

RESEARCH ARTICLE



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Sustainable Agrotourism Development of Beneng Taro (*Xanthosoma undipes* K. Koch) Through an Integrated Environmental and Tourism Suitability Approach in Pandeglang

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Abstract

Indonesia's biodiversity and agricultural potential remain underutilized due to a limited understanding of the environmental suitability and tourism potential of local plant species, constraining equitable economic benefits. This condition occurs in Pandeglang Regency, where Beneng taro (*Xanthosoma undipes* K. Koch) has not been optimally utilized as an agrotourism resource. This study aims to discuss the harmony of the environment and tourism potential for the development of sustainable agrotourism based on Beneng taro. Data were collected through physical methods (soil and climate conditions) and social methods (field observations and structured interviews with 30 key respondents at each location). A Principal component analysis (PCA) was used to explain the environment variable, while ADO-ODTWA criteria are used in the evaluation of the tourism. The PCA results show that two primary components (PC1 and PC2) account for 92.90% of the total data variation, with PC1 contributing 80.20% and PC2 contributing 12.70%. Environmental variables that have a positive effect on the Beneng taro habitat include altitude, silt, air humidity, organic matter. The tourism feasibility assessment showed that Karangtanjung (Juhut) obtained the highest score (666.67), followed by Mandalawangi (555) and Mount Karang (515), while Jiput obtained the lowest score (465). Juhut is recommended as a priority for Beneng taro agrotourism development. This study integrates environmental suitability analysis using PCA with tourism feasibility evaluation through a modified ADO-ODTWA framework as an integrated approach for agrobiodiversity-based agrotourism planning. The findings offer a scientific basis for policies promoting biodiversity conservation, community empowerment, and local economic development.

Keywords: agrotourism, beneng taro, biodiversity, native plant, resource

1. Introduction

Biodiversity conservation, agricultural production, and rural economic development are increasingly seen as interrelated objectives in sustainable landscape management. The integration of local plants, traditional knowledge, and distinctive landscape characteristics can create multifunctional land-use systems that support socio-ecological sustainability. Several international models demonstrate the success of this approach, and the Satoyama framework in Japan is an example of integrating biodiversity conservation, cultural heritage, and community-based agriculture at the landscape scale [1,2]. Additionally, the agriturismo model in Italy [3] and the development of agrotourism in the Todgha Oasis, Morocco [4] demonstrate how rural tourism can strengthen local economies while maintaining traditional agricultural landscapes. Furthermore, research in Vietnam [5], China [6], and South Africa [7] indicates that the use of local plants and underutilized species can be an important basis for agrotourism development that supports biodiversity conservation and rural livelihoods.

Current evidence indicates that most agrotourism studies continue to emphasize the development of landscape-based destinations and general agricultural activities, with limited attention to the ecological suitability of local plant species that serve as key tourist attractions. Existing research also tends to focus more on socioeconomic dimensions and

community participation, whereas biophysical assessments of environmental conditions supporting local plant resources are often overlooked. As a result, the relationships among plant ecological potential, environmental suitability, and tourism attractions are seldom examined through an integrated approach in sustainable agrotourism planning. This research gap is particularly important in Indonesia, a country with exceptionally high agrobiodiversity and megabiodiversity that ranks as the second most biodiverse nation in the world [8], yet the use of these resources to support agrotourism-based rural economic development remains relatively limited. A similar situation can be observed in Pandeglang District, Banten Province, where abundant natural resources and local food crops have not yet translated into substantial improvements in community welfare [9].

One local commodity that has great potential in this context is Beneng taro (*Xanthosoma undipes* K. Koch), which is a plant native to Pandeglang with important cultural and economic value. This plant has high economic potential [4,10] and ecological benefits such as its ability to control erosion and increase soil moisture [11,12]. In addition, Beneng taro is also beginning to be considered as part of nature-based solutions and agrobiodiversity-based livelihood strategies [13,14]. However, research on this plant has mostly been limited to agronomic, nutritional, and food processing aspects [10], while comprehensive evaluations of its environmental suitability and potential for development as a basis for sustainable agrotourism remain very limited.

This study provides conceptual and methodological contributions to the field of agrotourism by integrating environmental suitability analysis of local plant species with tourism potential evaluation into a unified framework. By doing so, it establishes a robust scientific foundation for sustainable agrotourism planning rooted in local agrobiodiversity a model replicable in regions with similar biological characteristics. Based on this, this study aims to analyse and evaluate environmental suitability and tourism potential in the development of sustainable agrotourism based Beneng taro (*Xanthosoma undipes* K. Koch) in Pandeglang Regency, Banten. This is achieved by integrating environmental factors using Principal Component Analysis (PCA) and assessing attractions through the ADO-ODTWA framework as a basis for planning the development of agrotourism based on local agrobiodiversity that can provide input for natural resource management policies and sustainable regional development.

2. Materials and Methods

2.1. Study Area

This study was conducted from April to October 2024 in Pandeglang Regency, Banten Province, Indonesia. In terms of geography, Pandeglang is situated between 6°21'–7°10' S and 104°48'–106°11' E, with an area of 2,747 km², which is approximately 29.98% of Banten Province. The district's ecology is varied, with lowland agricultural zones to upland agroforestry landscapes, all of which impact microclimate patterns, soil characteristics, vegetation composition, and smallholder land-use practices. The selection of four research sites in Karangtanjung (Juhut), Mandalawangi, Mount Karang, and Jiput, which are considered to represent differences in the natural occurrence and cultivation of Beneng taro, ecological gradients (altitude, soil conditions, and humidity), and different levels of community involvement and tourism readiness (Figure 1). These landscape differences contribute to the ecological sustainability challenges in the region, which are linked to different levels of land-use pressure, soil erosion risk, and cultivation intensity.

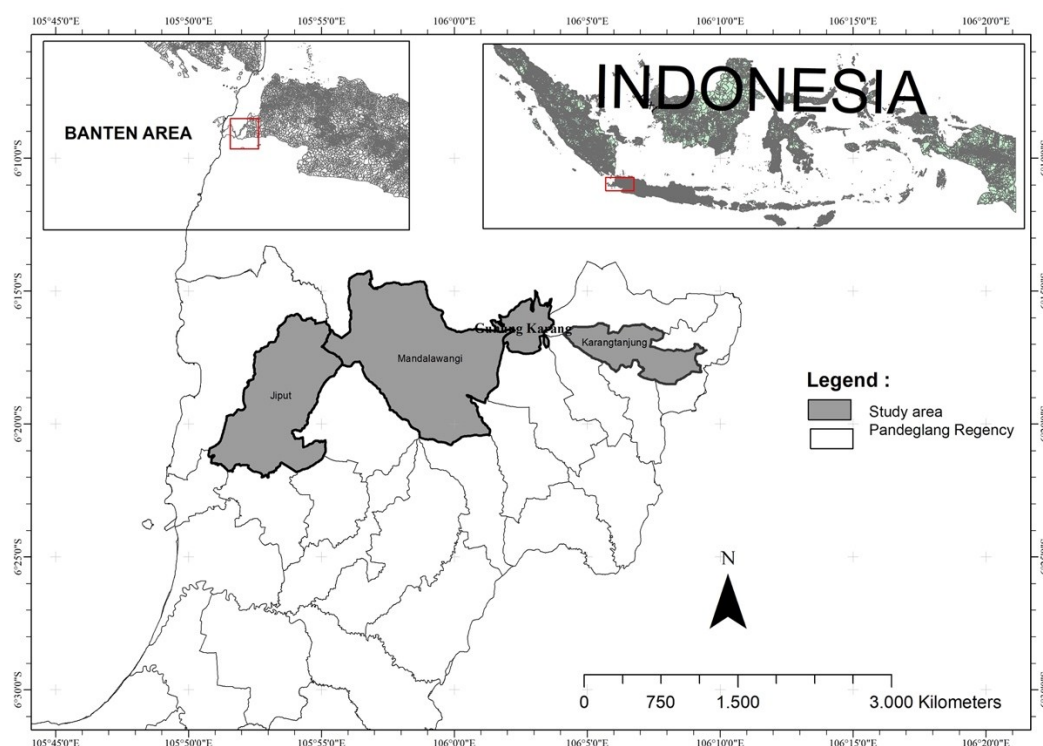


Figure 1. Research sites in Pandeglang Regency Karangtanjung (Juhut), Mandalawangi, Mount Karang, and (Jiput) selected based on the historical cultivation of Beneng taro.

2.2. Data Collection

Data collection was conducted in an integrated manner, encompassing three main categories environmental and biophysical data, social and community data, and tourism feasibility and site-readiness data, field measurements, through laboratory analysis, structured interviews, and tourism suitability assessments. Each data category was collected using complementary methods to ensure comprehensive and accurate results. The data collection process included direct field measurements to obtain factual conditions and laboratory analysis to test biophysical parameters in greater depth. Furthermore, structured interviews were conducted to elicit social information and local community perceptions of tourism development potential. All data was then combined based on the ADO-ODTWA criteria used in tourism evaluation, with tourism imbalance assessment to determine the overall level of readiness and potential of the location.

2.2.1. Environmental and biophysical data

The collected environmental parameters include altitude, temperature, relative humidity, rainfall, soil texture, pH, soil organic carbon, soil organic nitrogen, and soil erosion. Additionally, climate parameters such as temperature, rainfall, and humidity were directly observed at each location and confirmed with secondary data from the local meteorological agency. Direct identifications was conducted in the field to collect data related to the distribution and distribution patterns of Beneng taro. Furthermore, Principal Component Analysis (PCA) was used to identify the most dominant environmental factors influencing the distribution of Beneng taro based on the observed environmental parameters.

2.2.2. Soil sampling and laboratory analysis

Sampling was conducted using a purposive sampling method at several locations deemed representative of the environmental conditions where Beneng taro grows. This method was chosen because it ensures that the observed locations truly reflect the variations in land characteristics relevant to the research objectives. This approach allows researchers to focus more on areas with the most significant information potential. At each research location, five representative plots were selected as the primary observation units. These maps were

carefully selected to ensure that the data obtained more accurately and comprehensively depict environmental conditions.

Soil samples were collected using a soil auger at a depth of 25 cm at each research location according to the method established by Kabala *et al.* [15] and Zakari *et al.* [16]. A total of eight subsamples were systematically collected from each plot and then combined into a single composite sample to represent the soil conditions in that plot. To improve data transmission and minimize measurement error, three replicate samplings were performed at each observation location to better represent the variation in soil conditions within the research location. The composite samples were then stored in labeled plastic bags and transported to the laboratory for further analysis.

Several laboratory analyses were conducted to identify environmental factors affecting the balance of Beneng taro. These included soil pH measurements using the potentiometric method, organic carbon (C-organic) analysis using the Walkley–Black method. Additionally, soil texture analysis using the pipette/hydrometer method. Furthermore, soil erodibility was calculated based on the Wischmeier and Smith approach within the Universal Soil Loss Equation (USLE) framework, taking into account soil texture parameters, organic matter content, and soil structure as the main erodibility factor components (K).

2.2.3. Social data collection

Social data assessment was conducted by analyzing data related to the level of knowledge, perception, and community participation in the cultivation of Beneng taro (*Xanthosoma undipes* K. Koch) and the potential for developing agrotourism based on local commodities. Respondents were selected using a purposive sampling method by determining criteria, including farmers, MSMEs, and communities who have experience or involvement in agricultural activities and knowledge related to Beneng taro cultivation. The Slovin formula was used to determine the minimum number of respondents so that the error rate was 10%. This sampling approach was carried out during data collection to increase data reliability, ensuring variations in community perceptions and participation could be represented more comprehensively. A questionnaire was then used as a guide for structured interviews as a method of data collection to ensure consistency of answers between respondents.

The research instrument was tested for validity and reliability using the Cronbach's Alpha coefficient. Before the interview was conducted, all respondents were first given a written consent form (informed consent) as a form of approval for participation in accordance with the ethical principles of social research. The total number of respondents involved in this study was 120 people spread across four locations, namely Juhut ($n = 30$), Mandalawangi ($n = 30$), Mount Karang ($n = 30$), and Jiput ($n = 30$). Table 1 shows the number of respondents based on their characteristics.

Table 1. Number of respondents based on characteristics.

Research Location	Gender		Occupation		
	Male	Female	Farmer	Self-Employed/Sme	Civil Servant
Karangtanjung (Juhut)	20	10	17	10	3
Mount Karang	15	15	22	5	3
Mandalawangi	18	12	12	14	4
Jiput	30	0	22	6	2

2.2.4. Tourism suitability assessment using a modified ADO-ODTWA

Tourism suitability was evaluated using the Natural Tourism Object and Attractions Analysis (*Analisis Daerah Operasi Objek dan Daya Tarik Wisata/ADO-ODTWA*) guidelines, modified from Meta jitro *et al.* [17], Nguyen and Lee [18], ICOMOS [19], and Efendi *et al.* [20]. This method is used to assess the potential of tourism attractions at the research sites. The assessment is based on several indicators reflecting the condition of natural resources, the environment, community social conditions, and supporting facilities at the research sites. It

includes 28 indicators grouped into six main criteria, with each criterion consisting of several sub-indicators evaluated using a balanced scoring system.

Each indicator has three alternative scoring conditions (a, b, and c) that reflect different levels of suitability. The evaluation uses a tiered scoring system to systematically categorize these varying levels. Conditions most conducive to agrotourism development are given the highest score, conditions that are sufficiently conducive receive a medium score, and conditions that are less conducive are assigned the lowest score (30, 20, and 10). Actual field conditions obtained through observation and interviews during the research are the basis for the assessment.

Table 2 shows the criteria and assessment elements used to assess the noise level of a location in the development of Beneng taro-based agrotourism. The assessment covers several key aspects, namely attractiveness, accessibility, environmental conditions, services, facilities, infrastructure, and clean water availability. Each assessment element is scored based on a specific distance, then summed to obtain a total score for each criterion. All criterion scores are then accumulated into a total suitability score, which is used to assess the feasibility and potential for agrotourism development. The higher the score, the higher the level of readiness and readiness of the location to be developed as a Beneng taro-based agrotourism area.

Table 2. Assessment table of suitability criteria for beneng taro-based agrotourism development based on tourism suitability assessment criteria using a modified ADO-ODTWA.

Criteria	Assessment Elements	Value Element of Assessment	Score	Total	Total Criteria Score
Attractiveness	Uniqueness of plant forms	Range value 30-10	6	Assessment elements $\times$ score	The total score value of all criteria
	Educational value and agricultural knowledge				
	Local authenticity				
	Connection to local culture and traditions				
	Economic value				
	Aesthetics of planted land				
	Potential of local resources				
	Safety and comfort				
Accessibility	Road conditions		5		
	Road types				
	In addition to travel time from the city center				
Environmental conditions	Soil fertility		5		
	Concerns regarding Beneng taro				
	Community engagement with Beneng taro				
	Predominant occupations				
Services	Friendliness		4		
	Politeness and ethics				
	Openness to newcomers				
Facilities and infrastructure	Availability of Beneng taro farming systems and cultivation techniques		3		
	Harvesting systems and techniques				
	Industrial and processing systems				
	Telecommunications facilities				
	Maintenance and functionality of facilities				
Availability of clean water	Supply volume		6		
	Distance of clean water location to				

Criteria	Assessment Elements	Value Element of Assessment	Score	Total	Total Criteria Score
	object location Water quality in the vicinity. Suitability for consumption Condition of clean water availability around the Beneng taro location				

2.3. Data Analysis

Principal Component Analysis (PCA) was used to identify the ecological variables that most influence the growth of Beneng taro. PCA was used to reduce the dimensionality of the data and reveal the relationship patterns between environmental variables that are mutually detrimental. The obtained environmental data were arranged in the form of an $n \times p$ data matrix, where n is the number of observation units (research locations), and p is the number of environmental variables analyzed, which include soil parameters and environmental factors relevant to the growth of Beneng taro. PCA-assisted analysis was carried out using a correlation matrix in Minitab 19, thereby minimizing scale differences among variables. Principal components with eigenvalues greater than 1 were retained based on the Kaiser Criterion.

The results of the analysis were then interpreted using variable loading values, plot scores, and the contribution of each variable to the principal components, so that dominant environmental factors and patterns of similarities and differences between observation units could be identified. In addition to the ecological analysis, social data were analyzed using a quantitative descriptive approach integrated into the modified ADO-ODTWA assessment system. Social aspects assessed based on the ADO-ODTWA assessment criteria include attractiveness, accessibility, environmental conditions, services, facilities, infrastructure, and availability of clean water (Table 1). Tourism suitability was assessed using the modified ADO-ODTWA scoring system, with each criterion calculated using the Equation 1.

$$S = N \times B \quad (1)$$

Note:

S : Score or value of a criterion,

N : The sum of assessment element values, and

B : The weighting factor

The interval value is used to determine the classification class of the level of tourism potential development. The maximum value is the highest value that can be obtained for each variable element assessment, while the minimum value is the lowest value that can be obtained for each variable element assessment. The number 3 used as the divisor represents the number of classification classes to be formed, where in this study, three levels of suitability were used: Suitable, Quite Suitable, and Not Suitable. The following formula is used to find the interval value and the maximum and minimum scores for each variable for each classification are calculated using the Equation 2.

$$I = \frac{\text{maximum value} - \text{Minimum Value}}{K} \quad (2)$$

Note:

Interval : Range value in classification determination

Maximum value : Highest score value

Minimum value : Lowest score

K : Number of assessment classifications

After obtaining the values, the next step is to compare them with the development classification for each evaluated criterion. This comparison aims to clearly determine the level of suitability of each parameter. The weighted values for each criterion are then averaged to obtain a final score that representing the overall condition. The results of this calculation are then grouped into three categories suitable, fairly suitable, and not suitable. The classification intervals for these results are presented in Table 3.

Table 3. Suitability class intervals for Beneng taro agrotourism.

No.	Number	Suitability level
1	660–879	Suitable
2	480–659	Fairly suitable
3	281–479	Not suitable

Source: Efendi *et al.* [20]

Field validation was carried out to enhance analytical accuracy by verifying the consistency between ADO-ODTWA scoring and observed site conditions. In order to avoid respondent bias and align perceived and actual conditions, social data from interviews was triangulated. In order to identify the priority areas for sustainable agrotourism development, a comprehensive analysis was performed on environmental (PCA) and tourism (modified ADO-ODTWA). The biophysical-social integration provides a holistic basis for natural resource management and landscape planning.

3. Results and Discussion

3.1. Results

Environmental conditions and PCA results provide a quantitative basis for understanding the distribution of Beneng taro across the study sites. This analysis identifies patterns and relationships between environmental variables that influence plant growth. Furthermore, PCA results highlight the dominant factors that differentiate each site. Meanwhile, ADO-ODTWA scores indicate varying levels of tourism for agrotourism development in each area. Overall, these findings offer a geological overview of the ecological environment and tourism potential across the study sites.

3.1.1. Environmental Conditions

Table 4 shows that environmental parameters at Mount Karang, Mandalawangi, Karangtanjung (Juhut), and Jiput exhibit significant variation. These differences reflect the unique physical and ecological characteristics of each location. Variations in environmental factors such as soil, climate, and topography influence the growing conditions of Beneng taro. This diversity of parameters also contributes to differences in land suitability for agrotourism development. Overall, the results indicate that each location has distinct environmental conditions that influence agricultural potential and tourism suitability.

Table 4. Environmental parameters associated with Beneng taro growth area.

Parameter	Study Site			
	Mount Karang	Mandalawangi	Karangtanjung (Juhut)	Jiput
Quantity of Beneng taro	781	354	745	62
Elevation (masl)	798.26	497.71	441.9	143.86
	High	Medium	Medium	Low
pH	5.1	4.8	4.5	6.2
Sand	76.36	75.61	68.33	87.42
Silt	21.82	17.07	30	9.98
Clay	1.82	7.32	1.67	9.98
Air Humidity	84	81	72	52
Rainfall Intensity (mm)	303.0	303.0	303.0	303.0
Temperature	22°C	28°C	27°C	30°C
Erodibility	Moderately high (0.39)	Moderately high (0.36)	High (0.54)	High (0.44)
C-Organic	1.96	1.8	1.28	0.24
B-Organic	3.39	3.11	2.21	0.42

Environmental parameters at the four study sites show varying biophysical conditions that explain the ecological gradient from lowlands to highlands namely, Mount Karang has the highest elevation (798.26 masl) with relatively low temperatures (22°C) and high humidity (84%), while Jiput is located in the lowlands (143.86 masl) with the highest temperatures (30°C) and lowest humidity (52%). The relatively moderate microclimate conditions are found in the mid-altitude zone of Mandalawangi and Karangtanjung (Juhut), this variation is also reflected in the number of Beneng taro plants at each location. Plant population data shows that Mount Karang and Karangtanjung have relatively high populations of 781 and 745 plants, respectively. A moderate plant population was found in Mandalawangi, with 354 plants, while the lowest population was found in Jiput, with 62 plants. This indicates that areas in the mid- to highlands are more favorable for the growth of Beneng taro than in lowland areas.

Environmental conditions with good soil fertility can influence plant productivity. This is based on research results that the dominant soil characteristic in all study locations is sandy texture with varying clay and silt contents. Laboratory analysis results indicate that soil organic matter content varies between locations, where the Mount Karang location showed the highest organic carbon content at 1.96%, while the lowest was in Jiput, at 0.24%. Some locations also had relatively higher soil moisture levels. These differences were reflected in the variation of Beneng taro population at each location, indicating that variations in environmental conditions between locations are primarily influenced by a combination of altitude, microclimate conditions, and soil quality. This combination of factors is the primary determinant in determining the habitat balance for Beneng taro growth in the study area.

3.1.2. Principal Component Analysis (PCA)

The Beneng taro population value explains the quantitative variation in plant distribution among different research locations. These observations formed the foundation for later multivariate analysis. The PCA analysis of environmental conditions for Beneng taro cultivation began with an eigen_analysis of the Correlation Matrix. Table 5 displays the findings of the eigenvalue analysis.

Table 5. Variance of each PCA resulting from the eigen analysis of the Correlation Matrix for the environmental conditions associated with Beneng taro growth area.

	PC1	PC2	PC3	PC4-PC11
Eigenvalue	8.8821	1.4000	0.7785	0.0000
Proportion	0.802	0.127	0.071	0.000
Cumulative	0.802	0.929	1.000	1.000

*Note:

PC1 =: data diversity that has a positive influence is the variables of Beneng taro quantity, altitude, silt, air humidity, organic carbon and organic nitrogen; PC2 = data diversity that has a positive influence is the variables of Beneng taro quantity, silt, temperature, and erodibility; PC3-PC11 = very small data diversity because they have eigenvalues close to zero, thus not providing significant additional information.

A PCA analysis was conducted to identify the dominant environmental factors influencing the distribution of Beneng taro. The results showed that the first two principal components explained most of the variation in the environmental data. The first principal component (PC1) had an eigenvalue of 8.88 and explained 80.20% of the total variation in the data. PC1 was positively correlated with the number of Beneng taro plants, elevation, silt content, air humidity, organic carbon, and organic nitrogen. Different environments with soil fertility and microclimate gradients have been described in this component, which are cooler, humid, and rich in organic matter conditions compared to environments with drier and less fertile conditions.

The second principal component (PC2) has an eigenvalue of 1.40 and explains 12.70% of the data variation. Contributing variables include plant number, soil silt, temperature, and soil erodibility. This component explains the gradient of soil physical properties and environmental stress related to soil susceptibility to erosion. The combination of microclimate factors, soil fertility, and soil physical properties is the most influential factor overall in components PC1 and PC2, with a total value of 92.90%.

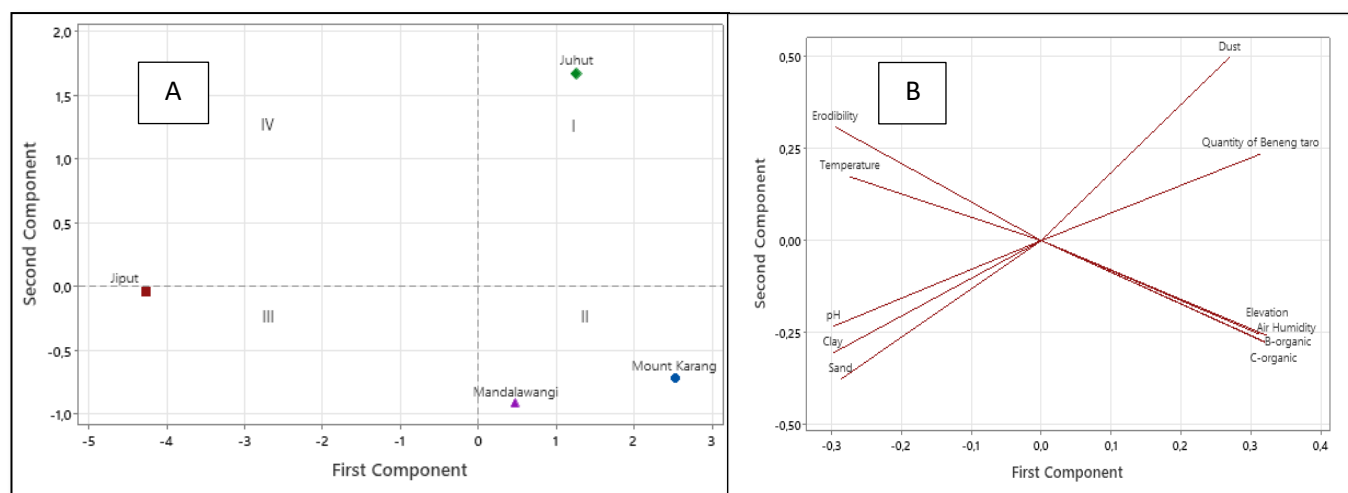


Figure 2. The Principal Component Analysis is presented in score plot (A) and loading plot (B), which is the result of environmental factor analysis at four research locations.

The distribution of differences in environmental characteristics based on the research locations is shown in score plot (Figure 2A) and loading plot (Figure 2B). Quadrant I shows that Karangtanjung (Juhut) has a positive influence on the number of Beneng taro plants and soil silt content. Mount Karang and Mandalawangi are located in quadrant II, reflecting the influence of altitude, air humidity, and soil organic matter content. These conditions describe the characteristics of a humid and relatively fertile highland ecosystem.

Meanwhile, Jiput is located in quadrant III, reflecting the influence of high temperatures and a predominance of sandy soil texture. These characteristics describe an environment with drier conditions. Consequently, this makes the area less suitable for Beneng taro growth. The PCA analysis indicates that differences in location explain the elevation gradient and soil fertility, which are the main factors influencing the distribution of Beneng taro plants.

3.1.3. Tourism Suitability Scores (modified ADO-ODTWA)

Using six criteria is crucial in identifying, analyzing, and evaluating strategic and appropriate locations for the development of Beneng taro agrotourism in four research locations. The tourism suitability assessment was based on the criteria of attractiveness, accessibility, environmental conditions, management and services, facilities and infrastructure, and clean water availability. Table 6 shows the assessment scores for the suitability of Beneng taro agrotourism in various locations. The assessment scores for each criterion component were obtained based on the maximum, minimum, and interval values.

Table 6. Development of suitability assessment scores utilizing six assessment criteria.

No.	Location	Criteria Aspect					
		Attractiveness	Accessibility	Surrounding Conditions	Services	Facilities and Infrastructure	Clean Water
1	Mount Karang	960 (NyS)	300 (NyS)	450 (NyS)	360 (S)	180 (NS)	840 (S)
2	Juhut	1,380 (S)	400 (S)	600 (S)	360 (S)	420 (S)	840 (S)
3	Mandalawangi	1,020 (NyS)	300 (NyS)	450 (NyS)	360 (S)	360 (S)	840 (S)
4	Jiput	660 (NS)	300 (NyS)	450 (NyS)	360 (S)	180 (NS)	840 (S)

NS = Not Suitable; NyS = Fairly Suitable; S = Suitable

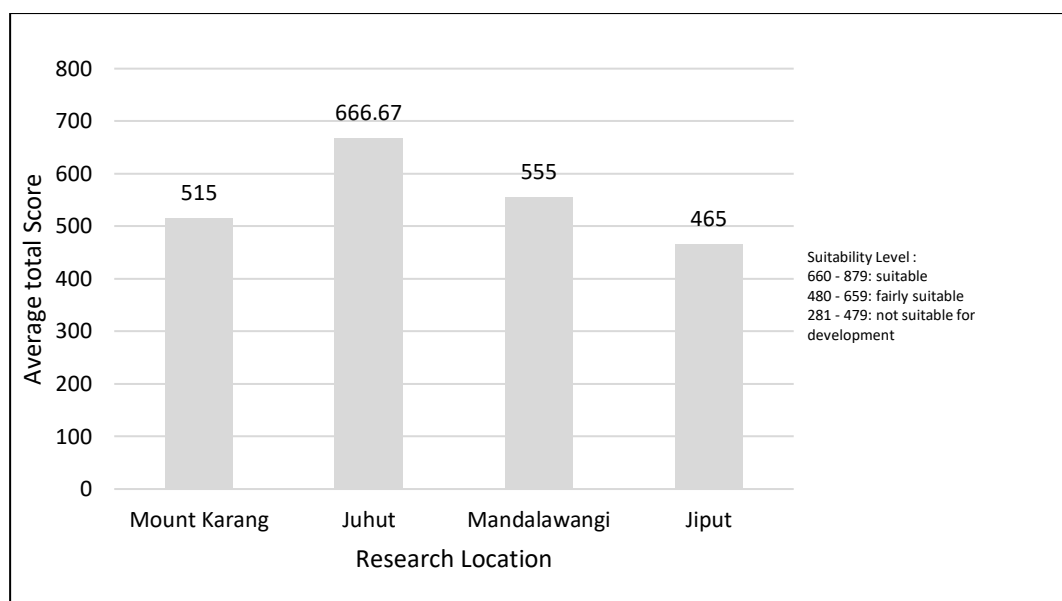


Figure 3. Comparison of the average land suitability scores for the development of Beneng taro agrotourism in four research locations, namely Mount Karang, Karangtanjung (Juhut), Mandalawangi, and Jiput.

Based on Table 6 and Figure 3, the analysis results show that Karangtanjung (Juhut) has the highest suitability score of 666.67. The assessment score obtained by the Juhut area is the only location suitable for the development of Beneng taro agrotourism. This condition is due to the assessment results of the highest tourist attraction criteria, supported by accessibility criteria, and relatively adequate facilities and infrastructure compared to other locations. The assessment results obtained by the area Mandalawangi and Mount Karang are quite suitable, with scores of 555 and 515, respectively. This area has environmental conditions that support the growth of Beneng taro.

However, it still requires interventions related to accessibility and facilities to support the development of Beneng taro agrotourism. Meanwhile, the assessment results for the Jiput area are not suitable, with a score of 465. This is because the environmental factors required for the growth of Beneng taro are not suitable, so interventions are needed to address environmental issues as a primary requirement for optimal growth. In addition, the criteria for tourist attractions are low, and facilities and infrastructure are still limited.

These conditions explain that the influential criteria in determining the suitability of agrotourism development are attractiveness and availability of facilities. Meanwhile, the criteria for environmental factors are the basic potential for taro Beneng to be developed as a major tourist attraction. Figure 3 shows the variations in total suitability scores in various locations. Juhut achieved the highest total suitability score of 666.67, which classifies it as 'suitable'. Mandalawangi received a score of 555, and Mount Karang received a score of 515, both classified as 'fairly suitable'. Jiput received the lowest score of 465, which classifies it as 'not suitable'.

3.2. Discussion

3.2.1. Ecological Gradients and Beneng Taro Abundance

The distribution of Beneng taro across the study sites demonstrates an environmental gradient related to the agro-ecological conditions of the landscape. Environmental conditions are more stable and suitable for Beneng taro growth when temperatures are more moderate, relative humidity is high, and soil organic matter content is high. These results align with the principles of tropical agroecological systems, where the interaction between microclimate conditions and soil quality plays a crucial role in determining local crop productivity. Tropical tuber crops are known to tolerate relatively humid environments with sufficient soil organic matter content because these conditions support soil microbiological activity and increase nutrient availability for plants [21,22]. This context explains the abundance of Beneng taro at

the site, highlighting that stable microclimatic conditions and fertile soils are key environmental factors determining local crop cultivation systems.

Areas with less stable environmental conditions exhibit a more limited ecological capacity to support plant growth. Increased temperatures and low soil organic matter content can reduce the soil's ability to retain moisture and nutrients necessary for plant growth [13,23]. The predominance of sandy soil textures found in some locations can increase susceptibility to erosion and reduce soil structural stability. These conditions have the potential to accelerate land degradation if not balanced with appropriate soil management practices [24,25].

From a management perspective, these findings highlight the importance of aligning native plant development with existing ecological conditions. High and mid-elevation zones are prioritized to support more stable cultivation systems, reduce the risk of land degradation, and increase landscape resilience. However, expansion into environmentally less ideal lowland areas may require costly soil rehabilitation. By identifying ecological thresholds related to elevation, moisture, temperature, and soil organic matter, evidence-based ecological zoning and conservation-oriented agrotourism development can be developed [13,14].

3.2.2. Dominant Environmental Factors from PCA

The PCA analysis conducted in this study provides a deeper understanding of the environmental factors that play a role in determining the habitat conditions of Beneng taro. The results of the analysis indicate that most environmental variation can be explained by two main ecological components that represent distinct environmental gradients. The first gradient relates to microclimate characteristics and soil fertility levels, as reflected in the relationship between altitude, air humidity, and soil organic matter content. This gradient illustrates the difference between ecosystems with cooler and more humid conditions and those that are relatively drier and less fertile. These biophysical factors are the main determinants of successful growth of Beneng taro, as demonstrated by the strong relationship between PC1 and plant abundance, and are in line with agroecological principles that influence tuber crop productivity [26,27].

The second gradient (PC2) relates to soil physical properties, specifically soil texture, temperature, and erodibility. Stable soil structure is crucial for supporting water retention and root system development. Conversely, high levels of erodibility can increase the risk of soil degradation, ultimately impacting the sustainability of agricultural systems [24,25]. Therefore, conservation-oriented soil management is a crucial factor in maintaining land productivity in tropical agricultural landscapes [26].

These findings indicate that the ecological suitability of Beneng taro is primarily influenced by relatively stable environmental factors. Specifically, these parameters include microclimate conditions and underlying soil fertility. This suggests that the development of local crop cultivation must carefully consider the overall agroecological characteristics of the landscape. The PCA analysis in this study can also serve as an analytical tool to support more sustainable land-use planning by identifying the most ecologically suitable zones for local crop development [27,28].

3.2.3. Suitability of Developing Beneng Taro Agrotourism

In addition to ecological factors, the development of agrotourism is strongly influenced by socio-economic conditions and infrastructure readiness. The modified ADO-ODTWA assessment identified Karangtanjung (Juhut) as the most suitable location for Beneng taro-based agrotourism development due to its favorable environmental conditions, attractive tourism potential, accessibility, and adequate facilities and services. Field observations further revealed that local communities play a central role in supporting agrotourism through strong knowledge of Beneng taro cultivation, high levels of concern for the commodity, active social interactions, and the predominance of farming-based livelihoods. These characteristics strengthen Juhut's position as a region with both biophysical and social advantages for sustainable agrotourism development. This finding is consistent with previous studies demonstrating that successful agro-biodiversity-based tourism depends on the integration

of natural resource potential, community participation, and adequate infrastructure and institutional support [29–31].

This finding is also echoed by Polaj *et al.* [32] and Vythoulka *et al.* [33], who noted that many agro-tourism systems exist in tropical regions, where local agricultural products often serve as a destination identity, attracting tourists and strengthening the local economy. The opposite situation also exists in several locations, indicating that there are inhibiting factors, including poor accessibility, infrastructure, and services, despite their high ecological potential. This demonstrates that the success of agrotourism development is determined not only by environmental harmony but also by the ability of local communities and institutions to manage resources as economically valuable tourism products. Similar findings are also found in various studies on rural agrotourism, which show that limited infrastructure and institutional capacity are often constraints in the development of agriculture-based tourism [34,35].

3.2.4. Implications for Regional Planning and Conservation Policy

The implications of this research provide important contributions to rural development planning. The results demonstrate that an ecological gradient-based approach can be used as a basis for zoning agrotourism development. Areas with better microclimate conditions and soil fertility can be prioritized as centers for developing agrotourism based on local crops. Furthermore, an effective regional development strategy for increasing the economic value of agricultural biodiversity can be achieved through the integration of local agricultural systems and the tourism sector. This approach can help create alternative income sources for rural communities while reducing pressure on natural resources by promoting land-use practices that prevent degradation and maintain soil health through sustainable Beneng taro cultivation.

This research also provides insights from a conservation policy perspective, as the development of agrotourism based on local crops can serve as a mechanism for maintaining the sustainability of agrobiodiversity. By embodying local crops as part of the destination's identity, local communities have an economic incentive to maintain traditional cultivation practices and preserve local plant genetic resources [6,36]. This approach also aligns with “the emphasis on integrating biodiversity conservation, local economic development, and sustainable natural resource management within a sustainable environmental management strategy [14,37]. The role of agrotourism is strengthened by these outcomes, not only as a tourism activity, but also as a strategic policy instrument for sustainable landscape governance. More broadly, the integration of native crop cultivation, community-based agrotourism, and ecological zoning supports the multiple Sustainable Development Goals (SDG), particularly SDG 8 (decent work and economic growth), SDG 12 (responsible consumption and production), and SDG 15 (life on land).

4. Conclusions

The research results show that microclimate conditions and soil fertility were identified as key factors determining the habitat suitability of Beneng taro in Pandeglang Regency. Among the study sites, Karangtanjung (Juhut) showed the highest potential for Beneng taro-based agrotourism development. The integration of environmental suitability and tourism feasibility assessments provides a practical basis for agrotourism planning and supports sustainable rural development through the conservation and utilization of local agricultural biodiversity. Thus, it can directly contribute to the achievement of sustainable development goals in rural areas.

Author Contributions

NH: Conceptualization, Methodology, Software, Investigation, Writing – Original Draft; **AS:** Writing – Review & Editing, Supervision; **EKSHM:** Writing – Review & Editing; and **S:** Writing – Review & Editing.

Conflicts of interest

There are no conflicts to declare.

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During the preparation of this work, the author(s) used Scispace.com and ScienceOS to search for suitable current references. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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