

ASSESSING POTENTIAL AREA FOR AGROFORESTRY-BASED ECOTOURISM DEVELOPMENT TOWARD SUSTAINABLE UPSTREAM WATERSHED MANAGEMENT

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Abstract : Agroforestry-based ecotourism (ABE) is a land-use management approach suitable for upstream watershed conservation. Assessing potential agroforestry land that supports ecotourism development is essential to sustainable watershed management planning. This study aims to determine the land potential for ABE development in the upstream watershed area. The assessment aspect includes the land suitability index, agroecological characteristics, and environmental carrying capacity. The data consist of primary field observation data and relevant secondary data from reliable sources. The analysis consists of: a weighted linear combination for land suitability assessment; a random forest analysis to identify the key variables of ABE suitability; a k-means cluster for agroecological classification; and the Douglas analysis for environmental carrying capacity assessment. The paired t-test evaluates current management by comparing actual tourist visits to the environmental carrying capacity. The analysis results showed that 22 agroforestry areas in the research location are suitable for ecotourism development. The key variables influencing the land suitability class were the availability of an agroforestry ecosystem to act as a watershed stabilizer, land cover, attractiveness, provision of wildlife habitat, and elevation. The k-means cluster shows there are four agroecological zones in the research location. Rainfall and farmers' socioeconomic conditions determine land-use patterns in each zone. Tourists' preferences for agroforestry landscapes for ecotourism include the completeness of agroforestry components, a balance of spatial patterns and composition, and a balance of cultivated plant species to support ecotourism activities. The number of tourist visits that does not exceed the environmental carrying capacity indicates that the research location remains well-maintained and offers opportunities for improved management. The research location has potential for the development of agroforestry-based ecotourism. Developing community capacity and implementing appropriate silvicultural technologies are essential to achieving sustainable management.

Keywords: agroecological zone, agroforestry-based ecotourism, carrying capacity, sustainable watershed management, tourism village

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INTRODUCTION

Agroforestry is a form of sustainable agriculture that maintains soil cover with multi-stratum crops, combining agriculture and forestry (Muschler, 2016). Crop plants and litter cover the lower stratum, while the middle and upper strata are covered by tree canopies (Dias et al., 2023). This cultivation technique provides benefits to the upstream watershed, particularly in maintaining soil fertility and water quality by reducing runoff and erosion, and increasing water infiltration into the soil (Mohan Singh Tomar et al., 2021). From an economic perspective, the variety of agroforestry crops planted in upstream watersheds can provide local communities with numerous alternative sources of income and reduce deforestation (Prabawani et al., 2024). Globally, agroforestry can help reduce CO₂ emissions and mitigate the impacts of climate change on the watershed hydrological cycle (Kumar et al., 2019). Agroforestry can also create aesthetic value that attracts ecotourists (Schuler et al., 2022). Tourists can visit agroforestry areas to enjoy the natural scenery, fresh air, and local culture (Damnet et al., 2024). Agroforestry can meet several tourists needs, including food, crafts, ornamental plants, and educational purposes (Pauletto et al., 2023). On the one hand, ecotourism is a form of sustainable tourism that emphasizes the preservation of nature and local culture, economic development, environmental education and awareness, and community economic development (Kiper, 2013). Developing ecotourism through agroforestry can help preserve upstream watershed areas from damage (Lodhiyal, 2011). The upstream watershed area naturally offers attractive landscapes that support the development of agroforestry-based ecotourism (ABE), including the planting of shade-tolerant crops and multipurpose trees that produce non-native food crops (NTFPs) popular with tourists (Locatelli et al., 2014). Therefore, ABE development in the upstream watershed is crucial to achieving sustainable development.

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The Pengga sub-watershed, located in Central Lombok District, West Nusa Tenggara Province, Indonesia, plays a crucial role in supplying water to the Pengga Reservoir. This reservoir is the largest on Lombok Island, serving irrigation, hydroelectric power generation, and raw water supply in the Mandalika Special Economic Zone (Evayanti & Sugiharta, 2021). As part of the Dodokan Moyosari watershed, this sub-watershed has experienced a decline in vegetated land cover, which can disrupt the hydrological cycle, particularly reducing flow discharge during the dry season and increasing the flood risk during the rainy season (Ilmi, 2019). The development of agroforestry-based ecotourism in the upstream of the Pengga Sub-watershed is an approach implemented to rehabilitate damaged upstream areas of the watershed and maintain intact vegetated regions. The ABE development aligns with the Central Lombok District's vision of integrating the agricultural, maritime, and tourism sectors to achieve sustainable development goals.

Recent research shows that agroforestry-based ecotourism plays a crucial role in watershed (DAS) management, providing simultaneous ecological and economic benefits. Developing agroforestry-based ecotourism in the upper reaches of a watershed can contribute to soil and water conservation, increased biodiversity, and carbon sequestration (Astarini et al., 2024). The EBA approach provides income diversification, helping farmers build economic resilience to climate change, particularly amid uncertain rainfall patterns. Successful agroforestry-based ecotourism management can also raise public awareness of the importance of forest and environmental conservation (Lugina et al., 2021). Several important aspects to consider in developing agroforestry-based ecotourism include holistic planning, strengthening institutional capacity, innovation in tourism packages, infrastructure development, active community participation, and regulation (Peng et al., 2025; Judijanto, 2025). An important element in the preparation of agroforestry-based ecotourism planning includes: land suitability, attractions, socio-economic characteristics of local communities, tourist interests, and environmental carrying capacity (Park et al., 2025; Lawasi et al., 2025). Agroforestry-based ecotourism development using an agroecological approach maintains ecological processes and fosters collaborative community development, potentially increasing tourist visits and local community income (Djuwendah et al., 2023). In the development of agroforestry, the knowledge of agroecological characteristics is crucial for sustainable agriculture, including recreational agroforestry (Wezel et al., 2025).

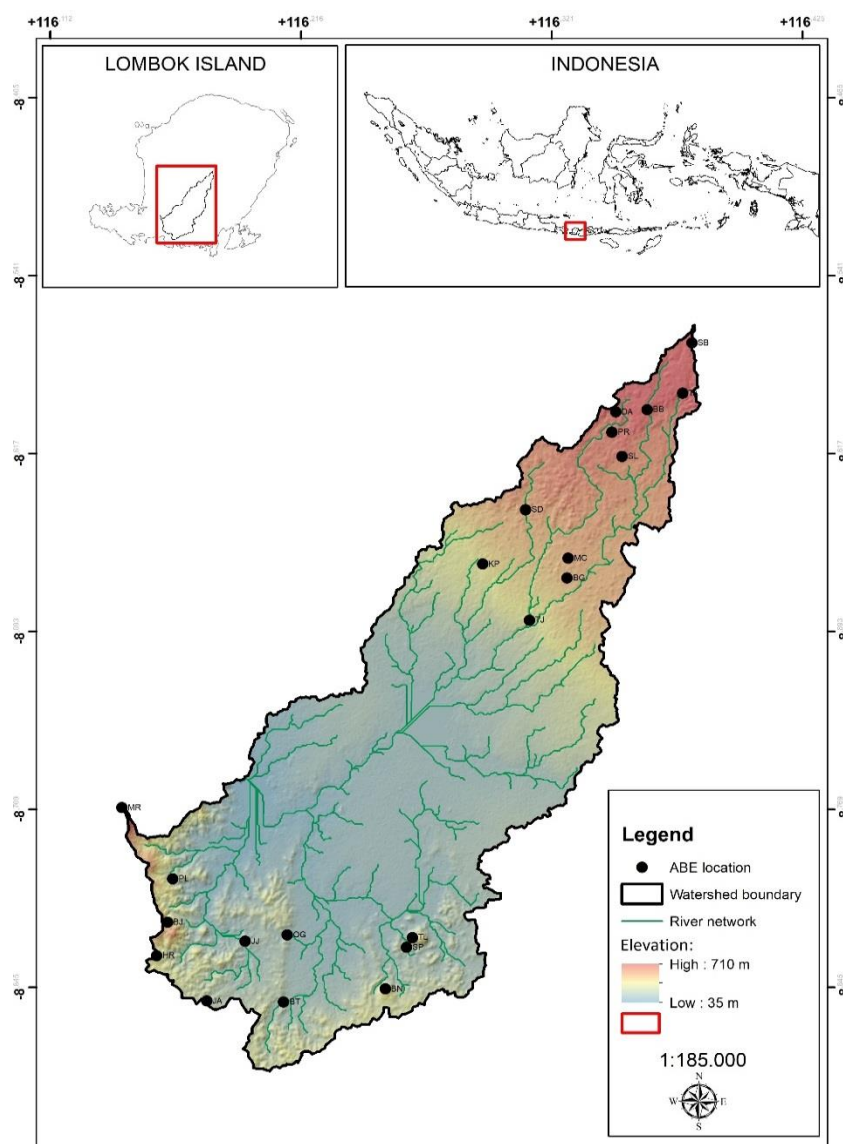


Figure 1. Research location map

The tourist attractions in agroforestry land include the sustainable farming method applied by farmers, products, landscapes, and supporting infrastructure (Ferreira & Sanchez-Martín, 2022). Tourists prefer visits to the agroforestry land that resembles natural landscape conditions (Iacopino et al., 2022). The recent literature review above shows that research on assessing potential land for agroforestry-based ecotourism development to produce information as inputs for holistic, sustainable watershed management planning faces several obstacles, including limited data, the complexity of agroforestry systems, uncertainty in socio-economic factors, researcher subjectivity, and a focus on a single aspect.

This study assesses potential areas for agroforestry-based ecotourism development to support sustainable upstream watershed management. Aims to identify suitable land for agroforestry-based ecotourism development in the upstream watershed. The method used in this study more comprehensively refines previous research by incorporating several key aspects required for the preparation of more holistic agroforestry-based ecotourism management plans. These aspects include land suitability, the socio-economic characteristics of local communities, tourist interest in agroforestry landscapes, and environmental carrying capacity. The expected research results will provide valuable information for preparing agroforestry-based ecotourism management plans as part of sustainable watershed management for implementation at the research location.

MATERIAL AND METHOD

Location

The research location was in the upstream of the Pengga sub-watershed, located in Central Lombok District, West Nusa Tenggara Province, Indonesia (Figure 1). The data assessment in the 22 agroforestry locations where has nature tourism activities, include: Agroforestry Sumbek (SB), Dao (DA), Tandung Andung (TA), Sade (SD), Kepok (KP), Muncan (MC), Batu Bokah (BT), Sepit (SP), Tele (TL), Orok Gendang (OG), Jangkih Jawe (JJ), Mareje (MR), Pelet (PL), Harapan (HR), Bage (BG), Tenjong (TJ), Bisok Bokah (BS), Bongak (BN), Batu Jangkih (BJ), Peresak (PR), Selojan (SL), and Jobar (JA). The research started from September 2022 to February 2023.

Data Collection Procedures

The types of data used in this study include tourist attractions, biodiversity, soil texture, visibility, topography, river networks, rainfall, accessibility, agroforestry ecosystem services as ecotourism providers, social characteristics of agroforestry farmers, tourist preferences for agroforestry landscapes, and land suitability priorities (Table 1).

Table 1. Data type and collection method

No	Data	Data collection method
1	Tourist attractions, biodiversity, and canopy coverage	Field observation
2	Soil texture	Soil map scale survey from the Ministry of Agriculture, accompanied by soil sampling and laboratory test
3	Visibility, elevation, slope, river network	DEM SRTM
4	Rainfall	Rainfall map from BMKG of West Nusa Tenggara
5	Proximity to settlement	Landsat-8 imagery interpretation
6	Proximity to road	Indonesia's Earth's Surface
7	Agroforestry ecosystem services as ecotourism providers	Structured interviews with tourists
8	Socioeconomic of farmers	Structured interviews with farmers
9	Land suitability parameters priority for ABE development	Structured interviews with experts and practitioners
10	Tourist preferences for agroforestry landscapes	Structured interviews with tourists

Biophysical parameters observation in the Plot 20 x 20 m. The plot consists of a 20 x 20 m subplot to measure trees with a diameter above 20 cm. A 10 x 10 m subplot to observe poles, i.e. trees with a dbh of 10-20 m; a 5 x 5 m subplot to observe saplings, i.e. trees with a dbh of 5-10 cm; and a 2 x 2 m subplot to observe undergrowth, crops, and saplings with a height of less than 1.3 m (Pitopang et al., 2021). Observations on vegetation included plant type, tree density, dbh, tree height, and tree canopy area. The observations of tourist attractions using the guidelines for the analysis of operational area for natural tourist objects and attractions (ADO-ODTWA) from the Indonesian Ministry of Forestry at each plot's centre (Rahayuningsih et al., 2016). At each ABE attraction location, plots were systematically placed at the four cardinal points, with a radius of 200 m and a distance of 30 m between plots within each transect (McIntosh et al., 2019), so that within each ABE attraction destination, there would be 12 observation plots. At the same time, structured interviews with 264 landowners of plot location assessed socioeconomic aspects. On the ecotourism side, observations of agroforestry ecosystem services as an ecotourism provider, based on interviews with 384 tourists visiting the ABE destination. The cross-sectional sampling method shown in equations 1 and 2 calculated the minimum sample (Al-Azzam et al., 2020).

$$S = N * \frac{X}{(X-1)+N} \quad (1)$$

$$X = Z^2 * \frac{p*(1-p)}{\epsilon^2} \quad (2)$$

Where S = minimum sample size, Z is the critical value for a large sample of normal distribution at a 95% confidence level (Z = 1.96), p = proportion of target population (p = 0.5), ϵ = allowable error ($\epsilon = 0.05$), and N = population size or average number of tourist visits per month. The key informants selected to assess the priority of criteria and indicators of land suitability for ABE development, using judgment sampling, comprised three experts and two practitioners. This method enabled the researcher to select members of the population based on their expertise and experience (Thukral & Singh, 2023).

Data Analysis

Data analysis included a multi-criteria analysis (MCA) to develop criteria and indicators (C&I) of land suitability for agroforestry-based ecotourism (Šiljeg et al., 2019). The MCA used a top-down approach, in which researchers identified the C&I based on references before the start of the research (Table 2). Experts and practitioners with experience in agro-based tourism management at the Central Lombok district and West Nusa Tenggara province levels reviewed the C&I. The weight of each C&I was determined using the analytical hierarchy process (AHP) (Mansour et al., 2020). Each C&I was assigned a score on an ordinal scale of 1-4, with 4 for parameters included in the S1 suitability category, 3 for S2, 2 for S3, and 1 for N. The observed C&I values were analyzed using the weighted linear combination (WLC) method as in equation 3 (Yin et al., 2020).

$$F = \sum_{i=1}^n w_i * x_i \tag{3}$$

Where F = land suitability value, W_i = weighted value of each C&I, and X_i = C&I. The land suitability value is then standardized to a land suitability index (FI) value with a ratio scale of 0-1 (Toba et al., 2023). There are four land suitability classes: S1 = Suitable ($FI \geq 0.75$), S2 = moderate ($0.5 \leq FI < 0.75$), S3 = marginally suitable ($0.25 \leq FI < 0.5$), and N = unsuitable ($FI < 0.25$). A random forest analysis determines the relative importance of variables to the land suitability index (Aldrich, 2020). K-means cluster analysis classifies the ABE agroecological zone based on the similarity of agroecological variables, thereby supporting ABE development (Iglesias et al., 2000). The importance value index (IVI) assesses the species composition of vegetation in ABE locations (Thammanu et al., 2021). As a land suitability index, standard values of 0-1 equalize the parameter values due to differences in the measurement units of each variable.

Table 2. Criteria and indicators of agroforestry land suitability for agroforestry-based ecotourism development

Criteria	Indicator	Suitability Class				Sources	
		Suitable (S1)	Moderate (S2)	Marginal Suitable (S3)	Not Suitable (N)		
1	Landscape attractiveness	1.1. Natural Attractiveness	High (NAI> 85%)	Moderate (NAI 80-85%)	Low (NAI 70-80%)	Very low (NAI < 70%)	Quantile analysis (Bihon et al., 2025)
		1.2. Visibility	Visible (7-15)	Moderate (3-7)	Low (0-3)	Not visible (0)	Bunruamkaew & Murayama (2012)
2	Landscape naturalness	2.1. Biodiversity	High ($H' > 2.7$)	Medium ($2.5 < H' < 2.7$)	Low ($2 < H' < 2.5$)	Very low ($H' < 2$)	Quantile analysis
		2.2. Landcover	>84%	82-84%	80-82%	< 80%	Bali et al., (2015)
3	Physical limiting factor	3.1. Elevation	>300 m.asl	200-300 m.asl	100-200 masl	< 100 msl	Quantile analysis (Bihon et al., 2025)
		3.2. Slope	0-5%	5-25%	25-35%	.35%	Bunruamkaew & Murayama (2012)
		3.3. Soil texture	Clay	Clay-loam	Sandy-clay-loam	Sandy	Bali et al., (2015)
		3.4. Rainfall	High (≥ 200 mm/m)	Medium (180-200 mm/m)	low (150-180 mm/m)	very low (< 150 mm/m)	Quantile analysis (Bihon et al., 2025)
4	Accessibility	4.1. Proximity to settlement	<500 m	500-1000 m	1000-5000 m	> 5000 m	Bali et al. (2015).
		4.2. Proximity to road	< 500 m	500-750 m	750-1000 m	> 1000 m	
		4.3. Proximity to the river	< 500 m	500-750 m	750-1000 m	> 1000 m	
5	Environmental services of agroforestry for ecotourism development	5.1. Food producer	High (4)	Moderate (3)	Low (2)	Very Low (1)	The criteria and indicators derived from Van Noordwijk (2021) and Azis et al. (2015). The suitability value adopted from Mgohele et al. (2025)
		5.2. Natural ornamental provider					
		5.3. Craft plant sources					
		5.4. Watershed stabilizer					
		5.5. Wildlife habitat					
		5.6. Educational function					

The Douglas method determines environmental carrying capacity (Zacarias et al., 2011) (equations 4, 5, 6, and 7).

$$PCC = \frac{A}{B} * Rf \tag{4}$$

$$Rf = \frac{L}{T} \tag{5}$$

$$RCC = PCC * Cfr * Cfsl * Cfs0 * Cfb \tag{6}$$

$$ECC = RCC * Cfm \tag{7}$$

$$Cfx = 1 - \left(\frac{M0}{Mt} \right) \tag{8}$$

Where PCC=physical carrying capacity, A=potential area for ecotourism development. According to Barančoková & Barančok (2020), the potential area for tourism development is around a 200-1200 m radius from the center of attractiveness. In this study, the potential area within a 200 m radius of the center of attractiveness is 125,664 m², due to the ABE development in the research location, which is still at an early development stage. B = minimum area required for tourists to achieve satisfaction in tourism activities. B value for picnic activity =65 m² refers to Insani et al. (2020). Rf=tourist rotation factor, L = length of tourist attraction service, T = length of tourist activity, RCC=real carrying capacity. Cfc=rain correction factor, Cfsl=slope correction factor, Cfs0=soil correction factor, Cfb=biodiversity correction factor, ECC=effective/environmental carrying capacity, Cfm=management correction factor, Cfx=correction factor from limiting variable x, Mx=observed value of limiting

factor x , and Mt =maximum value of limiting factor x . The t-test analysis evaluates the environmental carrying capacity at each ABE location, comparing the ECC value with the actual number of tourist visits (Han et al., 2021).

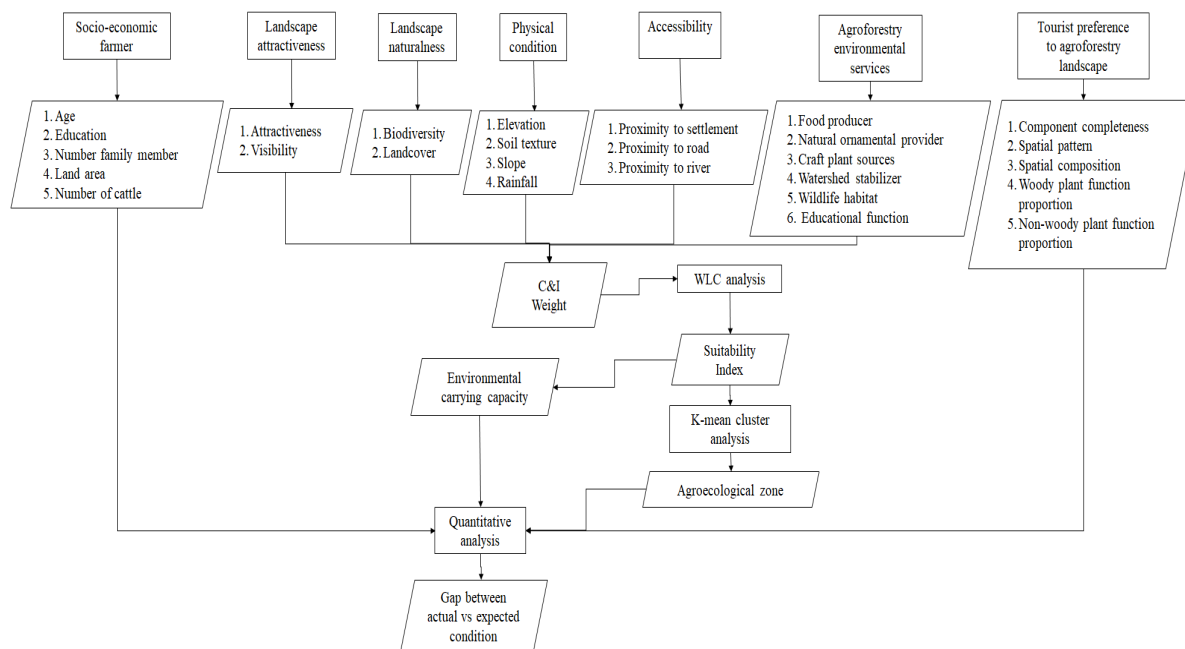


Figure 2. Data analysis flow

RESULT

Land Suitability Index

The analysis result shows that of the 22 ABE locations for agroforestry-based ecotourism development in the upstream of the Pengga Sub-watershed, 10 locations (45%) have a suitability class of S1 and 12 locations (55%) have a suitability class of S2 (Table 1). Locations with a land suitability index value of S1 include: SB, DA, TA, TL, MR, TJ, TS, BN, PR, and SL.

Table 3. Summary of land suitability classes for ABE development in the upstream Pengga Watershed

Criteria	w	Indicator	w	C&I Score in Each Location																						
				SB	DA	TA	SD	KP	MC	BT	SP	TL	OG	JJ	HR	PL	MR	BG	TJ	BS	BN	BJ	PR	SL	JA	
Landscape attractiveness	0.222	Natural attractiveness	0.167	3	4	4	1	1	3	2	4	4	3	3	4	3	4	1	4	3	4	3	3	4		
		Visibility	0.167	3	3	3	3	3	3	3	3	3	4	3	3	3	3	4	3	3	4	3	3	3	3	
Landscape naturalness	0.222	Biodiversity	0.111	3	3	3	3	3	2	3	3	4	3	3	3	4	2	3	4	3	4	4	3	3		
		Landcover	0.111	2	2	2	1	1	1	2	1	3	2	1	1	2	4	1	2	3	3	3	3	3	1	
Physical limiting factors	0.334	Elevation	0.056	4	4	4	4	3	4	2	2	3	2	2	3	3	4	3	3	4	3	3	4	4	2	
		Slope	0.056	3	3	3	3	3	3	3	3	2	3	3	3	3	1	3	3	3	2	2	3	3	3	
		Soil texture	0.056	4	4	4	4	4	4	4	4	4	2	2	3	3	3	4	3	3	2	2	4	4	3	
		Rainfall	0.056	4	4	4	4	4	4	2	1	1	2	2	2	2	2	4	4	4	1	2	4	4	2	
Accessibility	0.111	Proximity to settlement	0.037	4	4	4	4	4	4	4	4	4	4	4	3	1	1	1	4	4	3	1	4	4	1	
		Proximity to road	0.037	4	3	4	4	4	4	4	4	4	3	4	4	4	4	1	4	4	4	4	1	4	4	4
		Proximity to the river	0.037	1	4	4	4	3	1	4	4	4	3	4	4	1	3	1	3	4	4	3	2	3	3	1
Agroforestry environmental services provision for ecotourism	0.111	Food producer	0.019	4	3	3	3	3	3	2	2	3	2	3	3	3	1	3	3	4	2	3	4	4	3	
		Natural ornamental provider	0.019	4	1	1	3	3	2	2	2	1	2	3	3	2	3	1	2	3	3	1	3	3	3	
		Craft plant sources	0.019	3	3	3	3	2	3	3	3	2	3	3	3	2	3	3	3	2	2	2	2	3	3	
		Watershed stabilizer	0.019	3	3	3	1	3	1	2	2	3	2	2	2	2	4	1	3	4	3	4	4	3	2	
		Wildlife habitat	0.019	2	2	2	1	2	1	2	2	3	2	2	2	1	4	1	2	3	3	3	3	2	1	
		Educational function	0.019	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	4	4	3	4	3	
Land suitability index of ABE				0.77	0.81	0.82	0.66	0.65	0.68	0.68	0.72	0.83	0.69	0.66	0.68	0.68	0.81	0.60	0.79	0.83	0.78	0.72	0.84	0.81	0.67	
Land suitability class				S1	S1	S1	S2	S2	S2	S2	S2	S1	S2	S2	S2	S1	S2	S1	S1	S1	S2	S1	S1	S2		

These 10 locations have a combination of land suitability parameters for agroforestry-based ecotourism development that is higher than the other 12 locations. Based on the results of the analysis using random forest, it shows that the variables that provide a level of influence on the variation of the land suitability index for ABE development in the upstream area of the watershed include the land's ability to act as a stabilizer of the upstream region of the watershed, land cover, attractiveness, provision of wildlife habitat; and elevation (Figure 3). In addition to the predictor variable's weight, its influence on land suitability is also affected by variations in the predictor variable's value across the land suitability index. In this case, areas with a high land suitability index are potentially effective watershed stabilizers, with higher land cover, attractiveness, provision of wildlife habitat, and elevation values.

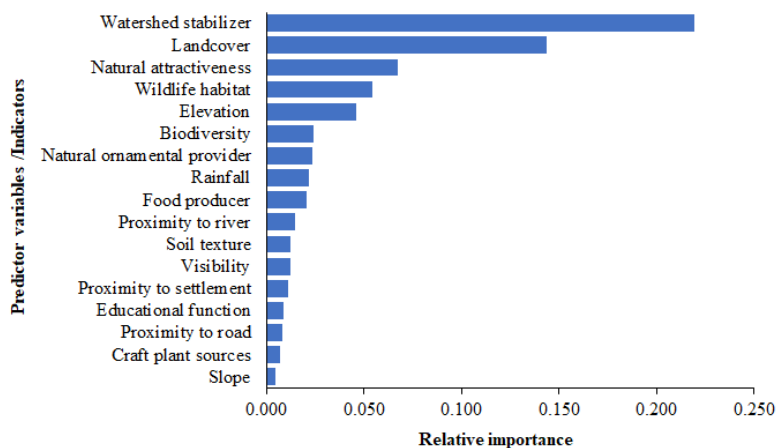


Figure 3. Relative importance of predictor variables of land suitability for ABE development

Agroecological characteristics

K-means cluster analysis classifies the ABE attraction object in the upstream area of the Pengga Sub-watershed into four clusters with distinct agroecological characteristics. Each cluster is then referred to as an agroecological zone for agroforestry-based ecotourism development, consisting of Agroecological Zones 1, 2, 3, and 4 (Figure 4).

Agroecological Zone 1 is located in the northern part of the watershed, closer to the Rinjani Mountain ecosystem. The land is majority in the suitable class category (S1). The agroforestry system developed by farmers is outside the forest area. Adequate physical conditions support the agroforestry system. This area is at an elevation of more than 300 m above sea level, with rainfall above 200 mm/month, and has a sandy loam-clay soil texture.

This cluster has adequate accessibility to support ecotourism activities. Farmers cultivate woody perennials and a variety of crops, but land cover is moderate (Figure 5 and Table 4).

Tourists feel that the diverse plant species are sufficient to meet food and craft needs; however, their capacity as ornamental plants and wildlife habitat is suboptimal. Easy accessibility and high tourist appeal make the area a valuable educational resource for various stakeholders, including those seeking soil and water conservation.

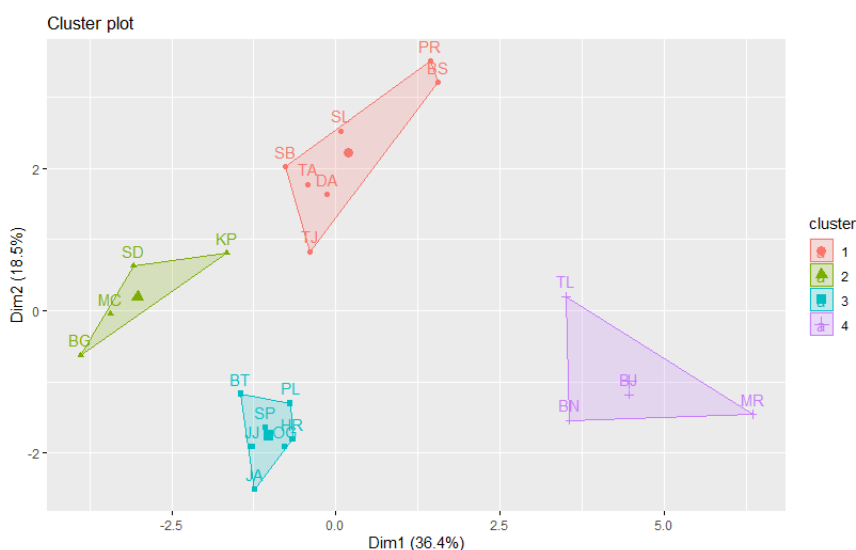


Figure 4. Graph of agroecological classification based on k-means cluster analysis

Agroecological Zone 2 also includes tourist attractions in the northern part of the watershed, but at lower elevations than Zone 1. Characteristics that distinguish it from Zone 1 include its lower attractiveness, biodiversity, and land cover. The agroforestry system's capacity as a watershed upstream stabilizer, wildlife habitat, and educational media is also in the

low-moderate category. The natural landscape in Zone 2 decreases due to its proximity to urban areas, leading to the conversion of natural ornamentation into buildings and artificial monoculture agricultural systems (Figure 5 and Table 4).

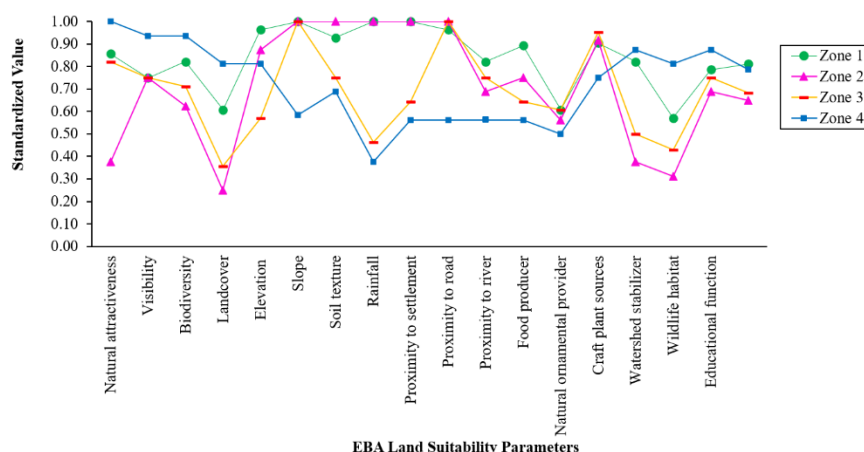


Figure 5. Standardized values of land suitability indicators in each agroecological zone

Zone-3 characteristics: In the southern part of the watershed, land use planning focused on community-managed forests, and the land was lower in elevation than in Zone 1. This area has a dry climate with rainfall below 200 mm/month, high community pressure in forest areas, and conditions that make forest and land conservation activities challenging. Characterized by land cover and plant diversity at low to moderate levels. The land's ability to provide ecosystem services, especially food, natural ornaments, watershed stabilization, and wildlife habitat, is also low. Zone-3, which is relatively close to the Indian Ocean, has beautiful natural scenery, attracts tourists, and has encouraged the development of education on forest and land rehabilitation. Farmers also grow crops to support crafts for souvenirs for tourists (Figure 5 and Table 4). Agroecological Zone 4 characteristics: in the southern part of the Pengga Watershed, but its elevation is higher than Zone 3, at >300 meters above sea level. Rainfall is also a significant obstacle to agroforestry development. In some locations, the vegetation remains intact forest with high levels of tree cover and plant diversity. However, this zone, a relatively well-preserved area, has lower accessibility compared to others. Preserving the natural environment enhances its capacity as a watershed stabilizer and wildlife habitat, making it superior to other zones. This area is a venue for environmental education activities, including land rehabilitation, for tourists with special interests, such as student outdoor enthusiasts. Unfavorable accessibility and geophysical conditions have reduced the area's demand for tourists, particularly for food, ornamental plants, and crafts.

Table 4. The scale and suitability class values of ABE C&I in each agroecological zone

Criteria	Indicator	Zone 1		Zone 2		Zone 3		Zone 4	
		Scale	Class	Scale	Class	Scale	Class	Scale	Class
Landscape attractiveness	Natural attractiveness	0.86	S1	0.38	S3	0.82	S1	1.00	S1
	Visibility	0.75	S1	0.75	S1	0.75	S1	0.94	S1
Landscape naturalness	Biodiversity	0.82	S1	0.63	S2	0.71	S2	0.94	S1
	Landcover	0.61	S2	0.25	S3	0.36	S3	0.81	S1
Physical limiting factor	Elevation	0.96	S1	0.88	S1	0.57	S2	0.81	S1
	Slope	1.00	S1	1.00	S1	1.00	S1	0.58	S2
	Soil texture	0.93	S1	1.00	S1	0.75	S1	0.69	S2
	Rainfall	1.00	S1	1.00	S1	0.46	S3	0.38	S3
Accessibility	Proximity to settlement	1.00	S1	1.00	S1	0.64	S2	0.56	S2
	Proximity to road	0.96	S1	1.00	S1	1.00	S1	0.56	S2
	Proximity to the river	0.82	S1	0.69	S2	0.75	S1	0.56	S2
Agroforestry Environmental services provision for ecotourism	Food provider	0.89	S1	0.75	S1	0.64	S2	0.56	S2
	Natural ornamental provider	0.61	S2	0.56	S2	0.61	S2	0.50	S2
	Craft plant sources	0.90	S1	0.92	S1	0.95	S1	0.75	S1
	Watershed stabilizer	0.82	S1	0.38	S3	0.50	S2	0.88	S1
	Wildlife habitat	0.57	S2	0.31	S3	0.43	S3	0.81	S1
	Educational function	0.79	S1	0.69	S2	0.75	S1	0.88	S1
Land suitability	Land suitability index	0.81	S1	0.65	S2	0.68	S2	0.79	S1
Number of cluster members		7 (SB, DA, TA, TJ, SL, PR, BS)		4 (SD, MC, KP, BG)		7 (BT, PL, SP, JJ, OG, HR, JA)		4 (TL, BN, BJ, MR)	

Woody Plant Composition

The analysis results show that Zone 1 has a higher proportion of woody plant species that produce food than other clusters. The proportion of perennial food-producing plants decreases from Zone 1 to 4. A decrease in crop species follows the increase in the proportion of multipurpose tree species (MPTS) and wood-producing plants in the composition. The

largest composition of MPTS plants is in Zone 2. The largest composition of wood-producing plants is in Zones 3 and 4 (Figure 6). In Zone 4, the natural plant species are predominantly *Ficus* sp. in the remaining natural forest, which provides ecosystem services, including stabilizing water sources and serving as wildlife food sources (Table 5).

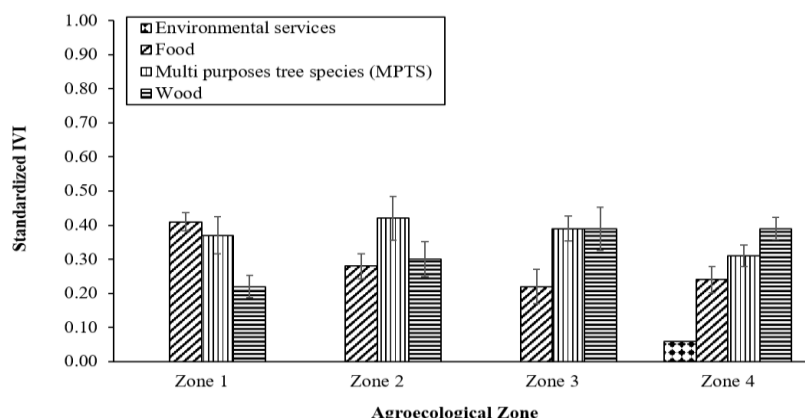


Figure 6. Composition of woody plant species based on function in each agroecological zone

The characteristics of woody plants in Zone 1 and 2, located in the north, differ from those in Zone 3 and 4, located in the south. The northern region, with its higher rainfall, allows farmers to grow a wider variety of crops to meet the community's diverse needs (Table 5). Several fruit-producing species that are tourist attractions in this region include *Psidium guajava*, *Durio zibethinus*, *Garcinia mangostana*, and *Coffea robusta*. Some MPTS plants, including *Arenga pinnata*, *Cocos nucifera*, and *Artocarpus heterophyllus*, produce fruit and sap, which tourists can enjoy. Currently, tourists purchase fruit and sap directly at tourist destinations during the harvest season.

They also purchase processed products produced by the community. In the drier upstream areas of the southern watershed, only drought-resistant species can grow. *Anacardium occidentale*, a fruit plant widely cultivated by the community and a typical souvenir from Lombok Island, is the fruit plant.

Tourists consumed some MPTS plants in the southern part, including *Cocos nucifera*, which the community widely plants for tourists to pick its young fruit as an ingredient in drinks. Some people make craft items from bamboo, coconut shells, teak, and rosewood for tourist souvenirs. Likewise, for building construction materials and tourist facilities, the community uses wood from agroforestry land. The development of processed products and construction as a household-scale industry in ecotourism locations faces challenges, because most farmers still sell their products to collectors who supply raw materials for downstream industries outside the tourist destination area.

Table 5. Composition of woody plant species based on function in each agroecological zones

Function	Species	Standardized IVI 0-1			
		Zone 1	Zone 2	Zone 3	Zone 4
Environmental services	<i>Ficus benjamina</i>	0.00	0.00	0.00	0.02
	<i>Ficus carica</i>	0.00	0.00	0.00	0.02
	<i>Ficus variegata</i>	0.00	0.00	0.00	0.02
	Total	0.00	0.00	0.00	0.06
Food	<i>Durio zibethinus</i>	0.06	0.00	0.00	0.00
	<i>Garcinia mangostana</i>	0.06	0.00	0.00	0.00
	<i>Baccaurea racemosa</i>	0.05	0.04	0.05	0.02
	<i>Mangifera indica</i>	0.05	0.11	0.06	0.02
	<i>Theobroma cacao</i>	0.05	0.00	0.00	0.00
	<i>Psidium guajava</i>	0.04	0.00	0.00	0.00
	<i>Coffea robusta</i>	0.03	0.00	0.00	0.00
	<i>Gnetum gnemon</i>	0.03	0.04	0.00	0.00
	<i>Lansium domestikum</i>	0.02	0.03	0.00	0.00
	<i>Naphelium lappaceum</i>	0.02	0.00	0.00	0.00
	<i>Ahuerites moluccanus</i>	0.00	0.06	0.04	0.03
	<i>Anacardium occidentale</i>	0.00	0.00	0.05	0.04
	<i>Artocarpus altilis</i>	0.00	0.00	0.02	0.01
	Total	0.41	0.28	0.22	0.24
Multipurpose tree species (MPTS)	<i>Artocarpus heterophyllus</i>	0.07	0.09	0.03	0.02
	<i>Cocos nucifera</i>	0.07	0.12	0.09	0.04
	<i>Areca catechu</i>	0.05	0.05	0.00	0.01
	<i>Bambusa</i> sp.	0.05	0.07	0.04	0.04
	<i>Sasbania grandiflora</i>	0.05	0.09	0.10	0.04
	<i>Arenga pinnata</i>	0.04	0.00	0.00	0.02
	<i>Tamarindus indica</i>	0.03	0.00	0.05	0.04
<i>Syzygium cumini</i>	0.01	0.00	0.02	0.02	

Function	Species	Standardized IVI 0-1			
		Zone 1	Zone 2	Zone 3	Zone 4
	<i>Calamus</i> sp.	0.00	0.00	0.00	0.02
	<i>Gliricidia siphium</i>	0.00	0.00	0.03	0.03
	<i>Schleichera oleosa</i>	0.00	0.00	0.03	0.03
	Total	0.37	0.42	0.39	0.31
Wood	<i>Swietenia mahagony</i>	0.09	0.09	0.10	0.05
	<i>Paraserianthes falcataria</i>	0.04	0.06	0.01	0.02
	<i>Alstonia spectabilis</i>	0.03	0.05	0.03	0.02
	<i>Anthocephalus cadamba</i>	0.03	0.03	0.04	0.02
	<i>Dalbergia latifolia</i>	0.03	0.00	0.05	0.03
	<i>Tectona grandis</i>	0.00	0.00	0.12	0.05
	<i>Acacia auriculiformis</i>	0.00	0.00	0.04	0.00
	<i>Alstonia scholaris</i>	0.00	0.00	0.00	0.02
	<i>Antidesma bunius</i>	0.00	0.00	0.00	0.02
	<i>Arthocarpus odoratissimus</i>	0.00	0.00	0.00	0.02
	<i>Cordia myxa</i>	0.00	0.05	0.00	0.04
	<i>Pterospermum diversifolium</i>	0.00	0.02	0.00	0.02
	<i>Pterospermum javanicum</i>	0.00	0.00	0.00	0.03
	<i>Syzygium</i> sp.	0.00	0.00	0.00	0.02
	<i>Voacanga foetida</i>	0.00	0.00	0.00	0.03
Total	0.22	0.30	0.39	0.39	

Non-Woody Plant Species Composition

Food crops dominate over non-woody plant species. The proportions of food, animal feed, and ornamental crops decrease from Zone 1 to 4. Conversely, the proportion of craft crops increases. Similarly, woody plant species are more diverse in Clusters 1 and 2 than in Clusters 3 and 4 (Figure 7).

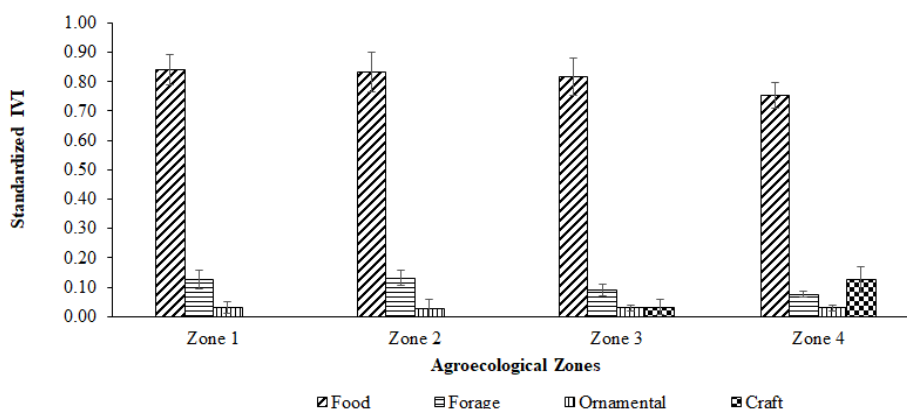


Figure 7. Composition of non-woody plant species based on function in each agricultural zone

Major food crops in the northern upstream watershed are *Oryza sativa*, *Musa acuminata*, *Colocasia esculenta*, and *Passiflora edulis*, supported by permanent irrigation channels and adequate rainfall. Meanwhile, in the southern area, there are *Amorphophallus muelleri*, *Musa acuminata*, *Diplazium esculentum*, *Zea mays*, and *Oryza sativa*. The crop cultivation method in the southern area is a rain-fed dryland system. The forage crop planted by farmers is *Pennisetum purpureum*, used as feed for beef cattle, under a silvopasture system. In the northern area, cattle are intensively farmed in pens, necessitating more intensive grass cultivation using alley cropping. In the southern region, cattle are raised semi-intensively with occasional releases, and the farmer plants grass in smaller portions along the land boundaries.

Ornamental plants, such as *Caleus scutellarioides*, are planted in intensively managed agroforestry areas for tourism development. In clusters 3 and 4, farmer use *Lygodium circinatum* grass to produce handicrafts, which initially grew naturally in preserved former forest areas around their agroforestry concessions. This handicraft product includes bags, hats, and wall hangings (Table 6). Villages that intensively develop non-timber plants to meet tourist needs are those designated as tourism villages. Farmer and tourism awareness groups in the tourism villages collaborate to explore the village's potential to cultivate plants to support tourist needs, both for direct harvest during visits and for processed food products and other souvenirs. As with woody plants, in this plant group, home industry creations are still being squeezed out by large-scale urban industries that depend on raw materials from agroforestry-based tourism villages.

Socioeconomic Characteristics of Farmers

The socioeconomic characteristics of Zones 2 and 3 are that farmers are younger than those in Zones 1 and 4. Junior farmers have smaller land areas and fewer family members than senior farmers. In terms of education levels, clusters 2 and 3 also have lower levels of education than those in Zones 1 and 4. The location of Zones 2 and 3 is closer to urban centers, which makes the agricultural sector less of a priority for residents.

Table 6. Composition of non-woody plant species based on their use in each agroecological zone

Function	Species	Standardized IVI 0-1			
		Zone 1	Zone 2	Zone 3	Zone 4
Food	<i>Oriza sativa</i>	0.21	0.25	0.22	0.12
	<i>Musa acuminata</i>	0.20	0.18	0.14	0.15
	<i>Colocasia esculenta</i>	0.15	0.10	0.00	0.00
	<i>Passiflora edulis</i>	0.10	0.10	0.00	0.00
	<i>Zea mays</i>	0.06	0.06	0.16	0.12
	<i>Carica papaya</i>	0.05	0.06	0.00	0.00
	<i>Manihot esculenta</i>	0.04	0.04	0.06	0.02
	<i>Amorphophallus muelleri</i>	0.03	0.05	0.23	0.22
	<i>Diplazium esculentum</i>	0.00	0.00	0.00	0.13
	Total	0.84	0.84	0.82	0.75
Forage	<i>Pennisetum purpureum</i>	0.13	0.13	0.14	0.12
Ornamental	<i>Caleus scutellarioides</i>	0.03	0.03	0.01	0.01
Craft	<i>Lygodium circinatum</i>	0.00	0.00	0.03	0.13

Meanwhile, the majority of farmers in zones 1 and 4 are older and live farther from urban centers. Farmers in zones 1 and 4 have emotional ties to their education and continue to prioritize working in the agricultural sector in their villages. Some are retired employees who initially worked in urban areas and returned to their villages to farm (Table 7).

Table 7. The socioeconomic characteristics of farmers in each agroecological zone

Agro-ecological Zone	Socioeconomic Farmers						Land Management of Agroforestry			
	Average				Education level proportion (%)		Space Allocation/ proportion (%)		Major Spatial Pattern	Agroforestry Components
	Age (y)	Family Member (person)	Land Size (ha)	Number of cattle (tail)	Low (< 12y)	High (> 12y)	Woody plant	Non Woody plant		
Zone 1	51.1	5.4	0.52	3.3	47%	54%	51%	49%	Alley cropping & Long trees border	Agrosilviculture, Silvopasture, Silvofishery
Zone 2	39.3	4.1	0.30	2.1	58%	43%	33%	67%	Long trees border	Agrosilviculture, Silvopasture
Zone 3	44.2	3.7	0.36	2.4	57%	44%	39%	61%	Long trees border	Agrosilviculture, Silvopasture
Zone 4	58.0	5.9	0.64	3.6	53%	48%	67%	33%	Alley cropping & Mix	Agrosilviculture, Silvopasture

The socioeconomic characteristics of farmers influence the land management of the agroforestry system. Senior farmers with more land tend to allocate more space to woody plants than junior farmers with smaller land areas.

More junior farmers with less land and fewer family members are more likely to adopt non-timber crops as a source of income immediately. The strong motivation to grow non-timber crops leads junior farmers to prefer planting trees along land embankment boundaries. Conversely, more senior farmers, especially in zone 4, tend to allocate space to trees through alley cropping and mixed systems. Their larger land ownership influences this.

Dry climate conditions also make it difficult for farmers to choose non-timber crops for intensive cultivation; they plant crops under the shade of woody trees. In addition to junior and senior farmers, there are also middle farmers (Zone 1), who allocate more space for woody and non-woody plants in a balanced manner using alley cropping and long tree borders. Farmers in Zone 1 also have extensive land, but more favorable climate conditions allow them to cultivate a broader range of plant types through alley cropping and long tree borders. This condition allows this group of farmers to integrate more agroforestry components, including agriculture, forestry, and fisheries.

Meanwhile, in another zone, the farmer has only two agroforestry components available to implement.

Tourist Preference to Agroforestry Landscape

Based on interviews with tourists, tourists prefer land use with complete agroforestry components. According to them, the completeness of agroforestry components will further enhance the alternative ecotourism attractions available to tourists. These attractions can include providing a more complete range of tourist needs. Furthermore, they believe that adding more components will also increase farmers' incomes, thereby encouraging greater environmental awareness through agricultural intensification rather than solely focusing on land extensification (Table 8).

Regarding spatial planning, most tourists prefer alley cropping. This pattern is attractive because it harmonizes the alternating rows of woody and non-woody plants. Tourists hope that a balanced mix of woody and non-woody plants will give farmers more space to grow a more diverse crop, supporting ecotourism activities that meet economic, social, and ecological needs. Regarding the proportion of woody plants producing food, multipurpose plants, and timber, tourists also tend to prefer balanced planting for various uses in agroforestry areas. The different tourism product options offered by the agroforestry system will be more effective in meeting their needs during tourism activities. Furthermore, they believe that their goal in ecotourism is to attract tourists to natural scenery safely and preserve nature. Mitigating environmental damage, such as natural disasters, and the extinction of flora and fauna, will be more effective

by planting protective plants alongside productive ones. As with woody plants, the majority of tourists also believe that a balanced proportion of plants produces food, animal feed, natural ornaments, and crafts. Developing an agroforestry system aims to sustain economic, social, and ecological functions in a balanced manner.

Table 8. Tourist preference for the agroforestry landscape

Land Management Aspects	Measured Parameters	Tourist Proficiency			
		Dislike (1)	Few like (2)	Moderate (3)	Like (4)
Completeness of the agroforestry component	Only agrosilviculture	0%	8%	48%	44%
	Agrosilviculture + Silvopasture	2%	5%	44%	49%
	Agrosilviculture + Silvopasture + Silvofishery	1%	7%	41%	52%
	Agrosilviculture + Silvopasture + Silvofishery+ Apiculture	0%	5%	44%	55%
Spatial pattern	Alley cropping	2%	6%	39%	53%
	Long trees border	9%	16%	30%	45%
	Mixed	8%	18%	34%	40%
Spatial composition	50% woody plant; 50% non-woody plant	1%	11%	35%	53%
	75% woody plant; 25% non-wood plant	24%	28%	26%	22%
	25% woody plant; 75% non-woody plant	37%	36%	14%	13%
Woody plant purposes composition	25% food; 25% Mpts; 25% wood; 25% ES	1%	9%	36%	54%
	40% food; 20% Mpts; 20% wood; 20% ES	7%	22%	38%	33%
	20% food; 40% Mpts; 20% wood; 20% ES	12%	23%	35%	30%
	20% food; 20% Mpts; 40% wood; 20% ES	15%	35%	23%	27%
	20% food; 20% Mpts; 200% wood; 40% ES	11%	26%	32%	31%
Non-woody plant composition	25% food; 25% forage; 25% ornamental; 25% craft	4%	17%	28%	51%
	40% food; 20% forage; 20% ornamental; 20% craft	6%	31%	33%	30%
	20% food; 40% forage; 20% ornamental; 20% craft	11%	37%	28%	24%
	20% food; 20% forage; 40% ornamental; 20% craft	14%	39%	28%	19%
	20% food; 20% forage; 20% ornamental; 40% craft	17%	35%	26%	22%

The Suitability of Tourist Preferences to the Current Agroforestry Landscape

By comparing tourist preferences with agroforestry landscape conditions, it is evident that Zone 1 has a more complete agroforestry component and aligns better with tourist preferences than the other zones. The agroforestry components in Zone 1 include agrosilviculture, silvopasture, and silvofishery, whereas the different zones have only the first two components. The spatial arrangement in Zones 1 and 4, which implement alley cropping, is more in line with tourist interests than in Zones 2 and 3, which predominantly implement long tree borders. In terms of spatial composition, Zone 1 has a more balanced distribution of woody and non-woody plants than the other zones. In Zones 2 and 3, the proportion of woody plants is less than that of non-woody plants. Conversely, in Zone 4, the proportion of woody plants is higher. MPTS and wood producers dominate the composition of woody plant species planted by farmers across all zones, rather than food crops or environmental service providers. Likewise, the composition of non-woody plants is unbalanced, with food plants accounting for a higher proportion than forage, ornaments, and handicraft plants (Figure 8 and Table 8).

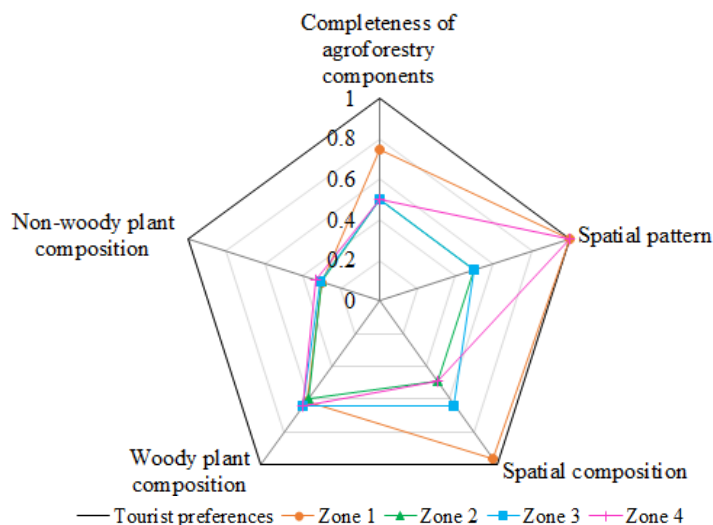


Figure 8. The suitability of agroforestry landscapes built by farmers with tourist preferences

Environmental Carrying Capacity

Based on the analysis, the average environmental carrying capacity for ecotourism management in 22 locations upstream of the Pengga Watershed is 460 tourists per day, exceeding the average actual tourist visits of 4 tourists/day. The locations with the highest carrying capacity values are Zone 3 and Zone 1, followed by Zone 2, and the lowest is

Zone 4 (Figure 9 and Table 9). Several factors that contribute to high carrying capacity include the duration of tourist activities. In zone 4, tourist attractions are mountains with a more natural landscape and more difficult accessibility, attracting tourists for adventure and camping. Tourists need more time to complete their activities, so the number of transitions for tourists in a given day is also lower than in other zones.

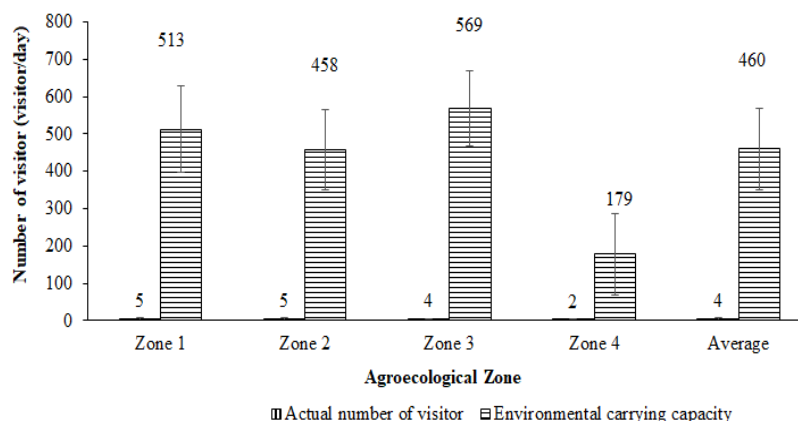


Figure 9. Comparison of actual tourist visits and ECC in each agroecological zone

Another factor influencing carrying capacity is the biogeophysical limiting factor. Zone 4 has a steeper slope than the others, so the discount rate for the slope aspect is higher than in other locations. From a biodiversity perspective, the location of tourist attractions in Zone 4 also has higher biodiversity value than other locations, so tourism activities need to be limited to avoid disturbing the ecological processes within it. In the socioeconomic context, Zone 2 comprises non-tourism villages, resulting in weaker guidance for tourists compared to locations developed as tourism villages.

In the Tourism villages, the government has programs that integrate cross-sectoral village development with tourism. The development of village tourism can accelerate improvements in attractions, infrastructure, and tourism management institutions more rapidly than in non-tourist villages.

Table 9. Environmental carrying capacity for ABE development based on agroecological zones

Agroecological Zone	A (m ²)	N (v/d)	B (m ²)	T (h/v)	L (h/d)	Rf (v/d)	PCC (v/d)	Correction factor of Bio-geophysical limiting factors (Cf)				RCC (v/d)	Cfm	ECC (v/d)
								Cfr	Cfsl	Cfso	Cfb			
Zone 1	125,664	5 ^{ax}	65	1.64	9.00	5.81	11,236	0.90	0.85	0.66	0.24	1,401	0.36	513 ^{az}
Zone 2	125,664	5 ^{ax}	65	1.48	9.00	6.27	12,128	0.90	0.88	0.64	0.31	1,831	0.25	458 ^{bz}
Zone 3	125,664	3 ^{bx}	65	1.67	9.00	6.08	11,754	0.90	0.83	0.69	0.28	1,724	0.36	569 ^{az}
Zone 4	125,664	2 ^{cx}	65	5.70	9.00	2.49	48,05	0.90	0.70	0.73	0.20	505	0.38	179 ^{cz}
Average	125,664	4^x	65	2.36	9.00	5.38	10,394	0.90	0.82	0.68	0.26	1419	0.34	460^z

Remark: N = average number of visitors (visitors/day),

A = potential area for ecotourism with a 200 m radius from the center of the destination (m²)

B = The area required by a tourist to obtain satisfaction from a picnic (65 m²)

T = Length of tourist activity (hour/visitor); Tls = Length of services (hours/day);

Rf = Tourist rotation factor (visitor/day); PCC = Physical carrying capacity (visitor/day);

RCC = Real carrying capacity (visitor/day); ECC = Effective carrying capacity (visitor/day);

Cfr = Correction factor of rainfall; Cfsl = Correction factor of slope; Cfso = Correction factor of soil;

Cfb = Correction factor of biodiversity; Cfm = Correction factor of management;

a, b, c, x, z: Based on the t-test, the mean values with the same letter do not differ at the 95% confidence level

DISCUSSION

The analysis results show that the ability to stabilize the upstream watershed, land cover, attractiveness, provision of wildlife habitat, and elevation influence land suitability for agroforestry-based ecotourism (ABE) development.

These findings align with previous research, which shows that a watershed is more stable when its upstream area has denser vegetated land cover. Higher vegetation cover will increase infiltration and soil water storage while preventing erosion and flooding (Decsi et al., 2020). Excessive and continuous erosion and flooding can disrupt the hydrological cycle and reduce the watershed's ability to regulate the water balance (Qiu et al., 2021).

Agroforestry systems implemented in the upstream watershed area can create denser vegetated land cover with complete vertical and horizontal structures, thereby reducing soil erosion and flooding (Rolo et al., 2023). Vegetated land with complete structures can provide habitat for various animals and increase ecotourism appeal (Santoro, 2023).

On the other hand, upstream watershed areas at higher elevations have the potential for beautiful natural scenery as tourist destinations. The land is undulating and steep, making it a priority for conservation (Chaudhary et al., 2019).

Proximity to tourist attractions with beautiful panoramas can encourage community, stakeholder, and tourist-led conservation education and land rehabilitation, thereby enhancing the natural appeal (Damastuti et al., 2022).

Efforts to conserve upstream watershed areas through an integrated agroforestry and ecotourism approach should begin by developing management plans properly (Narendra et al., 2021). Appropriate knowledge of landscape preferences must be considered in sustainable nature tourism planning (Gomez et al., 2024). The results of this study indicate that the four agroclimatic zones identified have distinct biogeophysical characteristics. The determining component of the agroclimatic zones at the study site is the availability of adequate rainfall.

These results align with previous research showing that adequate water availability is a key determinant of the formation of a complete vegetation structure (De Castro Nunes Santos Terra et al., 2018). Water plays a crucial role in photosynthesis, plant respiration, and nutrient transport. A lack of water will cause plants to wilt, but excessive water availability will cause plant death by disrupting their metabolic processes (Huntley, 2023).

Water availability in agroforestry areas is determined by rainfall intensity, soil texture, dryness, air temperature, and plant type (Wang et al., 2023). Areas with high rainfall will have more soil moisture, making it easier for plants to access water (Xu et al., 2012). Soil with a pure clay texture will store and retain water more readily, but because of its few pores, it can become waterlogged, hindering plant respiration. Conversely, soil with a pure sandy texture will easily lose water due to its high porosity (Gavrilescu, 2021). Therefore, good soil texture has an equal proportion of clay, silt, and sand. Air temperature influences evapotranspiration, thereby accelerating water loss from the soil. The intensity and duration of sunlight, elevation, and the microclimate created by vegetation influence temperature (Mellouli et al., 2000). In addition to creating a microclimate and inhibiting evaporation, plants play a role in the water cycle by increasing water infiltration into the soil by inhibiting erosion and runoff (Dharmawan et al., 2023). Therefore, favorable agroecological conditions will help farmers develop agroforestry systems with a broader range of products (Singh et al., 2022). Healthy biodiversity and aesthetic landscapes enhance the attractiveness of agroforestry land for ecotourism. These conditions offer visitors a more pleasant and enriching experience by providing attractive scenery, a greater variety of plant and animal life, and recreation opportunities, beyond just the success of the agricultural products themselves (Bhandari et al., 2026).

Tourists as eco-travelers are interested in ecotourism activities not only for entertainment but also to gain experience and literacy about conservation and environmental education (Fang et al., 2018). From an ecological perspective, tourists expect to experience the natural conditions of the upperstream watershed area. This natural condition includes low soil erosion, dense tree cover that can create a microclimate, serve as habitat for wildlife, and simultaneously conserve soil and water (Pedroso & Bui Kung'u, 2019). From a socioeconomic perspective, the upperstream watershed area has a higher elevation, which supports better visibility, lower temperatures, and fresher air quality than the downstream region. This condition allows tourists to engage in more tourism activities that can provide socioeconomic benefits for tourists and residents (Sigala, 2016). To achieve sustainable agroforestry-based ecotourism management in the upperstream watershed area, a focus on optimal land management—namely, stabilizing its function as a catchment by considering topography, soil, climate, vegetation, and the community's socioeconomic activities (Van Noordwijk et al., 2020).

The higher social pressures resulting from urban development can impact the naturalness of natural resources (Chen et al., 2020). The direct decline in land naturalness will also reduce the attractiveness of nature tourism (Guo et al., 2022). The condition of upstream forest land in watersheds in coastal dryland agroclimatic zones is often subject to high social pressure and poses challenges for forest and land rehabilitation (Waskitho et al., 2021). Conversely, remote areas and areas with extreme conditions will have better ecosystem preservation due to reduced social pressure (Knez et al., 2018). However, to develop sustainable ecotourism, a balance is needed between maintaining environmental naturalness and providing ecological education while meeting tourists' socioeconomic needs, such as food, souvenirs, and accommodation, produced through agroforestry activities (Ivona, 2021). Increasing species diversity in woody and non-woody plants can be achieved in agroforestry systems by implementing intensive silviculture (Octavia et al., 2022).

In areas with wetter agroecological zones, silviculture can emphasize efforts to increase plant productivity by balancing spatial arrangements between woody and non-woody plants (Ollinaho & Kröger, 2021; Masrurroh et al., 2022), selecting superior species, and enriching agroforestry components more comprehensively (Seidel et al., 2021). Meanwhile, in drier agroecological zones, stakeholders can focus on improving silviculture by selecting drought-resistant species (Swaminathan & Kesavan, 2012), optimizing tree and crop spacing, and implementing environmental management such as reservoir construction, water-absorption wells, drip irrigation, or hydroponic systems (Maucieri et al., 2019).

Senior farmers with more established resources dominate those at more advanced agroforestry levels compared to those at earlier stages (Jha et al., 2021). Given their experience, senior farmers prefer to allocate space to woody plants rather than non-timber plants (Gebu et al., 2019). More experienced farmers have greater knowledge of managing agricultural diversification by planting a wider variety of crops to provide alternative income and to anticipate price declines (Tacconi et al., 2022). Optimal development of tourism potential can increase farmers' motivation to develop agroforestry systems (Burgess & Rosati, 2018). Tourists are intensely interested in visiting sustainably managed land (Santos & Castanho, 2023). Sustainably managed agroforestry land has completed components, allocates space to woody and non-woody plants in equal portions, and provides balanced ecosystem services (Salimath et al., 2022). Land intended for agroforestry-based ecotourism development should adequately meet tourist needs while simultaneously serving as a conservation medium, increasing community income, and preserving local culture (Fang et al., 2025). The challenge of developing agroforestry-based ecotourism is ensuring the availability of agricultural products that meet tourist needs. Some of the obstacles often faced by farmers in providing agricultural products are closely related to

quality, service capacity to tourists, production and processing technology, available resources, market conditions, and policies (Welteji & Zerihun, 2018). Factors influencing the carrying capacity of a tourism area include area size, service hours, duration of tourist activity, biophysical limiting factors, and management (Sunkar et al., 2022). Areas with pristine scenery and difficult accessibility have fewer tourists. However, they spend more time in activities than in artificial tourist attractions, requiring management that accounts for factors related to tourist transition and rotation (Bursa et al., 2022). Implementing slope barriers during tourism activities not only reduces soil erosion but also protects visitors from accidents and natural disasters (Scott, 2022). Ecosystems with higher biodiversity are highly vulnerable to disturbances caused by human activity, so in these areas, tourist activities need to be limited (Coombes et al., 2008).

The destination within tourism villages has strong institutions, as indicated by the presence of tourism awareness groups (Zainal et al., 2022). This group collaborates with village-owned enterprises as a business unit focused on managing tourist attractions and providing optimal services to tourists (Wijayanto et al., 2022). To improve tourism management and optimize the existing carrying capacity in the research location by community capacity building to enhance tourist attractions, community-based ecotourism businesses, and effective, efficient marketing.

Government support and training by experienced facilitators can improve community capacity in tourism management (Sutawa, 2012; Yasir et al., 2021). The application of green technologies, such as organic farming, has become a brand in itself to enhance tourist attractions (Zhong et al., 2022). Likewise, the use of renewable energy can also be a tourist attraction (Ahmadi, 2022). To improve ecotourism marketing, the community can collaborate with travel agents or educational institutions to develop an annual calendar of environmental education and conservation events and implement a digital marketing system (Happ & Horváth, 2020).

CONCLUSION

Agroforestry land in the upperstream watershed area of the research location has potential for agroforestry-based ecotourism development. The level of land suitability is closely related to the availability of an agroforestry system as a watershed stabilizer, land cover, landscape attractiveness, wildlife habitat, and elevation. Agroecological variables, particularly rainfall and farmers' socioeconomic characteristics, influence the formation of agroforestry systems. In wetter climates, senior farmers with adequate capacity and resources are better able to manage land for ABE development that aligns with tourist preferences and is more sustainable. Tourist perceptions of agroforestry landscapes for ecotourism include the completeness of agroforestry components, a balance of spatial patterns and composition, and a balance of cultivated plant species to support ecotourism activities. Some ABE locations, particularly those with favorable agroecological characteristics, have led to an agroforestry system that closely aligns with tourist preferences; however, some aspects of it still need improvement.

The tourist visit to the ABE location in all agroecological zones still does not exceed the environmental carrying capacity. This situation indicates that there is still room to increase the current carrying capacity by attracting more tourists.

Developing community capacity in sustainable ecotourism management, including enhancing tourist attractions, developing community-based ecotourism businesses integrated with tourism village programs, and strengthening marketing systems and risk management, will improve current management practices and make them more sustainable.

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