated for residential development in Lassar Village represents the ongoing conversion of agricultural land to non-agricultural uses, which may also indicate a gradual shift in rural livelihoods away from farming activities. This pattern is consistent with previous studies showing that agricultural land-use change is frequently driven by economic considerations, with farmers often shifting their land to alternative commodities or sectors that offer higher returns (Rondhi et al., 2018).

Such transitions are often influenced by a combination of economic, social, and policy-related factors involving multiple stakeholders, including spatial planning policies that determine land allocation among competing agricultural and non-agricultural uses (Arnawa et al., 2022). The conversion of agricultural land to residential areas observed in Lassar Village reflects a common phenomenon in rural regions, where farmers move away from traditional crops due to declining profitability and resource constraints (Indarwanto et al., 2025). This process is frequently associated with de-agrarianization, characterized by the gradual transition of rural livelihoods from agricultural to non-agricultural sectors (Amiruddin, 2025). Similar dynamics have been widely documented across Southeast Asia as part of broader regional development trends (Appelt et al., 2022).

Overall, these findings demonstrate that both land suitability and land availability constraints significantly limit the potential for pepper plantation development within the study area. The predominance of marginally suitable land (S3), combined with the mismatch between existing plantations and designated land use, suggests that current pepper cultivation is not yet fully aligned with spatial planning objectives and environmental conditions. This situation indicates that without appropriate land management measures and stronger alignment between cultivation activities and the allocation of suitable land, the long-term sustainability of pepper production is likely to remain constrained.

Analysis of regional development based on tourism infrastructure

Regional development was analyzed using the scalogram method, which produced the TIAI, reflecting spatial disparities in the distribution of tourism infrastructure. The index was used to classify villages into regional hierarchies according to the availability and diversity of tourism-supporting facilities.

The TIAI values are classified into regional hierarchies based on the number and diversity of facilities; areas with more comprehensive infrastructure are assigned to higher hierarchies and perform stronger service functions (Shi et al., 2022; Jumiyanti et al., 2026). Based on Murtadho et al. (2018), infrastructure completeness is further categorized into 3 hierarchies: 1 (highly developed), 2 (moderately developed), and 3 (less developed). The TIAI and regional hierarchy are presented in Table 10.

Based on Table 10, Hierarchy 1 includes Pulau Seliu Village (91.02), Padang Kandis Village (84.19), and Gunung Riting Village (81.10), while Hierarchy 2 consists of Mentigi Village (67.84) and Perpat Village (58.43). Villages in Hierarchy 1 possess more comprehensive tourism facilities than those in other hierarchies and are prioritized for tourism planning and development in Membalong Sub-district due to their more suitable infrastructure. This hierarchy tends to be concentrated in the southern part of Membalong Sub-district. The southern area of Membalong serves as one of the tourism destinations in southern Belitung Regency, including Pulau Seliu and Tanjung Rusa Village. Hierarchy 2 (Mentigi and Perpat) involves areas with potential for

Table 10. Regional development based on regional hierarchy

No.	Village	TIAI	Hierarchy
1	Pulau Seliu	91.02	Hierarchy 1
2	Padang Kandis	84.19	Hierarchy 1
3	Gunung Riting	81.10	Hierarchy 1
4	Mentigi	67.84	Hierarchy 2
5	Perpat	58.43	Hierarchy 2
6	Tanjung Rusa	51.61	Hierarchy 3
7	Simpang Rusa	44.60	Hierarchy 3
8	Bantan	43.12	Hierarchy 3
9	Kembiri	42.89	Hierarchy 3
10	Lassar	39.99	Hierarchy 3
11	Membalong	35.72	Hierarchy 3

developing nature-based tourism, such as mountain and agricultural attractions, thereby enhancing tourism appeal and diversification in Membalong Sub-district, Belitung Regency.

The classification of villages into Hierarchies 1, 2, and 3 was primarily influenced by differences in the number and diversity of tourism-supporting facilities. Villages classified as Hierarchy 1 possessed a more complete combination of facilities, including transportation access, public services, accommodation, and tourism-supporting infrastructure, resulting in higher TIAI values. Hierarchy 2 villages had a moderate level of infrastructure availability, while Hierarchy 3 villages were characterized by limited facility diversity and lower service capacity. This pattern indicates that the regional hierarchy in Membalong Sub-district is strongly associated with the concentration of tourism infrastructure and public service facilities. As illustrated in Figure 9, Hierarchy 1 villages are concentrated in the southern part of the sub-district, while lower-hierarchy villages are more widely distributed across the study area.

Although regional hierarchies indicate differences in development levels, spatial mismatches exist between infrastructure readiness and agricultural potential, reflecting inefficiency in regional development allocation. Villages in Hierarchy 1 exhibit higher infrastructure capacity but do not overlap with the main pepper plantation areas or suitable land. Conversely, villages with pepper plantations and more supportive land resources are located in Hierarchy 2, indicating that potential areas are not yet supported by adequate infrastructure. The overlay between pepper distribution, land availability classes, and regional hierarchy is presented in Figure 10.

This condition reflects regional development imbalances, in which infrastructure is misaligned with the distribution of agricultural resources, potentially hindering the integration of agriculture and tourism. Infrastructure plays a crucial role in regional development, while its limitations both reflect and reinforce spatial inequalities (Fahmi et al., 2025; Sjaf et al., 2025). Tourism infrastructure can increase visitor arrivals and support rural economies (Harahap et al., 2015; Kartika and Wahyono, 2019; Ariyani and Fauzi, 2023; Saputro et al., 2023). These findings are consistent with the distribution of pepper plantations, which remain limited and concentrated, and are not strategically supported by infrastructure development. Consequently, the constraints in pepper cultivation are also influenced by insufficient infrastructure support in the primary production areas. Based on land suitability classes and land availability, although dominated by Class S3, sufficient land remains available, leaving opportunities for pepper development open.

However, infrastructure limitations hinder the utilization of potential land and its transformation into agrotourism areas. The success of pepper-

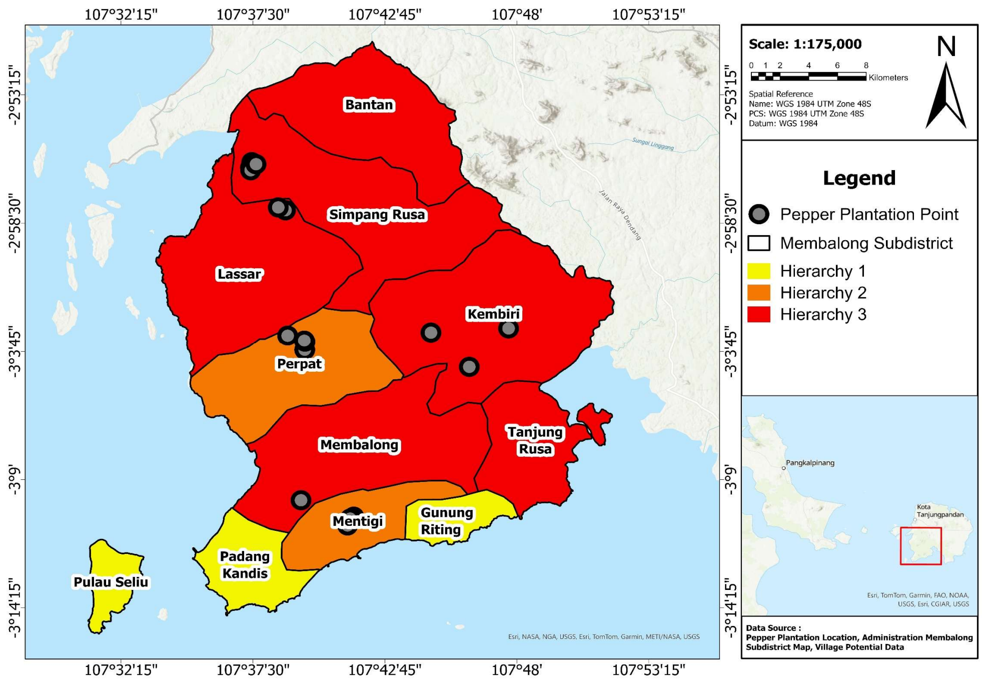

Figure 9. Regional hierarchy in the Membalong Sub-district

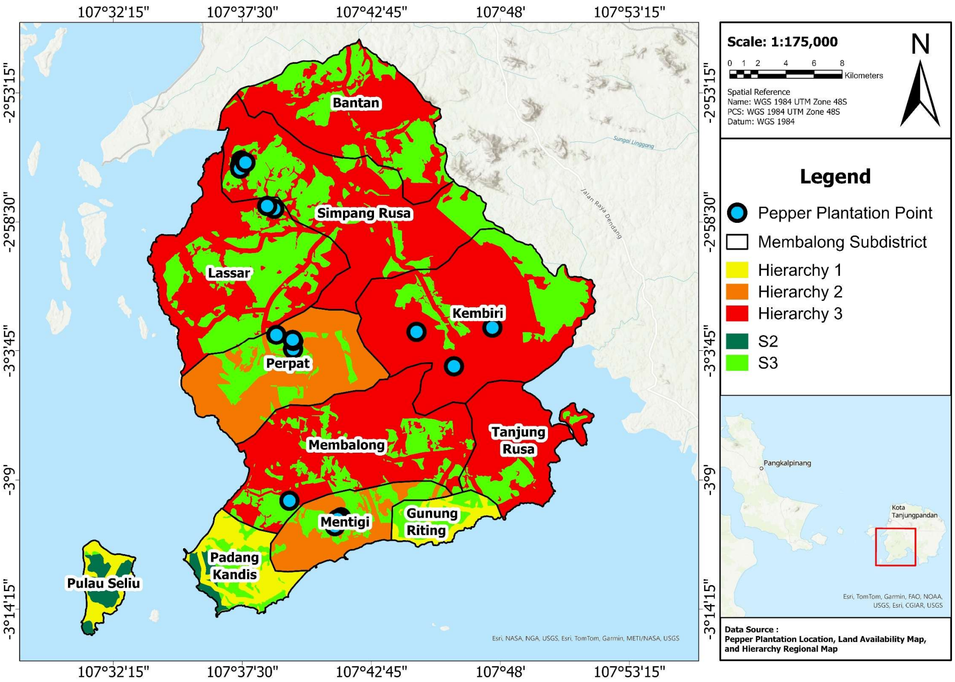

Figure 10. The overlay results between the distribution of pepper plantations, available land, and the regional hierarchy

based agrotourism planning depends on integrating land resources and ensuring infrastructure readiness. Thus, the inequality between tourism infrastructure development and the distribution of key agricultural resources has become a challenge in regional development in Membalong Sub-district. This condition highlights the lack of integration in development planning, particularly in supporting pepper-based agrotourism. A comprehensive analytical framework is required to synthesize land potential, existing conditions, and regional development levels in order to establish more effective prioritization.

Analysis of agrotourism area planning recommendations

Spatial analysis reveals a mismatch among areas with high pepper production, the distribution of available land, and areas with adequate infrastructure for agrotourism planning. As shown in Figure 9, some villages have land suitable for pepper cultivation but lack adequate infrastructure and accessibility. Conversely, some areas have relatively good infrastructure but face limitations in land suitability or in the size of existing plantations. These conditions highlight the importance of an integrative approach to agrotourism planning, as agriculture-based tourism requires a balance between the potential of natural resources and the readiness of regional infrastructure (Nyompa et al., 2022).

To formulate recommendations for agrotourism planning zones, a multi-criteria approach was used to identify priority areas more comprehensively than single-aspect methods. This approach aligns with Kousar and Kausar (2025), who emphasize the need to integrate social and environmental aspects into sustainable agrotourism planning. Using the SAW method, prioritization is based not only on the presence of pepper crops but also on regional development readiness, as measured by 5 variables: the number of pepper plantations, plantation area, availability of S2-class land, availability of S3-class land, and the TIAI.

Each variable plays a different role in the recommendation results. The number and area of pepper plantations represent the concentration of existing agricultural resources; the classes of available land suitability (S2 and S3) reflect the potential for future plantation expansion, while the TIAI reflects the readiness of supporting infrastructure for tourism. The average weightings assigned by the experts are presented in Table 11.

The results of the recommendations, which involved experts' assessment and weighting of these variables, led to 3 priority levels for agrotourism planning in Membalong Sub-district, as presented in Table 12.

The research results show that Simpang Rusa Village has the highest score, making it the top priority for pepper agrotourism development in

Table 11. Average expert weightings

Number of pepper plantations	Area of pepper plantations (ha)	Available land area class S2/Sufficiently suitable (ha)	Available land area class S3/Marginally suitable (ha)	TIAI
0.20	0.20	0.24	0.19	0.17

Membalong Sub-district. This result stems from a combination of several key factors, such as the relatively large number of pepper plantations and the availability of land suitable for expansion. Of the 5 variables used as criteria for determining priorities, the experts assigned the highest weight to the availability of S2-class land, followed by the number of pepper plantations and the area of the plantations. This indicates that land quality and the availability of plantation resources are considered the most important factors in determining priorities for pepper agrotourism planning.

The final results of this scoring also align with those of Arifin et al. (2009), who state that a prerequisite for agrotourism suitability is land suitable for developing agricultural and plantation commodities. Furthermore, conducting regional planning and development in accordance with land-use zoning and identifying the potential of flagship agricultural commodities that align with agricultural land suitability are necessary first steps. In this context, pepper plantations in Belitung Regency, particularly in Membalong Sub-district, represent a distinctive crop whose cultivation is beginning to decline. The distribution of the recommended agrotourism planning areas is presented in Figure 11.

These findings also indicate a strong connection between the spatial analysis results and the regional policy directions outlined in the RIPPARKAB. In addition to designating Simpang Rusa Village as part of the Nature Adventure Tourism Development Area, other villages identified as second-priority locations, including Perpat, Mentigi, and Lassar, have also been included in the development plan. One of the

Table 12. Priority recommendations for agrotourism planning areas

No.	Village	Scoring	Priority
1	Simpang Rusa	1.697	Priority - 1
2	Mentigi	1.269	Priority - 2
3	Pulau Seliu	1.237	Priority - 2
4	Perpat	1.010	Priority - 2
5	Lassar	0.999	Priority - 2
6	Padang Kandis	0.904	Priority - 2
7	Kembiri	0.824	Priority - 3
8	Gunung Riting	0.539	Priority - 3
9	Bantan	0.477	Priority - 3
10	Membalong	0.468	Priority - 3
11	Tanjung Rusa	0.242	Priority - 3

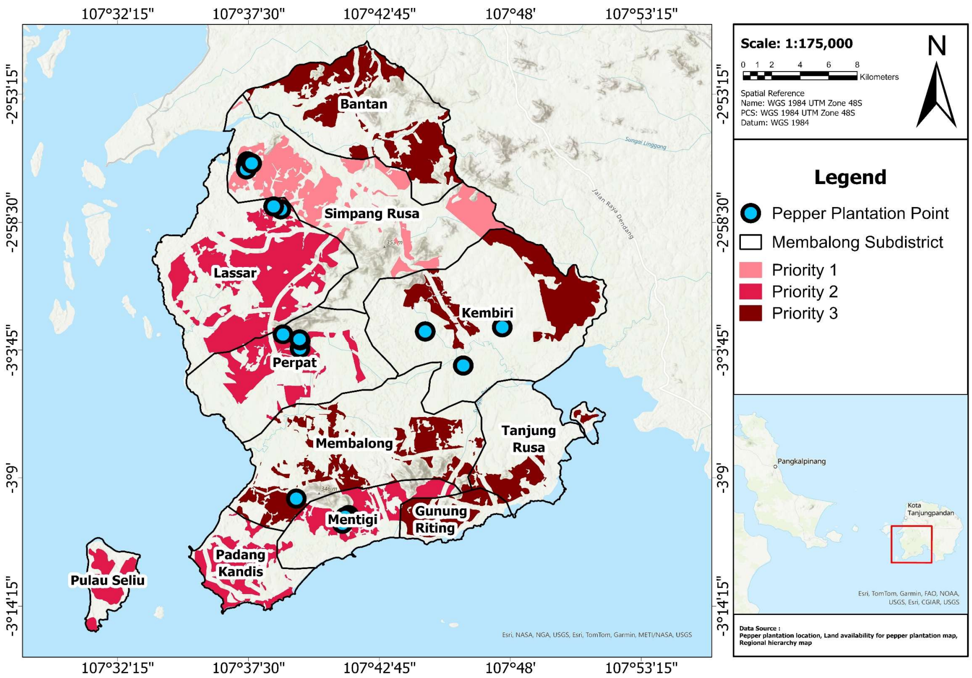

Figure 11. Map of recommendations for agrotourism area planning at Membalong Sub-district

key objectives stated in the plan is to increase the value added by Belitung's distinctive pepper plantations.

Based on the results, Simpang Rusa Village, with the largest number of pepper plantations and a relatively large area of available land, offers considerable potential for agrotourism development, with pepper as the main attraction. This study not only identifies priority villages but also provides a more detailed spatial basis to support the implementation of pepper-based agrotourism programs already proposed in the RIPPARKAB. The consistency between the analysis results and regional development policies suggests that a GIS-based spatial analysis approach, combined with multi-criteria decision-making methods, can serve as an effective tool for supporting more targeted and data-driven tourism planning (Trang Le et al., 2025).

Despite the significant findings of this study, several limitations should be acknowledged. The spatial analysis for identifying pepper plantations relied on field surveys and Google Earth imagery to delineate plantation boundaries, given the difficulty of distinguishing them due to the lack of distinctive features. In addition, the study focused on spatial variables, land suitability, and tourism-supporting infrastructure, thereby omitting economic feasibility, tourist preferences, and market factors that may influence agrotourism planning. The weighting process in the SAW method was based on assessments by 3 experts to represent the relative importance of each criterion in the context of pepper agrotourism planning. However, sensitivity analysis of weight variations was not conducted, so the stability of the ranking results under different weighting scenarios could not be evaluated. Future research could address these limitations by integrating higher-resolution spatial data and additional socio-economic variables and by conducting sensitivity analysis to test the robustness of the priority results.

CONCLUSIONS

Pepper plantations in Membalong Sub-district comprise 19 sites covering a total area of 15.75 ha. The evaluation results show that the study area is dominated by S3-class land (marginally suitable), while S2-class land (moderately suitable) is available in limited quantities. Thirteen of the 19 plantations are located on available land with development potential. Based on the SAW method, Simpang Rusa Village was selected as the highest priority for planning pepper agrotourism development in Membalong Sub-district. This study demonstrates that integrating GIS-based spatial analyses, such as land suitability and land availability assessments, with multi-criteria decision-making can identify priority areas for agrotourism planning in a more systematic and data-driven manner. The results of this study can serve as a basis for determining regional priorities to support the implementation of the Belitung Regency RIPPARKAB, particularly in planning pepper agrotourism development within the Membalong Sub-district nature tourism area.

ACKNOWLEDGEMENT

This study was independently funded and supported by the Food Security and Agriculture Office of Belitung Regency during the survey activities.

DECLARATION OF GENERATIVE AI USE

The authors used ChatGPT (OpenAI) as an AI-assisted language support tool during manuscript preparation. The tool was used solely for language refinement, grammar correction, sentence restructuring, and improving the manuscript's readability. No AI tools were used to generate research data, perform statistical analyses, produce research results, create scientific conclusions, or generate references. All analyses, interpretations, and conclusions presented in this manuscript were conducted, verified, and approved by the authors, who take full responsibility for the content of the manuscript.

REFERENCES

Adeola, O., & Evans, O. (2020). ICT, infrastructure, and tourism development in Africa. *Tourism Economics*, *26*(1), 97–114. https://doi.org/10.1177/1354816619827712

Agricultural Data and Information System Center. (2022). *Outlook komoditas perkebunan lada*. Secretariat General of the Ministry of Agriculture. Retrieved from https://satudata.pertanian.go.id/details/publikasi/362#:~:text=Produksi%20lada%20di%20Indonesia%20tahun,0%2C55%25%20per%20tahun

Al Zarliani, W. O., Muzuna, & Sugianto, S. (2023). Behavior and marketing analysis of pepper (*Piper nigrum* L.): A comparative study of farmers, trading districts and retailers in Southeast Sulawesi, Indonesia. *Caraka*

Tani: Journal of Sustainable Agriculture, *38*(1), 14–25. https://doi.org/10.20961/carakatani.v38i1.59193

Alif, T., Hartono, S., & Sulandari, S. (2018). Karakterisasi virus penyebab penyakit belang pada tanaman lada (*Piper nigrum* L.). *Jurnal Perlindungan Tanaman Indonesia*, *22*(1), 115–123. https://doi.org/10.22146/jpti.30354

Amini, S., Rohani, A., Aghkhani, M. H., Abbaspour-Fard, M. H., & Asgharipour, M. R. (2020). Assessment of land suitability and agricultural production sustainability using a combined approach (Fuzzy-AHP-GIS): A case study of Mazandaran Province, Iran. *Information Processing in Agriculture*, *7*(3), 384–402. https://doi.org/10.1016/j.inpa.2019.10.001

Amiruddin. (2025). From rice fields to industry: The social impact of agricultural land conversion on the socio-economic lives of farmers. *Socious Journal*, *2*(4), 1–12. https://doi.org/10.62872/rwzdej42

Ammirato, S., Felicetti, A. M., Raso, C., Pansera, B. A., & Violi, A. (2020). Agritourism and sustainability: What we can learn from a systematic literature review. *Sustainability*, *12*(22), 9575. https://doi.org/10.3390/su12229575

Amorita, C., Daryanto, A., & Sahara. (2021). Competitiveness analysis of Indonesian pepper in international market. *International Journal of Research and Review*, *8*(5), 38–52. https://doi.org/10.52403/ijrr.20210507

Anshar, M., Siradjuddin, I., Rezki, M., & Kusmiran, A. (2022). Land suitability and potential agriculture analysis to regional development based on agro-tourism. *Jurnal Pembangunan Wilayah dan Kota*, *18*(2), 112–127. https://doi.org/10.14710/pwk.v18i2.37531

Appelt, J. L., Rojas, D. C. G., Verburg, P. H., & Van Vliet, J. (2022). Socio-economic outcomes of agricultural land use change in Southeast Asia. *Ambio*, *51*(5), 1094–1109. https://doi.org/10.1007/s13280

Apriyanti, M. E., Sumaryoto, & Meirinaldi. (2024). The importance of tourism infrastructure in increasing domestic and international tourism. *International Journal of Research in Vocational Studies (IJRVOCAS)*, *3*(4), 113–122. https://doi.org/10.53893/ijrvocas.v3i4.46

Arifin, H. S., Munandar, A., Nurhayati, H. S. A., & Kaswanto, R. L. (2009). *Potensi kegiatan agrowisata di perdesaan (Buku seri IV: Manajemen lanskap perdesaan bagi kelestarian dan kesejahteraan lingkungan)*. Ministry of Agriculture of the Republic of Indonesia. Retrieved from https://www.researchgate.net/publication/365131648_Potensi_Kegiatan_Agrowisata_di_Perdesaan_Buku_Seri_IV_Manajemen_Lanskap_Perdesaan_bagi_Kelestarian_dan_Kesejahteraan_Lingkungan

Ariyani, N., & Fauzi, A. (2023). Pathways toward the transformation of sustainable rural tourism management in Central Java, Indonesia. *Sustainability*, *15*(3), 2592. https://doi.org/10.3390/su15032592

Arnawa, I. K., Columna, N. T., & Tariningsih, D. (2022). Functional shifting from agricultural land into non-agriculture. *SOCA: Jurnal Sosial, Ekonomi Pertanian*, *16*(1), 109–117. https://doi.org/10.24843/soca.2022.v16.i01.p10

Azahari, D. H., Purba, H. J., Erwidodo, Darwis, V., Dabukke, F. B. M., Hestina, J., & Yusuf, E. S. (2021). The competitiveness of Indonesia's pepper export and its challenges. *IOP Conference Series: Earth and Environmental Science*, *892*(1), 012074. https://doi.org/10.1088/1755-1315/892/1/012074

Baehaqi, A., Sitorus, S. R., & Achsani, N. A. (2010). *Pengembangan komoditas unggulan tanaman pangan di Kabupaten Lampung Tengah* [Thesis]. Bogor, Indonesia: IPB University. Retrieved from https://repository.ipb.ac.id/handle/123456789/40824

Bagwan, W. A., Gavali, R. S., & Maity, A. (2023). Quantifying soil organic carbon (SOC) density and stock in the Urmodi River watershed of Maharashtra, India: Implications for sustainable land management. *Journal of Umm Al-Qura University for Applied Sciences*, *9*(4), 548–564. https://doi.org/10.1007/s43994-023-00064-3

Bande, L. O. S., Hadisutrisno, B., Somowiyarjo, S., & Sunarminto, B. H. (2015). Peran unsur cuaca terhadap peningkatan penyakit busuk pangkal batang lada di sentra produksi lada daerah Sulawesi Tenggara. *Jurnal Manusia dan Lingkungan*, *22*(2), 187–193. https://doi.org/10.22146/jml.18741

Croes, R., & Vanegas, M. (2008). Cointegration and causality between tourism and poverty reduction. *Journal of Travel Research*, *47*(1), 94–103. https://doi.org/10.1177/0047287507312429

Danuartha, D., Santi, R., Pratama, D., & Setiawan, F. (2023). Evaluasi kesesuaian lahan tanaman lada di Kabupaten Bangka Selatan. *Agrisaintifika Jurnal Ilmu-Ilmu Pertanian*, *7*(2(is), 53–65. https://doi.org/10.32585/ags.v7i2(is).4348

Daras, U., & Pranowo, D. (2009). Kondisi kritis lada putih Bangka Belitung dan alternatif pemulihannya. *Jurnal Penelitian dan Pengembangan Pertanian*, *28*(1), 1–6. Retrieved from https://media.neliti.com/media/publications/178782-ID-kondisi-kritis-lada-putih-bangka-belitun.pdf

Dwyer, L. (2023). Tourism development and sustainable well-being: A beyond GDP perspective. *Journal of Sustainable Tourism*, *31*(10), 2399–2416. https://doi.org/10.1080/09669582.2020.1825457

Fahmi, M. N., Harefa, M. S., Lubis, D. P., & Permana, S. (2025). Analysis of scalogram and centrality in Labuhan Batu Regency: Implications for service facility distribution. *Geographica: Science & Education Journal*, *7*(1), 1–12. https://doi.org/10.31327/gsej.v7i1.2497

Firdaus, Hendri, J., & Saidi, B. B. (2022). Evaluasi kesesuaian lahan untuk pengembangan komoditas lada di Kabupaten Tanjung Jabung Timur. *Jurnal Ilmiah Ilmu Terapan Universitas Jambi*, *6*(2), 181–191. https://doi.org/10.22437/jiituj.v6i2.22955

Hao, Y., Fan, R., Zhao, Y., Nie, K., Wang, L., Zhao, T., ... & Guan, X. (2025). Intra species dissection of *Phytophthora capsici* resistance in black pepper. *Journal of Advanced Research*, *74*, 121–136. https://doi.org/10.1016/j.jare.2024.10.015

Harahap, M. S., Winata, E., & Abbas, M. (2015). *Pengaruh pembangunan prasarana pariwisata terhadap peningkatan kunjungan wisatawan pada obyek wisata Danau Linting Kabupaten Deli Serdang*. https://doi.org/10.31227/osf.io/xb56n

Hardjowigeno, S., & Widiatmaka. (2007). *Evaluasi kesesuaian & perenanaan tata guna lahan*. Universitas Gadjah Mada Press. Retrieved from https://ugmpress.ugm.ac.id/en/product/pertanian/evaluasi-kesesuaian-lahan-dan-perencanaan-tataguna-lahan

Indarwanto, Yuwana, Romeida, A., & Senoaji, G. (2025). Agricultural land conversion drivers and irrigation conflict impacts in sustainable land protection areas: A case study from Muara Beliti, Indonesia. *International Journal of Environmental Sciences*, *11*(6), 2025. https://doi.org/10.64252/z50gbr63

Jonni, Nurhayati, Sutjahjo, S. H., Pravitasari, A. E., & Rosadi. (2024). Agro-tourism development sustainable analysis based on agricultural landscapes in Nagari Pandai Sikek, Tanah Datar District, West Sumatera. *Journal of Degraded and Mining Lands Management*, *11*(2), 5339–5351. https://doi.org/10.15243/jdmlm.2024.112.5339

Jovanovic, S., & Ilic, I. (2016). Infrastructure as important determinant of tourism development in the countries of Southeast Europe. *Ecoforum*, *5*(1), 288–294. Retrieved from https://www.academia.edu/download/125147559/216.pdf

Jumiyanti, K. R., Machimu, J. S., & Walahe, D. (2026). Service center hierarchy in Gorontalo: Empirical analysis throgh scalogram and centrality. *Journal of Applied Economics in Developing Countries*, *11*(1), 1–20. https://doi.org/10.20961/jaedc.v11i1.110515

Kammerer, M., Iverson, A. L., Li, K., & Goslee, S. C. (2024). Not just crop or forest: An integrated land cover map for agricultural and natural areas. *Scientific Data*, *11*(1), 137. https://doi.org/10.1038/s41597-024-02979-w

Kartika, F. K., & Wahyono, H. (2019). Pengaruh perkembangan infrastruktur dasar pariwisata terhadap minat kunjungan wisatawan Candi Gedong Songo Kecamatan Bandungan. *Teknik PWK (Perencanaan Wilayah Kota)*, *8*(4), 217–225. https://doi.org/10.14710/tpwk.2019.25448

Khan, A., Bibi, S., Lorenzo, A., Lyu, J., & Babar, Z. U. (2020). Tourism and development in developing economies: A policy implication perspective. *Sustainability*, *12*(4), 1618. https://doi.org/10.3390/su12041618

Kim, H. K., & Lee, T. J. (2018). Brand equity of a tourist destination. *Sustainability*, *10*(2), 431. https://doi.org/10.3390/su10020431

Kousar, S., & Kausar, N. (2025). Multi-criteria decision-making for sustainable agritourism: An integrated fuzzy-rough approach. *Spectrum of Operational Research*, *2*(1), 175–191. https://doi.org/10.31181/sor21202515

Lestari, N. I., Rianto, F., & Syahputra, E. (2023). Identification of *Phytophthora capsici* attack causes stem rot disease on pepper seedlings. *Jurnal Pertanian Agros*, *25*(3), 3047–3052. Retrieved from https://e-journal.janabadra.ac.id/index.php/JA/article/viewFile/3376/2111

Mahdi, N. N., & Suprehatin, S. (2021). Posisi pasar lada Indonesia di pasar global. *Jurnal Ekonomi Pertanian dan Agribisnis*, *5*(2), 595–605. https://doi.org/10.21776/ub.jepa.2021.005.02.26

Malczewski, J. (1999). *GIS and multi-criteria decision analysis*. J. Wiley & Sons. Retrieved from https://scholar.google.co.id/scholar?cites=11649115425330933578&as_sdt=2005&sciodt=0,5&hl=id

Malefaki, S., Markatos, D., Filippatos, A., & Pantelakis, S. (2025). A comparative analysis of multi-criteria decision-making methods and normalization techniques in holistic sustainability assessment for engineering applications. *Aerospace*, *12*(2), 100. https://doi.org/10.3390/aerospace12020100

Mandic, A., Mrnjavac, Ž., & Kordic, L. (2018). Tourism infrastructure, recreational facilities and tourism development. *Tourism and Hospitality Management*, *24*(1), 41–62. https://doi.org/10.20867/thm.24.1.12

Mangkunegara, M., & Firdamayanti, E. (2021). Evaluasi kesesuaian lahan dan kelayakan ekonomi tanaman lada (*Piper nigrum* L.) di Kabupaten Luwu. *Wanatani: Jurnal Ilmu Pertanian*, *1*(2), 55–62. https://doi.org/10.51574/jip.v1i2.32

Mardani, A., Jusoh, A., Nor, K. M. D., Khalifah, Z., Zakwan, N., & Valipour, A. (2015). Multiple criteria decision-making techniques and their applications - A review of the literature from 2000 to 2014. *Economic Research-Ekonomska Istrazivanja*, *28*(1), 516–571. https://doi.org/10.1080/1331677X.2015.1075139

Mesgaran, M. B., Madani, K., Hashemi, H., & Azadi, P. (2017). Iran's land suitability for agriculture. *Scientific Reports*, *7*(1), 7670. https://doi.org/10.1038/s41598-017-08066-y

Miranda, J., Britz, W., & Börner, J. (2024). Impacts of commodity prices and governance on the expansion of tropical agricultural frontiers. *Scientific Reports*, *14*(1), 9209. https://doi.org/10.1038/s41598-024-59446-0

Mohammed, A. S., Kutaila, A. F., Al-Hinai, H. S., Ahmed, A. B., Sharma, D., Patra, B., ... & Meena, R. (2025). Sustainable agriculture in Oman: Evaluating treated wastewater irrigation effects on soil quality, heavy metal accumulation, and alfalfa growth. *Journal of the Saudi Society of Agricultural Sciences*, *24*(8), 81. https://doi.org/10.1007/s44447-025-00070-3

Mujiyo, Sutarno, Suwarto, Budiono, R., & Sutopo, N. R. (2020). Inhibiting factors of land suitability for *Piper nigrum* L. in a hilly area of Tirtomoyo District, Central Java. *Journal of Tropical Soils*, *25*(1), 29–37. https://doi.org/10.5400/jts.2020.v25i1.29

Munir, S., Haq, I. U., Cheema, A. N., Almanjahie, I. M., & Khan, D. (2025). The role of tourists, infrastructure and institutions in sustainable tourism: A structural equation modeling approach. *Sustainability*, *17*(7), 2841. https://doi.org/10.3390/su17072841

Murtadho, A., Wulandari, S., Wahid, M., & Rustiadi, E. (2018). Perkembangan wilayah dan perubahan tutupan lahan di Kabupaten Purwakarta sebagai dampak dari proses konurbasi Jakarta-Bandung. *Journal of Regional and Rural Development Planning*, *2*(2), 195–208. https://doi.org/10.29244/jp2wd.2018.2.2.195-208

Naeimi, M., Akbari, M., Nahvinia, M. J., & Mardian, M. (2026). A GIS-based MCDM approach to achieve optimal cropping pattern (theory and application in a semi-arid region). *Scientific Reports*, *16*(1), 3599. https://doi.org/10.1038/s41598-025-33496-4

Nyompa, S., Maru, R., Wahyuddin, & Darma, G. (2022). The utilization of geographic information systems (GIS) for the suitability of agro-tourism land. *EnvironmentAsia*, *16*(1), 37–48. https://doi.org/10.14456/ea.2023.4

Palit, I. G., Talumingan, C., & Rumagit, G. A. J. (2017). Strategi pengembangan kawasan agrowisata Rurukan. *Jurnal Agri-SosioEkonomi*, *13*(2A), 21–34. https://doi.org/10.35791/agrsosek.13.2A.2017.16558

Panggabean, M. T., Amanah, S., & Tjitropranoto, P. (2016). Persepsi petani lada terhadap diseminasi teknologi usahatani lada di Bangka Belitung. *Jurnal Penyuluhan*, *12*(1), 61–73. https://doi.org/10.25015/penyuluhan.v12i1.11321

Panuju, D. R., & Rustiadi, E. (2013). *Teknik analisis perencanaan pengembangan wilayah*. IPB University. Retrieved from https://scholar.google.co.id/scholar?cites=9838235124827121738&as_sdt=2005&sciodt=0,5&hl=id

Petrova, M., Dekhtyar, N., Klok, O., & Loseva, O. (2018). Regional tourism infrastructure development in the state strategies. *Problems and Perspectives in Management*, *16*(4), 259–274. https://doi.org/10.21511/ppm.16(4).2018.22

Pravitasari, A. E., Kusumaningtyas, A. R., Mulya, S. P., Wulandari, S., Stanny, Y. A., & Hor, S. (2023). Land suitability analysis and direction for plantation commodities development in Pekalongan Regency, Central Java. *IOP Conference Series: Earth and Environmental Science*, *1133*(1), 012053. https://doi.org/10.1088/1755-1315/1133/1/012053

Ritung, S., Nugroho, K., Mulyani, A., & Suryani, E. (2011). *Petunjuk teknis evaluasi lahan untuk komoditas pertanian*. Agricultural Research and Development Agency, Ministry of Agriculture. Retrieved from https://repository.pertanian.go.id/items/0a9fcbfb-2d07-41d2-9d44-5d94a199b7ad

Riyadi. (2012). *Arahan dan strategi pengembangan perkebunan lada di Kabupaten Belitung*. IPB University.

Rogerson, C. M., & Rogerson, J. M. (2020). COVID-19 tourism impacts in South Africa: Government and industry responses. *GeoJournal of Tourism and Geosites*, *31*(3), 1083–1091. https://doi.org/10.30892/gtg.31321-544

Rondhi, M., Pratiwi, P. A., Handini, V. T., Sunartomo, A. F., & Budiman, S. A. (2018). Agricultural land conversion, land economic value, and sustainable agriculture: A case study in East Java, Indonesia. *Land*, *7*(4), 148. https://doi.org/10.3390/land7040148

Rustiadi, E., Pravitasari, A. E., Priatama, R. A., Singer, J., Junaidi, J., Zulgani, Z., & Sholihah, R. I. (2023). Regional development, rural transformation, and land use/cover changes in a fast-growing oil palm region: The case of Jambi Province, Indonesia. *Land*, *12*(5), 1059. https://doi.org/10.3390/land12051059

Sangnak, D., Poo-Udom, A., Tamnanwan, P., Kongduang, T., & Chanthothai, S. (2025). Agritourism as a catalyst for sustainable rural development: Innovations, challenges, and policy perspectives in the post-COVID-19 era. *Journal of Infrastructure Policy and Development*, *9*(1), 11185. https://doi.org/10.24294/jipd11185

Saputro, K. E. A., Hasim, Karlinasari, L., & Beik, I. S. (2023). Evaluation of sustainable rural tourism development with an integrated approach using MDS and ANP methods: Case study in Ciamis, West Java, Indonesia. *Sustainability*, *15*(3), 1835. https://doi.org/10.3390/su15031835

Sawaludin, S., Iswandi, R. M., Kangkuso, A., Jaya, L. M. G., Firihu, M. Z., Widayati, W., ... & Sutariati, G. A. K. (2026). Spatial assessment of land suitability for agromarine tourism on Wawonii Island, Indonesia. *Bulletin of the Serbian Geographical Society*, *106*(1), 263–286. Retrieved from https://www.glasniksgd.rs/index.php/home/article/view/1941/pdf

Shi, S., Liu, M., & Xi, J. (2022). Hierarchical structure and organizational model of county tourism network of the Tibetan plateau. *Land*, *11*(11), 1880. https://doi.org/10.3390/land11111880

Singha, C., & Swain, K. C. (2016). Land suitability evaluation criteria for agricultural crop selection: A review. *Agricultural Reviews*, *37*(2), 125–132. https://doi.org/10.18805/ar.v37i2.10737

Sitorus, S. R. P., Leonataris, C., & Panuju, D. R. (2012). Analisis pola perubahan penggunaan lahan dan perkembangan wilayah di Kota Bekasi, Provinsi Jawa Barat. *Jurnal Tanah Lingkungan*, *14*(1), 21–28. Retrieved from https://www.academia.edu/download/113555154/295099600.pdf

Sjaf, S., Malik, A., Harits, A., Maulana, S. A. B., Hakim, L., Arsyad, A. A., ... & Cakrawinata, F. (2025). Analysis of spatial inequality and rural development in the supporting region for nusantara capital city, Indonesia. *Wellbeing, Space and Society*, *9*, 100286. https://doi.org/10.1016/j.wss.2025.100286

Solarin, S. A., Ulucak, R., & Erdogan, S. (2024). Assessing the economic impacts of tourism markets and activities diversification: Evidence from a new dynamic regression approach. *Journal of Travel Research*, *63*(8), 2078–2093. https://doi.org/10.1177/00472875231203395

Sriyadi, Akhmadi, H., & Yekti, A. (2021). Impact of agrotourism development on increasing value added of agricultural products and farmers' income levels (A study in Karangtengah, Bantul, Yogyakarta). *E3S Web of Conferences*, *232*, p. 02013. https://10.1051/e3sconf/202123202013

Statistics Agency of Belitung Regency. (2025). *Belitung Regency in figures 2025*. Retrieved from https://belitungkab.bps.go.id/id/publication/2025/02/28/b12707642039e777efea58dc/kabupaten-belitung-dalam-angka-2025.html

Supriatna, J., Setiawati, M. R., Sudirja, R., & Suherman, C. (2026). Enhancing soil fertility, inorganic fertilizer efficiency, and oil palm productivity through bio-compost application in oxium biodegradable sacks on former mining land-podzols: Insights from a field study in Indonesia. *Journal of the Saudi Society of Agricultural Sciences*, *25*, 1. https://doi.org/10.1007/s44447-025-00091-y

Syafi'i, R. A., & Santoso, E. B. (2015). Identifikasi kemampuan pelayanan ekonomi dan aksesibilitas pusat kegiatan lokal Ngasem di Kabupaten Kediri. *Jurnal Teknik ITS*, *4*(1), C17–C21. https://doi.org/10.12962/j23373539.v4i1.8966

Taghizadeh-Mehrjardi, R., Nabiollahi, K., Rasoli, L., Kerry, R., & Scholten, T. (2020). Land suitability assessment and agricultural production sustainability using machine learning models. *Agronomy*, *10*(4), 573. https://doi.org/10.3390/agronomy10040573

Taherdoost, H. (2023). Analysis of simple additive weighting method (SAW) as a multi-attribute decision-making technique: A step-by-step guide. *Journal of Management Science & Engineering Research*, *6*(1), 21–24. https://doi.org/10.30564/jmser.v6i1.5400

Tercan, E., & Dereli, M. A. (2020). Development of a land suitability model for citrus cultivation using GIS and multi-criteria assessment techniques in Antalya Province of Turkey. *Ecological Indicators*, *117*, 106549. https://doi.org/10.1016/j.ecolind.2020.106549

Trang Le, T. K., Nguyen, H. P., & Nguyen, N. Q. (2025). Assessing Vietnam's sustainable agritourism by integrated multi-criteria decision-making approach. *Journal of Open Innovation: Technology, Market, and Complexity*, *11*(4), 100652 https://doi.org/10.1016/j.joitmc.2025.100652

Turtureanu, A. G., Crețu, C. M., Pripoaie, R., Marinescu, E. Ș., Sîrbu, C. G., & Talaghir, L. G. (2025). Sustainable development through agritourism and rural tourism: Research trends and future perspectives in the pandemic and post-pandemic period. *Sustainability*, *17*(9), 3998. https://doi.org/10.3390/su17093998

Ustriyana, I. N. G., Saifulloh, M., Diara, I. W., & Suyarto, R. (2025). Mapping agrotourism potential using geospatial data and random forest: A case study from Bali. *Ecological Engineering and Environmental Technology*, *26*(3), 1–16. https://doi.org/10.12912/27197050/199323

Utama, I. G. B. R. (2011). *Agrowisata sebagai pariwisata alternatif* (Number April 2011). Depublish. Retrieved from https://www.researchgate.net/publication/277074027_AGROWISATA_SEBAGAI_PARIWISATA_ALTERNATIF

Utari, MG. E. S. (2015). Analisis sistem pusat pelayanan permukiman di Kota Yogyakarta tahun 2014. *Journal of Economics and Policy*, *8*(1), 1–88. https://doi.org/10.15294/jejak.v8i1.3856

Vafaei, N., Ribeiro, R. A., & Camarinha-Matos, L. M. (2022). Assessing normalization techniques for simple additive weighting method. *Procedia Computer Science*, *199*, 1229–1236. https://doi.org/10.1016/j.procs.2022.01.156

Wahyuno, D. (2009). Pengendalian terpadu busuk pangkal batang lada. *Perspektif*, *8*(1), 17–29. Retrieved from https://www.academia.edu/download/52183168/Pengendalian_Terpadu_Busuk_Pangkal_Batang_Lada.pdf

Wartini, S., Alfaqiih, A., Riswandi, B. A., & Park, J. (2022). The impacts of eco-tourism and agrotourism based on plant variety protection to sustain biological diversity and green economic growth in Indonesia. *International Journal of Law and Politics Studies*, *4*(2), 136–148. https://doi.org/10.32996/ijlps.2022.4.2.15

Winchenbach, A., Hanna, P., & Miller, G. (2022). Constructing identity in marine tourism diversification. *Annals of Tourism Research*, *95*, 103441. https://doi.org/10.1016/j.annals.2022.103441

Winkler, K., Fuchs, R., Rounsevell, M., & Herold, M. (2021). Global land use changes are four times greater than previously estimated. *Nature Communications*, *12*(1), 2501. https://doi.org/10.1038/s41467-021-22702-2

Wotlolan, D. L., Lowry, J. H., Wales, N. A., & Glencross, K. (2021). Land suitability evaluation for multiple crop agroforestry planning using GIS and multi-criteria decision analysis: A case study in Fiji. *Agroforestry Systems*, *95*(8), 1519–1532. https://doi.org/10.1007/s10457-021-00661-3

Yalew, S. G., van Griensven, A., Mul, M. L., & van der Zaag, P. (2016). Land suitability analysis for agriculture in the Abbay basin using remote sensing, GIS and AHP techniques. *Modeling Earth Systems and Environment*, *2*(2), 101. https://doi.org/10.1007/s40808-016-0167-x

Zolekar, R. B., & Bhagat, V. S. (2015). Multi-criteria land suitability analysis for agriculture in hilly zone: Remote sensing and GIS approach. *Computers and Electronics in Agriculture*, *118*, 300–321. https://doi.org/10.1016/j.compag.2015.09.016

Zukhri, N., Rosalina, E., & Christianingrum, C. (2021). Geopark Belitong : Environment based tourism branding in Belitung Island. *IOP Conference Series: Earth and Environmental Science*, *926*(1), 012075. https://doi.org/10.1088/1755-1315/926/1/012075

Zulgani, Z., Junaidi, J., Hastuti, D., Rustiadi, E., Pravitasari, A. E., & Asfahani, F. R. (2023). Understanding the emergence of rural agrotourism: A study of influential factors in Jambi Province, Indonesia. *Economies*, *11*(7), 180. https://doi.org/10.3390/economies11070180