

Research Article

Spatial Analysis and Visualization of Edu-Tourism Clusters in MAMMINASATA, South Sulawesi: A GIS Approach to Attraction Identification and Classification

Haedar Akib ^{a,*} • Didin ^a • Ahmad Wahidiyat Haedar ^b • Khairil Asnan Haedar ^c • Rudi Salam ^a • Muh. Darwis ^a • Muh. Ibrahim Halim ^d

^a Department of Administrative Science, Universitas Negeri Makassar, Makassar, Indonesia | ^b Department of Civil Engineering and Planning, Universitas Negeri Makassar, Makassar, Indonesia | ^c Department of Biology, Universitas Sibatokkong Mambo, Bone, Indonesia | ^d Department of Culture and Tourism, South Sulawesi Provincial Government, Makassar, Indonesia

ABSTRACT



Educational tourism is increasingly understood as a spatially embedded learning resource system, yet its metropolitan-scale planning remains underexamined. This study analyzes the spatial distribution and land suitability of Edu-tourism attractions in the MAMMINASATA Metropolitan Area, South Sulawesi, Indonesia, comprising Makassar, Gowa, Maros, and Takalar. Using a GIS-based weighted overlay approach, 36 georeferenced attractions were inventoried and classified into cultural, natural, man-made, and special-interest tourism. Spatial suitability was assessed through four criteria relevant to metropolitan planning: road accessibility, slope, vegetation density (NDVI), and proximity to activity centers. All datasets were standardized to a common suitability scale and integrated into a composite land-suitability model, after which suitability values were extracted at each attraction location. The results show that the Edu-tourism resource base is dominated by natural attractions (44.40%) and cultural attractions (27.8%), with the strongest concentration in Makassar, Gowa, and Maros. The weighted overlay indicates that 66.63% of the study area is very suitable and 29.84% is suitable for Edu-tourism development, meaning that 96.47% of the metropolitan area possesses supportive territorial conditions. At the site level, 58.3% of attractions are located in very suitable areas, 36.10% in suitable areas, and only 5.60% in moderately suitable areas, while no site falls into the not suitable class. These findings demonstrate that MAMMINASATA has strong potential for integrated Edu-tourism planning, particularly in the Makassar-Gowa corridor, while more selective accessibility and service improvements are needed in parts of Maros and Takalar.

KEYWORDS destination planning • geospatial decision support • life on land • metropolitan tourism • sustainable cities and communities • spatial suitability assessment • weighted overlay

ARTICLE CITATION

H. Akib, Didin, Ahmad W. Haedar, Khairil A. Haedar, R. Salam, M. Darwis, M.I. Halim, "Spatial Analysis and Visualization of Edu-Tourism Clusters in MAMMINASATA, South Sulawesi: A GIS Approach to Attraction Identification and Classification," International Journal of Environment, Engineering and Education, Vol. 8, No. 2, pp. 156-174, 2026. <https://doi.org/10.55151/ijeedu.v8i2.352>

*CORRESPONDENCE

Haedar Akib  haedarakib@unm.ac.id  Department of Administrative Science, Faculty of Social and Law Science, Universitas Negeri Makassar, Jalan Raya Pendidikan, Makassar, 90221, South Sulawesi, Indonesia  <https://orcid.org/0000-0003-3821-0583>



Copyright © 2026 by the author(s). Licensed by Three E Science Institute (International Journal of Environment, Engineering and Education). This is an open-access article distributed under the terms of the [Creative Commons Attribution-ShareAlike 4.0 \(CC BY-SA\)](https://creativecommons.org/licenses/by-sa/4.0/) International License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited and any derivative works are distributed under the same license.

1. INTRODUCTION

Tourism is increasingly expected to generate value beyond leisure consumption by facilitating learning, interpretation, reflection, and place-based engagement. Within this broader shift, educational tourism has evolved from a narrow association with school excursions and study-abroad programs into a wider domain of travel in which learning constitutes a primary or secondary motivation [1], [2]. More recent scholarship has further expanded this view by arguing that destinations and attractions themselves can function as tourism learning resources. These places contain educational content and stimulate learning through direct encounters with nature, heritage, culture, and everyday local life [3], [4]. From this perspective, educational tourism should not be reduced to formal academic mobility alone. However, it should also include a wider range of attractions capable of generating knowledge acquisition, reflection, skill development, and experiential understanding.

This conceptual shift is theoretically important because it suggests that educational tourism should be understood not merely as a destination category, but as a learning resource system. In such a system, the educational value of tourism is not located only in the theme of an attraction, but in the interaction between place, interpretation, infrastructure, and visitor experience. Tourism scholars have shown that learning in tourism settings may involve cognitive, affective, and behavioral change, especially when experiences are intentionally structured as learning processes rather than treated as passive sightseeing [5]. This argument supports a broader reconceptualization of educational tourism as a system of spatially embedded resources that enable formal, informal, and experiential learning across multiple destination types [6], [7].

Viewing educational tourism as a learning resource system has direct implications for regional planning. Learning-oriented attractions should be understood not as isolated destination assets, but as spatially embedded resources whose educational value emerges through the interaction of place attributes, interpretation, accessibility, and service networks [8], [9]. Tourism-learning research shows that meaningful learning depends not only on attraction content, but also on interpretive quality, visitor engagement, and experiential context [5], [10], [11]. Accordingly, museums, heritage buildings, parks, agricultural sites, religious places, waterfronts, and man-made recreation facilities may all function as learning resources. However, their contribution to destination development depends on how they are connected, interpreted, and positioned within the wider regional landscape [12]–[14]. In planning terms, their educational usefulness is shaped by accessibility, environmental quality, physical feasibility, and integration with urban and service networks, consistent with GIS-based tourism suitability studies that identify accessibility, topography, and environmental conditions

as key determinants of tourism development potential [14]–[16]. Therefore, treating attractions only as discrete points of interest risks overlooking the territorial conditions that structure visitor access, movement, safety, usability, and the capacity of destinations to function as coherent learning environments.

This is where Geographic Information Systems (GIS) and multi-criteria decision analysis (MCDA) become important. GIS-based suitability studies have consistently shown that tourism development potential can be assessed more rigorously by integrating multiple spatial variables into transparent and reproducible decision-support models. In tourism and ecotourism research, common suitability determinants include accessibility, topography, vegetation or land-cover conditions, proximity to settlements and services, and the quality of surrounding environmental attributes [10], [17]–[19]. More recent studies have confirmed the continuing relevance of geospatial multi-criteria frameworks for evaluating tourism potential, route prioritization, and spatial decision making in both natural and urban environments [20]–[23]. Collectively, this literature indicates that tourism value is shaped not only by attraction content but also by the spatial logic of connectivity, environmental support, and regional accessibility.

However, an important disconnect remains between the educational tourism literature and the geospatial tourism-planning literature. Educational tourism research has largely examined mobility-based learning, university-linked travel, and visitor learning outcomes. At the same time, tourism-learning scholarship has further emphasized transformative experience and behavior change rather than territorial planning [1], [8]. By contrast, GIS-MCDA tourism studies have mainly focused on ecotourism suitability, general tourism potential, and spatial prioritization, with strong attention to accessibility, topography, and environmental conditions, but limited application to educational tourism as a metropolitan planning issue [15], [24]. As a result, educational tourism attractions remain underexamined as spatially distributed learning resources within wider regional systems, despite recent conceptual work explicitly calling for tourism spaces to be understood as integrated learning resources and learning destinations [12]. This gap is important because educational tourism development requires not only identifying attractions with educational value, but also assessing whether their surrounding spatial conditions support access, interpretation, safety, movement, and integration into broader destination networks that can sustain meaningful learning experiences over time.

The MAMMINASATA Metropolitan Area in South Sulawesi, Indonesia, provides a relevant case for addressing this gap. Comprising Makassar, Gowa, Maros, and Takalar, the region contains a diverse mix of attractions with educational potential, including

historical and cultural sites, natural landscapes, artificial recreation spaces, and special-interest destinations. The dataset used in this study identifies 36 attractions across the four local governments, reflecting a metropolitan environment in which learning may occur through museums and heritage interpretation, ecological observation, Agri-educational experiences, religious encounters, and community-based interaction. Such diversity makes MAMMINASATA analytically valuable because it reflects the complexity of contemporary educational tourism in emerging metropolitan regions, where destination value depends not only on attraction diversity but also on territorial organization.

To move beyond descriptive listing, this study evaluates 36 inventoried attractions through a GIS-based weighted overlay model that integrates four planning-sensitive variables: road accessibility, slope, vegetation density, and proximity to activity centers. These criteria were selected because they capture the territorial conditions most relevant to metropolitan-scale educational tourism screening. Road accessibility represents visitor reachability and network integration; slope reflects physical feasibility and safety; vegetation density indicates environmental quality and landscape-based learning potential; and proximity to activity centers reflects the attraction's relationship with urban services, mobility systems, and supporting infrastructure [15], [16], [25], [26]. In methodological terms, this parsimonious combination is consistent with recent GIS-MCDA tourism research that emphasizes accessible, environmentally supportive, and service-connected locations as the most favorable settings for tourism development.

Against this background, this study addresses three questions. First, how are educational tourism attractions spatially distributed across the MAMMINASATA Metropolitan Area, and what typological pattern emerges from their classification? Second, how suitable are these attractions and their surrounding areas when evaluated through a GIS-based multi-criteria framework using accessibility, slope, vegetation density, and urban-center proximity? Third, which locations and subregions should be prioritized for future educational tourism planning and

development? By addressing these questions, the study seeks to reposition educational tourism as not only a pedagogical and experiential phenomenon, but also a problem of territorial organization and spatial planning.

This study makes three contributions to the literature and to planning practice. First, it advances educational tourism research by explicitly framing attractions as components of a learning resource system, thereby extending the field beyond mobility-based and program-based interpretations [3], [27]. Second, it fills a methodological gap by integrating attraction identification, typological classification, and GIS-based suitability assessment within a single metropolitan decision-support framework. Third, it demonstrates why the four selected criteria provide a parsimonious yet policy-relevant basis for screening educational tourism potential in emerging metropolitan regions, where development decisions must balance accessibility, environmental quality, spatial feasibility, and service connectivity. In this way, the article argues that the future of educational tourism depends not only on the richness of attractions, but also on the spatial intelligence used to organize them as interconnected learning resources.

2. MATERIALS AND METHODS

2.1. Design, Area and Attraction Inventory

This study employed a GIS-based weighted overlay design to evaluate the spatial suitability of educational tourism attractions in the MAMMINASATA metropolitan area. The workflow combined (1) compilation of a georeferenced attraction inventory, (2) preparation of four criterion layers, (3) raster-based standardization and weighted overlay modelling, and (4) extraction of suitability values at attraction locations for comparative interpretation [28]–[30]. The model was designed as a metropolitan-scale screening tool to support planning and prioritization rather than parcel-level site engineering or the direct measurement of visitor learning outcomes.

Table 1. Georeferenced inventory and classification of educational tourism attractions in the MAMMINASATA Metropolitan Area.

Tourism Type	Site Name	Regency/City	Longitude (X)	Latitude (Y)
Cultural Tourism	1. Fort Rotterdam	Makassar	119.4057	-5.13383
	2. Balla Lompoa Palace	Gowa	119.4527	-5.20677
	3. Makassar City Museum	Makassar	119.4086	-5.13443
	4. Somba Opu Fort	Gowa	119.4081	-5.19188
	5. Sheikh Yusuf Tomb	Makassar	119.4454	-5.18841
	6. Katangka Mosque	Gowa	119.4512	-5.19072
	7. Maudu Lompoa Festival, Cikoang	Takalar	119.4394	-5.53442
	8. Al-Markaz Al-Islami Jenderal Yusuf Mosque	Makassar	119.4265	-5.12975
	9. Losari Beach Culinary Area	Makassar	119.4068	-5.14227
	10. Somba Opu Traditional Area	Gowa	119.4061	-5.19085

Tourism Type	Site Name	Regency/City	Longitude (X)	Latitude (Y)	
Natural Tourism	11. Bantimurung-Bulusaraung National Park	Maros	119.6816	-5.01608	
	12. Rammang-Rammang Karst Area	Maros	119.6056	-4.92363	
	13. Leang-Leang Prehistoric Park	Maros	119.6300	-4.86424	
	14. Doli Bungaeja Tourism Site	Maros	119.6522	-4.94369	
	15. Parangtinggia Bat Village	Maros	119.6629	-5.02163	
	16. Savana River	Maros	119.7376	-5.12445	
	17. Takapala Waterfall	Gowa	119.8568	-5.27449	
	18. Lakkang Island	Makassar	119.4671	-5.12161	
	19. Bili-Bili Reservoir	Gowa	119.5843	-5.25489	
	20. Kampili Dam	Gowa	119.5129	-5.27702	
	21. Lantebung Mangrove Ecotourism	Makassar	119.4667	-5.07812	
	22. Samalona Island	Makassar	119.3437	-5.12447	
	23. Lae-Lae Island	Makassar	119.3903	-5.13499	
	24. Sanrobengi Island	Takalar	119.3427	-5.32353	
	25. Kuri Beach (Caddi)	Maros	119.4675	-5.03297	
	26. Topejawa Beach	Takalar	119.4308	-5.50721	
	Man-Made Tourism	27. Pucak Teaching Farm	Maros	119.6522	-5.14270
		28. Dairyland Farm Theme Park	Gowa	119.5873	-5.24928
		29. Bugis Waterpark Adventure	Makassar	119.4946	-5.14864
		30. Dewi Sri Waterpark	Gowa	119.4766	-5.21360
		31. Pakui Sayang Park	Makassar	119.4396	-5.14575
		32. Grandmall Waterboom	Maros	119.5541	-5.04597
	Special-Interest Tourism	33. PTB Maros Culinary Area	Maros	119.5749	-5.01434
		34. Beba Takalar Fish Auction Site	Takalar	119.3755	-5.27357
		35. Lego-Lego CPI Waterfront	Makassar	119.4036	-5.14537
		36. Denassa Garden	Gowa	119.5075	-5.34086

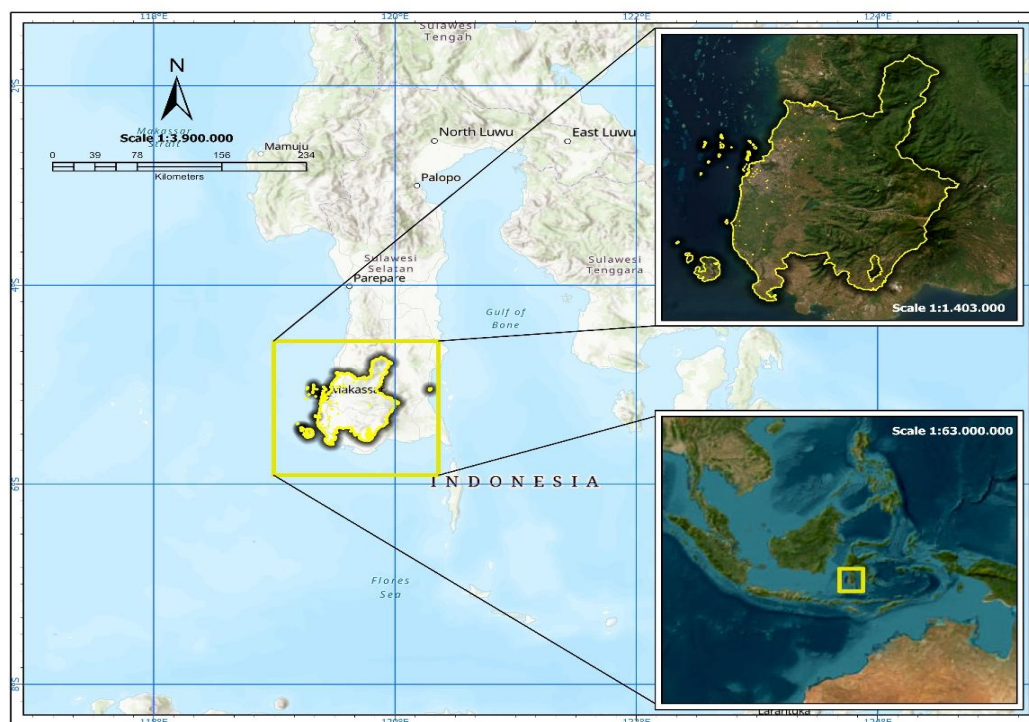


Figure 1. Study area of the MAMMINASATA Metropolitan Area in South Sulawesi, Indonesia, showing the administrative boundaries of Makassar, Gowa, Maros, and Takalar.

A total of 36 existing attractions located within the study boundary were inventoried and georeferenced. Sites were retained when they were publicly recognizable destinations, could be represented as point locations, and exhibited identifiable educational value related to heritage, ecology, religion, agriculture, recreation, or community life. Each site was then operationally classified into one of four categories - cultural tourism, natural tourism, man-made tourism, or special-interest tourism - to support subsequent spatial comparison.

2.2. Data Sources, Operational and Software

The attraction inventory was compiled from the analytical workbook used in this study and cross-checked against administrative boundaries and base maps to reduce locational errors and district mismatches. Spatial

modelling used four weighted criteria—slope, vegetation density, distance to roads, and distance to activity centers—consistent with GIS-MCDA suitability approaches that combine topographic, environmental, and accessibility factors in spatial evaluation. ArcGIS Pro was used for slope derivation, Euclidean distance, reclassification, weighted overlay, point extraction, and map production, following standard raster-based suitability procedures [28], [33]. Google Earth Engine was used to preprocess Sentinel-2 surface reflectance imagery and derive NDVI, a widely used indicator of vegetation greenness based on red and near-infrared reflectance [34], [35]. The results should therefore be interpreted as an inventory-based metropolitan screening exercise rather than an exhaustive tourism registry at the time.

Table 2. Spatial datasets, source institutions, software, and analytical use.

No	Dataset	Source/provider	Scale or resolution	Software	Analytical use
1	Slope	SRTM DEM, South Sulawesi	30 m	ArcGIS Pro	Slope derivation and class reclassification
2	Vegetation density	Sentinel-2A SR imagery (2025 composite) via Google Earth Engine	10 m source imagery; aligned to 30 m analysis grid	Google Earth Engine + ArcGIS Pro	NDVI calculation, export, resampling, and scoring
3	Distance to activity centers	Activity-center points (social-religious, education, government, health, industry, and economy) from RBI / Ina-Geoportal map layers	1:50,000	ArcGIS Pro	Euclidean distance surface and reclassification
4	Distance to road network	Road network from RBI / Ina-Geoportal	1:250,000	ArcGIS Pro	Buffer-based proximity zoning and reclassification
5	Land suitability surface	Derived from the four weighted criteria layers	Derived raster	ArcGIS Pro	Weighted overlay / weighted linear combination
6	Administrative boundary	Population and Civil Registration Office (administrative boundary data)	Boundary layer	ArcGIS Pro	Study-area clipping, validation, and map context
7	Road network	RBI / Ina-Geoportal	1:250,000	ArcGIS Pro	Input layer for the road-accessibility criterion
8	Rivers	OpenStreetMap	Vector layer	ArcGIS Pro	Hydrographic context for mapping and interpretation
9	Attraction point inventory	Author-compiled point database derived from the analytical workbook	36 georeferenced points	ArcGIS Pro	Inventory, point sampling, and pattern analysis

2.3. Spatial Data Preparation

All spatial datasets were clipped to the MAMMINASATA boundary and transformed into a common projected coordinate system in meters before distance-based analysis to ensure geometric consistency and comparable proximity measurement across layers [36]. Raster layers were then aligned to a common 30 m analysis grid based on the SRTM DEM, the coarsest raster input, to support cell-by-cell overlay and reduce uncertainty caused by grid misalignment and false spatial precision [37], [38].

Vector datasets were checked for duplication, topology errors, and attribute inconsistencies before use in distance analysis or raster conversion, as spatial data quality directly influences analytical reliability [39]. The 36 attraction points were also cross-checked against administrative boundaries and base maps to detect duplicate records, obvious outliers, and regency/city mismatches. Given the integration of 30 m, 10 m, and medium-scale vector inputs, the model is appropriate for

metropolitan-scale suitability screening and prioritization rather than detailed site design [40].

2.4. Derivation of Criterion Layers

Slope was derived from the SRTM DEM in ArcGIS Pro and reclassified into five terrain classes: 0-5, 5-15, 15-25, 25-35, and >35 degrees. Flatter terrain received higher suitability scores because it is generally easier to access, safer for visitors, and more feasible for tourism support facilities. Road accessibility and proximity to activity centers were modelled as distance-based criteria derived from the road network and activity-center points, respectively. Shorter distances were assigned higher suitability scores because they represent stronger connectivity to transport and metropolitan service networks.

Vegetation density was represented by the normalized difference vegetation index (NDVI) derived from the COPERNICUS/S2_SR_HARMONIZED image collection in Google Earth Engine. The image collection was filtered to the study boundary, restricted to 1 January-30 December 2025, limited to scenes with CLOUDY_PIXEL_PERCENTAGE below 20%, and masked using QA60 cloud and cirrus bits. A median composite was

then produced to reduce residual cloud contamination and temporal noise. NDVI was calculated from Band 8 (near infrared) and Band 4 (red) as follows:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \quad (1)$$

The exported NDVI raster was aligned to the 30 m analysis grid in ArcGIS Pro before reclassification into five greenness classes. Together, the four criterion layers captured topographic feasibility, environmental quality, transport accessibility, and metropolitan service connectivity, which were treated in this study as the main enabling spatial conditions for educational tourism development [41], [42].

2.5. Standardization, Weighting and Suitability Model

Table 2 presents the operational classes, suitability scores, and criterion weights used in the weighted overlay model. Each criterion was standardized to an ordinal suitability scale from 1 (least suitable) to 5 (most suitable) so that heterogeneous datasets could be combined within a single decision surface.

Table 3. Criteria standardization and normalized weights used in the suitability model.

Criterion	Operational Class	Suitability Score	Raw Weight	Normalized Weight
Slope	Flat (0-5°)	5	0.189	0.237
	Gentle (5-15°)	4	0.189	0.237
	Moderate (15-25°)	3	0.189	0.237
	Steep (25-35°)	2	0.189	0.237
	Very Steep (>35°)	1	0.189	0.237
Vegetation density (NDVI)	Non-vegetated (<0.15)	1	0.25	0.313
	Very Low Greenness (0.15-0.30)	2	0.25	0.313
	Low Greenness (0.30-0.45)	3	0.25	0.313
	High Greenness (0.45-0.60)	4	0.25	0.313
	Very High Greenness (>0.60)	5	0.25	0.313
Distance to roads	>5000 m	1	0.25	0.313
	3000-5000 m	2	0.25	0.313
	1500-3000 m	3	0.25	0.313
	500-1500 m	4	0.25	0.313
	0-500 m	5	0.25	0.313
Distance to activity centers	0-5 km	5	0.109	0.137
	5-10 km	4	0.109	0.137
	10-20 km	3	0.109	0.137

The raw weights adopted in the analytical workbook were 0.189 for slope, 0.250 for vegetation density, 0.250 for distance to roads, and 0.109 for distance to activity centers. Because these raw weights summed to 0.798 rather than 1.000, they were normalized prior to overlay in order to preserve their relative importance while satisfying the requirements of a weighted linear

combination model. In substantive terms, the model gave greatest emphasis to accessibility and environmental quality, while slope and proximity to activity centers acted as supporting planning criteria. The normalized weight of criterion *i* was calculated as:

$$w_i^{(\text{norm})} = \frac{W_i}{\sum_{i=1}^m W_i} \quad (2)$$

where W_i is the normalized weight of criterion i , W_i is the raw weight assigned to criterion i , and $\sum (W_i)$ is the total raw weight across all criteria.

After standardization and weight normalization, the composite suitability index for each raster cell was calculated using a weighted linear combination:

$$SI_j = \sum_{i=1}^m w_i^{(\text{norm})} s_{ij} \quad (3)$$

where SI_j is the suitability index of raster cell j , W_i is the normalized weight of criterion i , and s_{ij} is the standardized suitability score of criterion i at raster cell j . Because all criterion scores ranged from 1 to 5 and the normalized weights summed to 1, the theoretical range of the composite index was also 1 to 5.

2.6. Suitability Mapping, Class Assignment and Point Extraction

The four standardized criterion raster were integrated in ArcGIS Pro using weighted overlay or an equivalent raster-calculator implementation of the weighted linear combination. The output was a continuous suitability surface for the entire metropolitan area. For planning interpretation, the continuous index was subsequently grouped into four ordered classes - very suitable (S1), suitable (S2), moderately suitable (S3), and not suitable (N) - using the class thresholds adopted in the analytical workbook and applied consistently to the final raster.

The final suitability raster was then sampled at the coordinates of the 36 inventoried attractions to extract point-based suitability values. These values were summarized by attraction type and by regency or city using counts, mean scores, and class distributions so that the study could compare the relative planning conditions of existing destinations across MAMMINASATA. The raster-based extraction constituted the primary analytical output used for interpretation.

2.7. Spatial Distribution Assessment

To address the first research question, the spatial distribution of attractions was examined through mapped location patterns, district-level counts, and comparison across attraction types. In this revised manuscript, the term cluster is used in a descriptive metropolitan-planning sense to indicate areas of spatial concentration visible in the mapped distribution, rather than as a stand-alone inferential hotspot test.

The study prioritizes the integration of attraction distribution with the suitability surface, so that spatial concentration is interpreted together with accessibility, terrain conditions, vegetation context, and service

proximity. This allows the analysis to distinguish between places that merely contain multiple attractions and places whose surrounding territorial conditions are also supportive of educational tourism development.

2.8. Analytical Scope and Reproducibility

The workflow is reproducible in standard GIS software that supports projection, raster alignment, slope derivation, Euclidean distance, reclassification, weighted overlay, and point sampling. Its main outputs are: (1) a georeferenced inventory of 36 educational tourism attractions, (2) four standardized criterion layers, (3) a continuous suitability surface, (4) an ordinal suitability map, and (5) point-based suitability values for each attraction. The analysis is designed to support regional screening and planning prioritization; it does not directly measure interpretive quality, institutional capacity, visitor satisfaction, or actual learning outcomes at each site.

3. RESULTS AND DISCUSSION

3.1. Typological Distribution of the Inventory

The mapped inventory confirms that educational tourism in MAMMINASATA is not limited to a single attraction type or a single jurisdiction. The 36 inventoried sites comprise 16 natural tourism attractions (44.4%), 10 cultural tourism attractions (27.8%), 6 man-made attractions (16.7%), and 4 special-interest attractions (11.1%), indicating that the metropolitan edu-tourism resource base is dominated by nature-based and heritage-related learning settings.

In spatial terms, the inventory is distributed across all four local governments, with Makassar containing 12 sites (33.3%), Gowa 10 (27.8%), Maros 10 (27.8%), and Takalar 4 (11.1%). This pattern points to a multi-nodal metropolitan structure: Makassar and Gowa contribute the densest mix of urban cultural and service-connected destinations, whereas Maros contributes a larger share of natural attractions and Takalar remains more selective and peripheral within the present inventory.

3.2. Distribution of the Individual Suitability Criteria

3.2.1. Slope topographic conditions

Topographic conditions were generally favorable for education development (Tabel 4). Flat land (0-5°) covered 1,647.16 km² (41.58%) and gentle slopes (5-15°) covered 1,208.91 km² (30.52%), meaning that more than 72% of the modeled area fell within terrain that is relatively accessible and physically manageable for visitors and facilities. By contrast, steep and very steep slopes (>25°) accounted for only 341.97 km² (8.63%), indicating that severe terrain constraints were spatially limited.

Table 4. Slope classes, suitability scores, criterion weights, and areal distribution in the study area.

No.	Slope Class	Slope Range (°)	Suitability Score	Weight	Adjusted Area (km ²)	Percentage (%)
1	Flat	0-5	5	0.189	1647.16	41.58
2	Gentle	5-15	4	0.189	1208.91	30.52
3	Moderate	15-25	3	0.189	763.51	19.27
4	Steep	25-35	2	0.189	264.79	6.68
5	Very Steep	>35	1	0.189	77.18	1.95
Total					3961.55	100.00

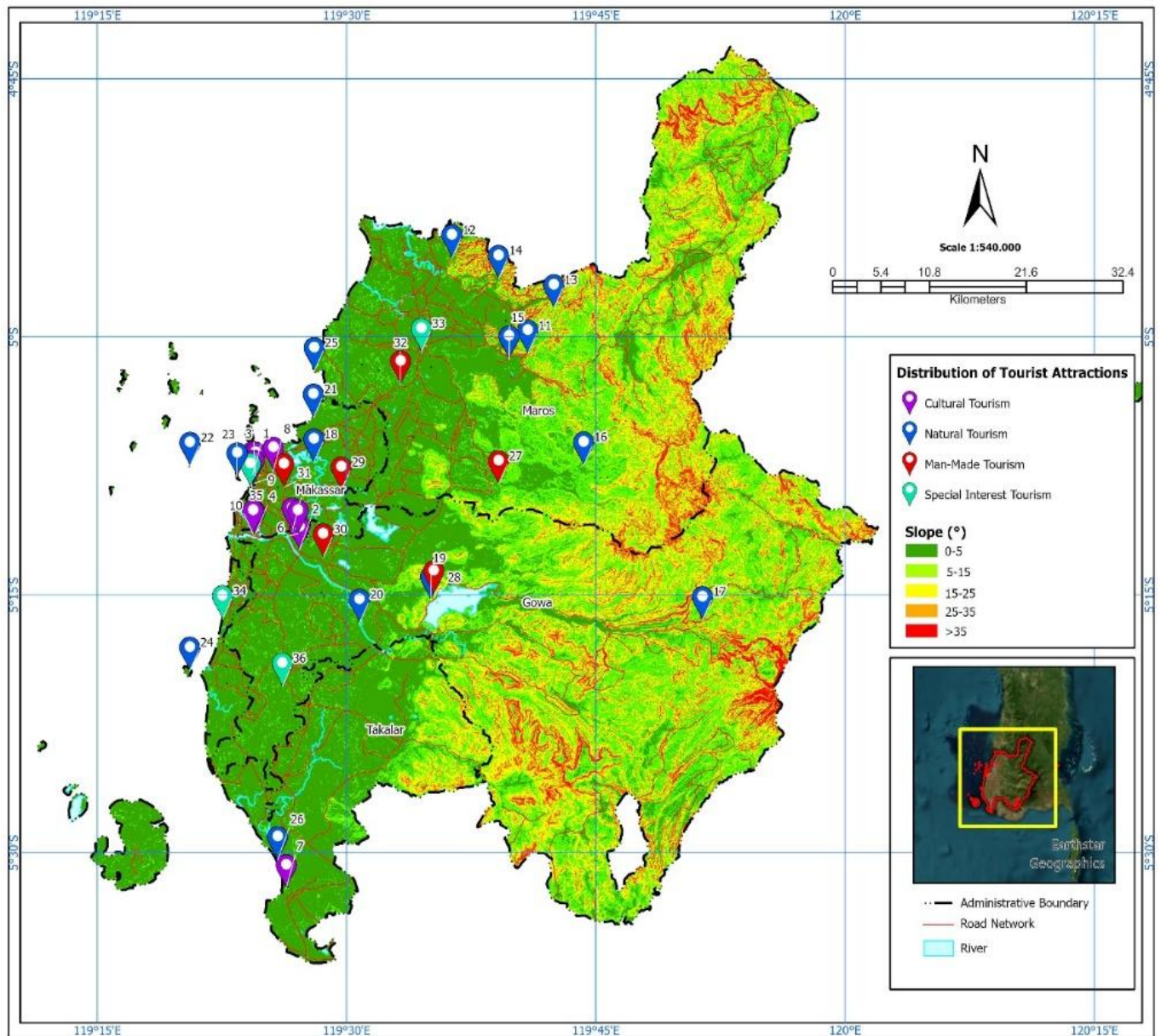


Figure 2. Slope classes in the MAMMINASATA Metropolitan Area derived from SRTM DEM and used as the topographic criterion in the edu-tourism suitability model.

Table 5. NDVI-based vegetation density classes, suitability scores, criterion weights, and areal distribution.

No.	Vegetation Density Class	NDVI Range	Suitability Score	Weight	Adjusted Area (km ²)	Percentage (%)
1	Non-vegetated	<0.15	1	0.250	257.68	6.50
2	Very Low Greenness	0.15-0.30	2	0.250	156.40	3.95
3	Low Greenness	0.30-0.45	3	0.250	347.33	8.77

No.	Vegetation Density Class	NDVI Range	Suitability Score	Weight	Adjusted Area (km ²)	Percentage (%)
4	High Greenness	0.45–0.60	4	0.250	638.52	16.12
5	Very High Greenness	>0.60	5	0.250	2561.62	64.66
Total					3961.55	100.00

Table 6. Road-accessibility distance classes, suitability scores, criterion weights, and areal distribution.

No.	Distance-to-Road Class (m)	Suitability Score	Weight	Adjusted Area (km ²)	Percentage (%)	
1	>5000	1	0.250	311.43	7.86	
2	3000–5000	2	0.250	467.73	11.81	
3	1500–3000	3	0.250	756.04	19.08	
4	500–1500	4	0.250	1233.96	31.15	
5	0–500	5	0.250	1192.39	30.10	
Total					3961.55	100.00

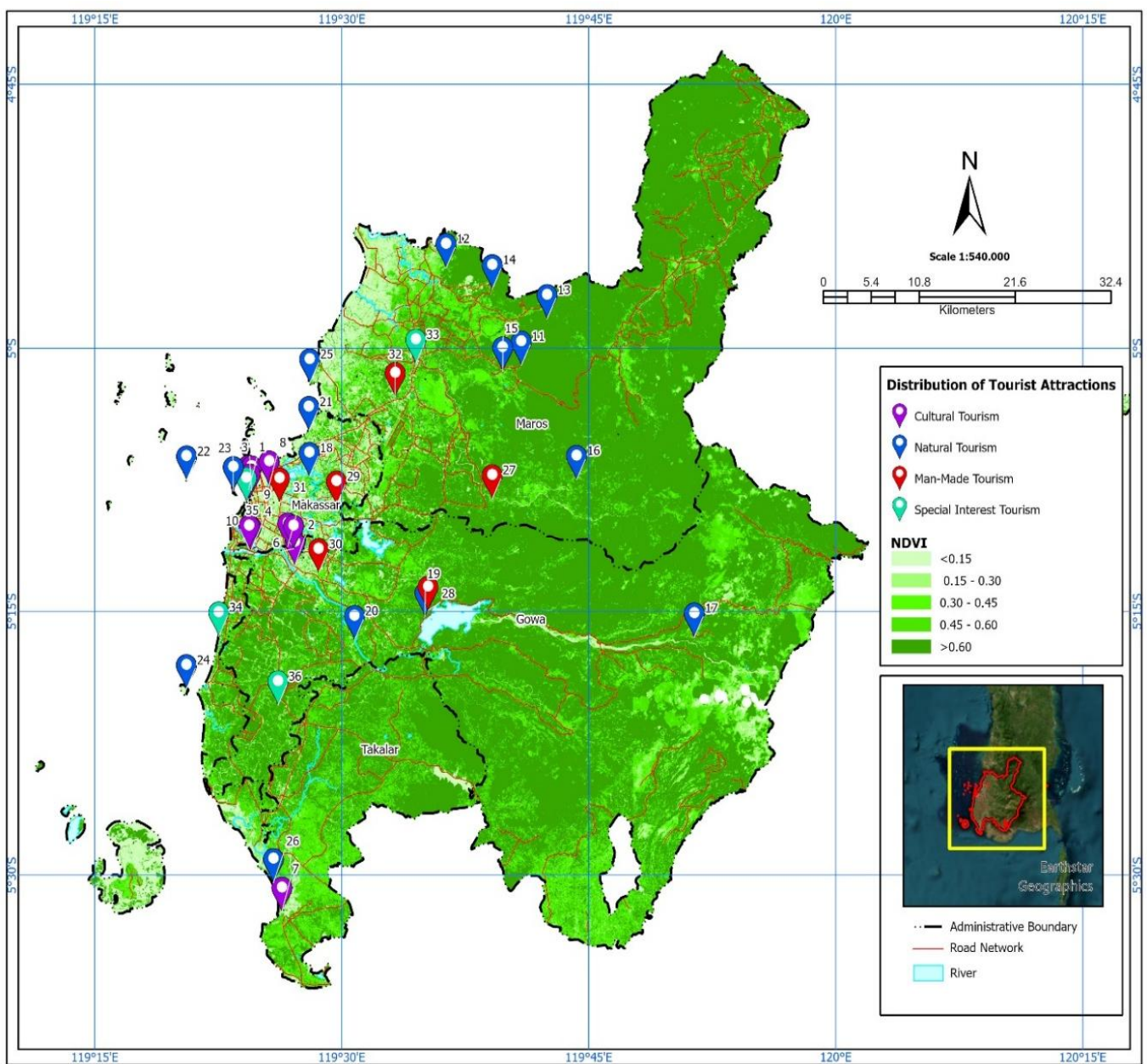


Figure 3. NDVI-based vegetation density classes in the MAMMINASATA Metropolitan Area derived from the 2025 Sentinel-2 composite.

3.2.2. Vegetation density (NDVI)

The vegetation layer also showed a strongly supportive environmental context. Areas with very high greenness (NDVI >0.60) covered 2,561.62 km² (64.66%), while high greenness (0.45-0.60) covered another 638.52 km² (16.12%). Lower-greenness classes were comparatively limited, which means that much of the metropolitan area retains the landscape quality and ecological setting that can strengthen nature-based and landscape-based learning experiences.

3.2.3. Road accessibility

Road accessibility was similarly favorable (Table 6). Land within 0-500 m of the road network covered 1,192.39 km² (30.10%), and the 500-1500 m class covered 1,233.96 km² (31.15%). Together, these two more accessible classes represented 61.25% of the study area, showing that a large share of MAMMINASATA is well connected to the metropolitan transport structure. Only 311.43 km² (7.86%) lay more than 5 km from the road network.

Table 7. Distance-to-activity-center classes, suitability scores, criterion weights, and areal distribution.

No.	Distance-to-Activity-Center Class	Suitability Score	Weight	Adjusted Area (km ²)	Percentage (%)
1	0-5	5	0.109	3666.72	92.56
2	5-10	4	0.109	281.35	7.10
3	10-20	3	0.109	13.48	0.34
Total				3961.55	100.00

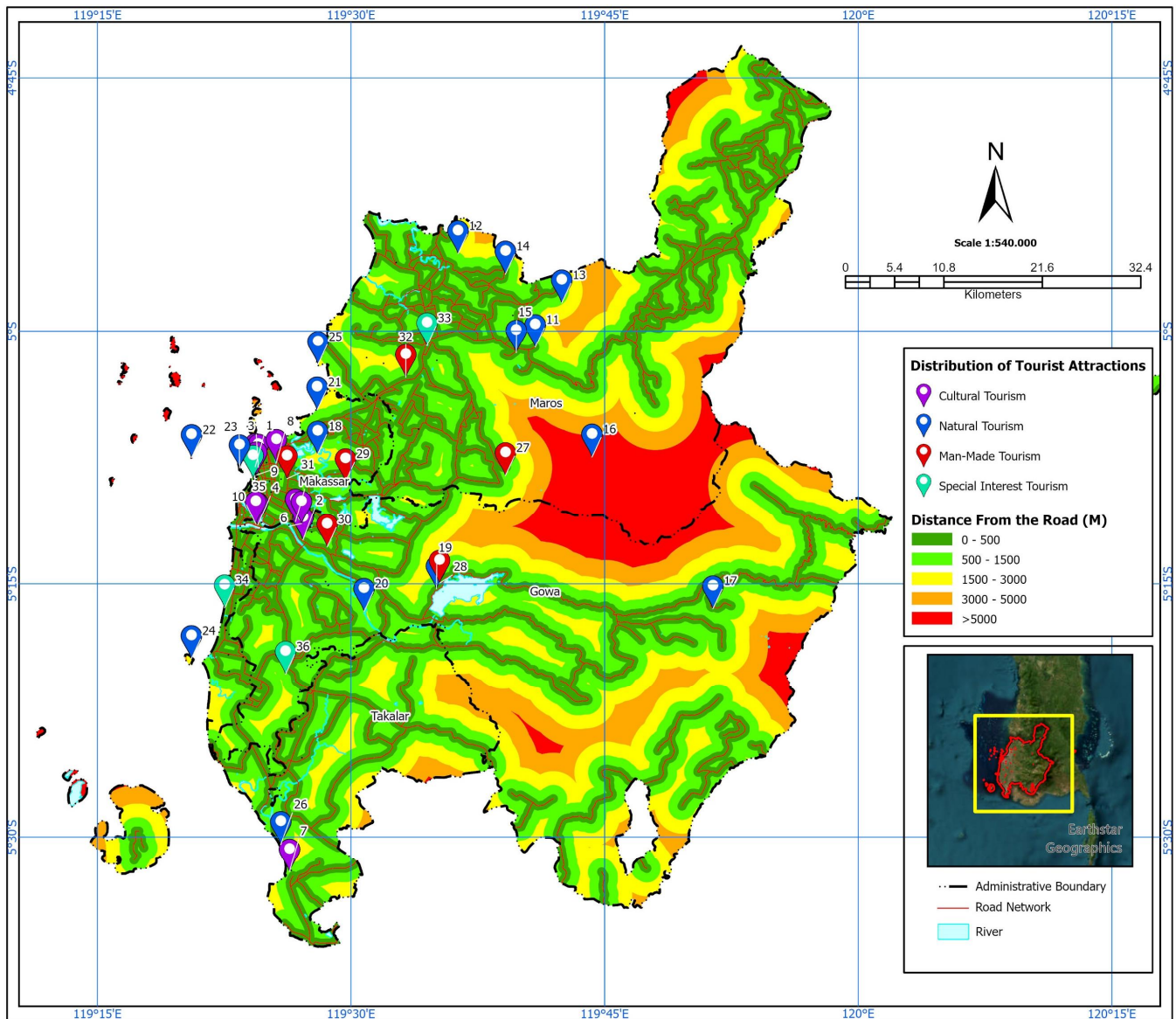


Figure 4. Road-accessibility classes in the MAMMINASATA Metropolitan Area based on distance from the road network.

3.2.4. Proximity to activity centers

Proximity to activity centers was the most spatially concentrated criterion. The 0-5 km class accounted for 3,666.72 km² (92.56%) of the study area, whereas the 5-10 km and 10-20 km classes accounted for only 281.35

km² (7.10%) and 13.48 km² (0.34%), respectively. This result indicates that most of the modeled landscape already lies within the metropolitan service sphere, so the activity-center criterion contributes comparatively little spatial differentiation relative to slope, vegetation, and road accessibility.

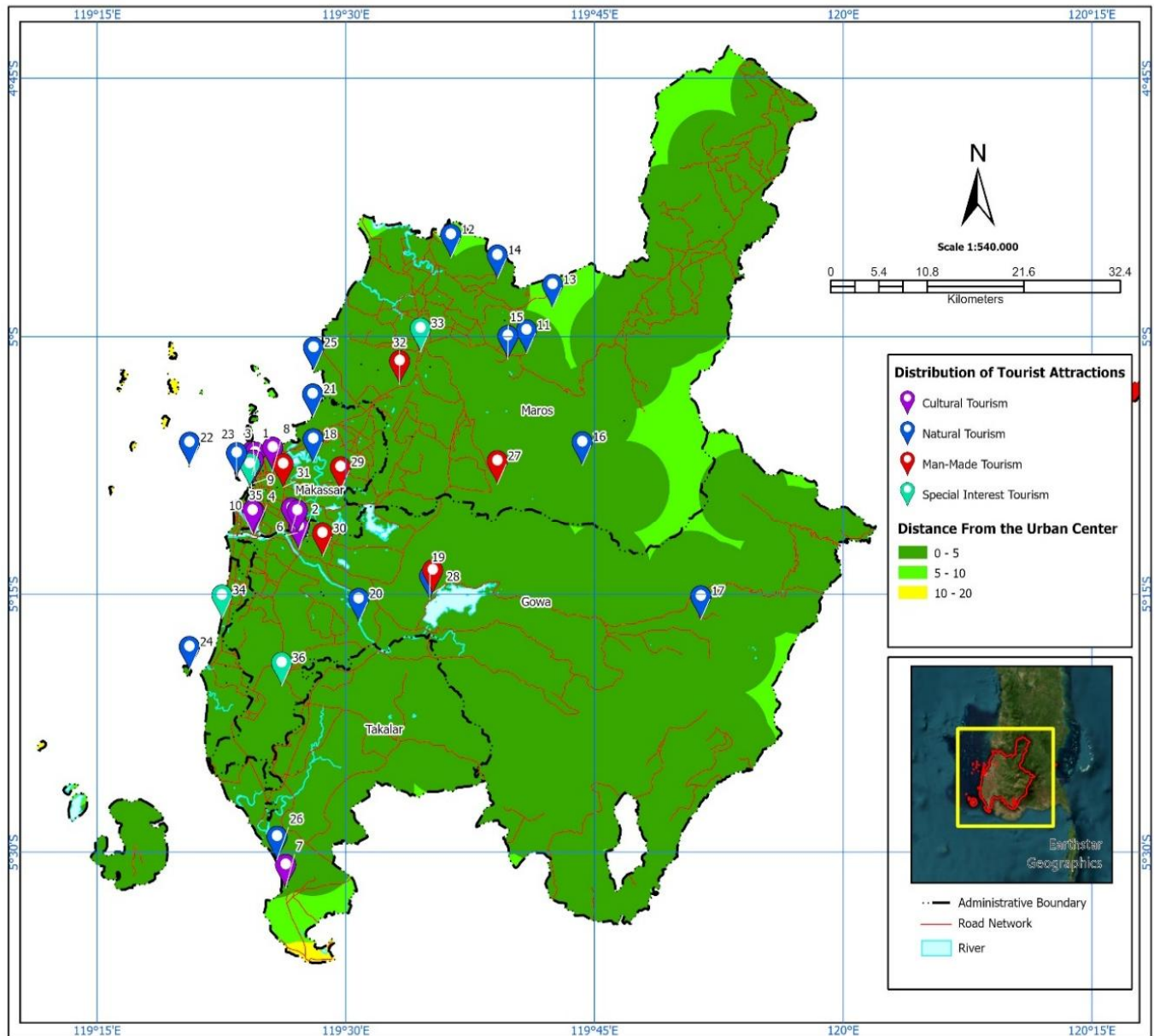


Figure 5. Proximity classes to metropolitan activity centers in the MAMMINASATA Metropolitan Area.

Table 8. Land-suitability classes and areal extent for Edu-tourism development in the MAMMINASATA metropolitan area.

No.	Suitability Class	Category	Suitability Range	Area (km ²)
1	Very Suitable	S1	4.2-5.0	2639.49
2	Suitable	S2	3.4-4.2	1182.10
3	Moderately Suitable	S3	2.6-3.4	121.76
4	Not Suitable	N	<2.6	18.20
Total				3961.55

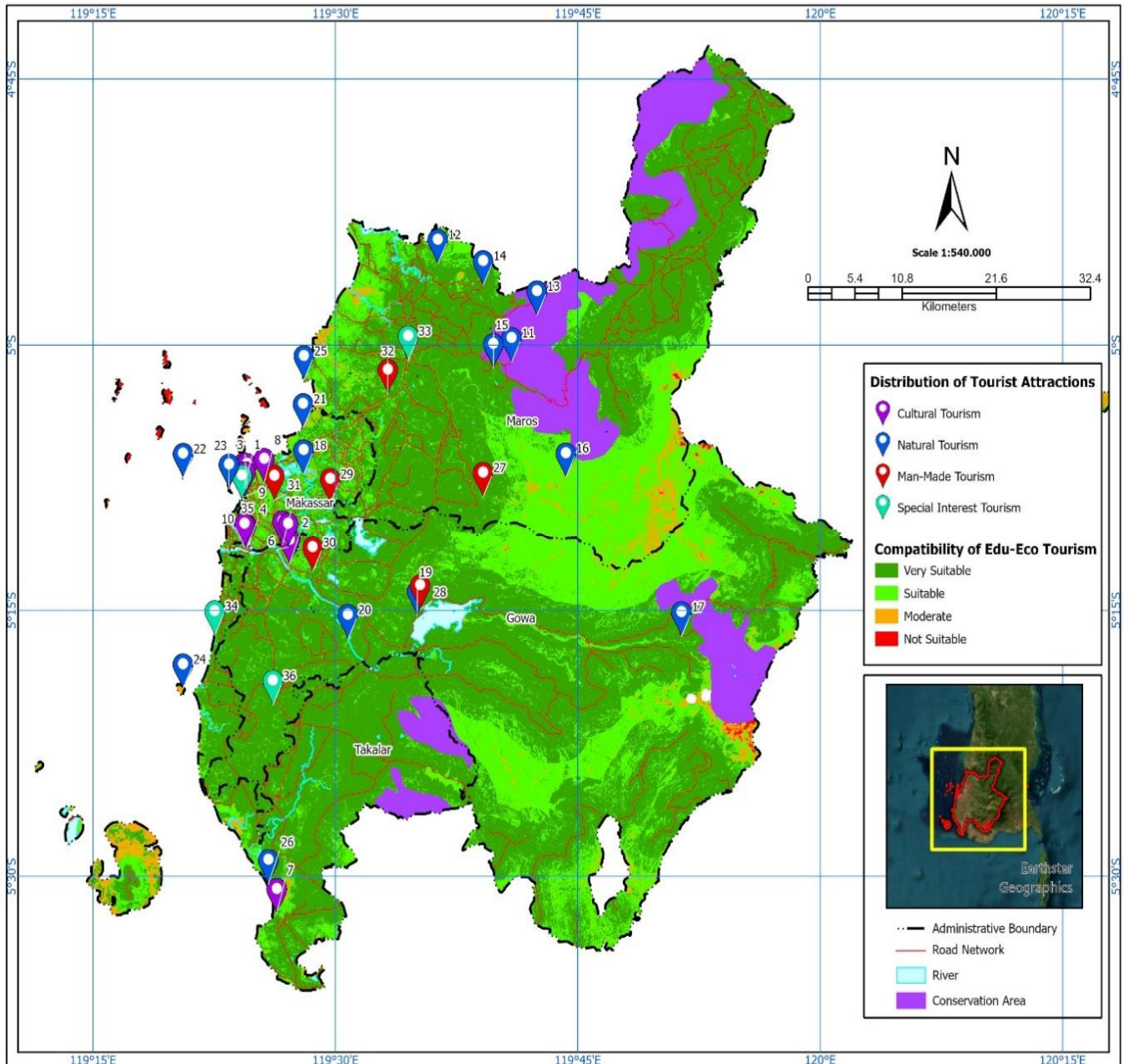


Figure 6. Composite land-suitability classes for edu-tourism development in the MAMMINASATA Metropolitan Area derived from the weighted overlay of slope, vegetation density, road accessibility, and activity-center proximity.

3.3. Composite Land Suitability Pattern

The weighted overlay produced a predominantly favorable land-suitability surface for Edu-tourism development. The very suitable class (S1) covered 2,639.49 km² (66.63%) and the suitable class (S2) covered 1,182.10 km² (29.84%). Combined, these two higher classes accounted for 96.47% of the modeled area, indicating that much of MAMMINASATA already meets the baseline territorial conditions required for educational tourism planning.

Lower suitability classes were spatially limited. The moderately suitable class (S3) covered 121.76 km² (3.07%), while the not suitable class (N) occupied only 18.20 km² (0.46%). In planning terms, this means that the main challenge in MAMMINASATA is less about

overcoming widespread physical unsuitability and more about prioritizing which already-favorable locations should be strengthened, interpreted, and connected within a metropolitan learning-resource network.

The suitability surface should be interpreted as a screening layer rather than as a direct measure of educational quality. The map identifies places with supportive territorial conditions - access, feasible terrain, greenness, and service proximity - but does not by itself capture interpretive programming, institutional readiness, or visitor learning outcomes.

3.4. Site-level Suitability of the Inventoried Attractions

Point extraction from the final suitability surface shows that existing Edu-tourism attractions are generally located in supportive territorial settings. Of the 36 inventoried sites, 21 (58.3%) fall in the very suitable class, 13 (36.1%) in the suitable class, and only 2 (5.6%) in the moderately suitable class. No inventoried site falls in the not suitable class, indicating that the current destination system is already concentrated in areas with at least moderate spatial support.

The site-based criterion profile clarifies why scores vary across attraction types (Table 8). Urban cultural sites in Makassar and Gowa are consistently associated with flat terrain, short road distances, and proximity to activity centers. At the same time, several natural and island-based destinations in Maros and Takalar show lower modeled support because they are farther from roads or activity centers and are more frequently associated with non-vegetated or lower-greenness classes.

Table 9. Site-based criterion characteristics extracted for each inventoried Edu-tourism attraction.

No.	Site Name	Regency/ City	Distance to Road (m)	Slope Class	Vegetation Density Class	Distance to Activity Center (m)
1	Fort Rotterdam	Makassar	80	Flat	Low Greenness	180
2	Balla Lompoa Palace	Gowa	80	Flat	Low Greenness	200
3	Makassar City Museum	Makassar	20	Flat	High Greenness	120
4	Somba Opu Fort	Gowa	80	Flat	High Greenness	>600
5	Sheikh Yusuf Tomb	Makassar	20	Flat	Low Greenness	380
6	Katangka Mosque	Gowa	10	Flat	Very Low Greenness	40
7	Maudu Lompoa Festival, Cikoang	Takalar	>310	Flat	Non-Vegetated Land	>600
8	Al-Markaz Al-Islami Jenderal Yusuf Mosque	Makassar	110	Gentle	Very Low Greenness	220
9	Losari Beach Culinary Area	Makassar	80	Flat	Non-Vegetated Land	200
10	Somba Opu Traditional Area	Gowa	10	Flat	High Greenness	>600
11	Bantimurung-Bulusaraung National Park	Maros	30	Steep	Non-Vegetated Land	>600
12	Rammang-Rammang Karst Area	Maros	>310	Flat	Non-Vegetated Land	>600
13	Leang-Leang Prehistoric Park	Maros	>310	Moderate	High Greenness	>600
14	Doli Bungaeja Tourism Site	Maros	110	Flat	High Greenness	>600
15	Parangtinggia Bat Village	Maros	110	Gentle	Low Greenness	160
16	Savana River	Maros	>310	Gentle	High Greenness	>600
17	Takapala Waterfall	Gowa	140	Very Steep	Moderate Greenness	>600
18	Lakkang Island	Makassar	>310	Gentle	Moderate Greenness	>600
19	Bili-Bili Reservoir	Gowa	160	Gentle	High Greenness	>600
20	Kampili Dam	Gowa	>310	Flat	Moderate Greenness	>600
21	Lantebung Mangrove Ecotourism	Makassar	>310	Flat	High Greenness	>600
22	Samalona Island	Makassar	>310	Flat	Non-Vegetated Land	>600
23	Lae-Lae Island	Makassar	>310	Flat	Non-Vegetated Land	>600
24	Sanrobengi Island	Takalar	>310	Flat	Non-Vegetated Land	>600
25	Kuri Beach (Caddi)	Maros	>310	Flat	Very Low Greenness	>600
26	Topejawa Beach	Takalar	>310	Flat	Non-Vegetated Land	>600
27	Pucak Teaching Farm	Maros	>310	Flat	Very Low Greenness	180
28	Dairyland Farm Theme Park	Gowa	>310	Flat	Low Greenness	>600
29	Bugis Waterpark Adventure	Makassar	>310	Flat	High Greenness	580
30	Dewi Sri Waterpark	Gowa	>310	Flat	Very Low Greenness	>600
31	Pakui Sayang Park	Makassar	150	Flat	Non-Vegetated Land	>600
32	Grandmall Waterboom	Maros	280	Flat	Non-Vegetated Land	600
33	PTB Maros Culinary Area	Maros	110	Flat	Non-Vegetated Land	140
34	Beba Takalar Fish Auction Site	Takalar	>310	Gentle	Non-Vegetated Land	500
35	Lego-Lego CPI Waterfront	Makassar	>310	Flat	Low Greenness	520
36	Denassa Garden	Gowa	>310	Flat	High Greenness	>600

Table 10. Extracted suitability scores and final suitability classes for the 36 inventoried Edu-tourism attractions.

Tourism Type	Site Name	Regency/City	Suitability Score	Suitability Class
Cultural Tourism	1. Fort Rotterdam	Makassar	4.70	Very Suitable
	2. Balla Lompoa Palace	Gowa	4.70	Very Suitable
	3. Makassar City Museum	Makassar	5.40	Very Suitable
	4. Somba Opu Fort	Gowa	5.40	Very Suitable
	5. Sheikh Yusuf Tomb	Makassar	4.70	Very Suitable
	6. Katangka Mosque	Gowa	4.35	Very Suitable
	7. Maudu Lompoa Festival, Cikoang	Takalar	3.65	Suitable
	8. Al-Markaz Al-Islami Jenderal Yusuf Mosque	Makassar	4.16	Suitable
	9. Losari Beach Culinary Area	Makassar	5.00	Very Suitable
	10. Somba Opu Traditional Area	Gowa	5.40	Very Suitable
Natural Tourism	11. Bantimurung-Bulusaraung National Park	Maros	3.43	Suitable
	12. Rammang-Rammang Karst Area	Maros	3.65	Suitable
	13. Leang-Leang Prehistoric Park	Maros	4.48	Very Suitable
	14. Doli Bungaeja Tourism Site	Maros	5.40	Very Suitable
	15. Parangtinggia Bat Village	Maros	4.51	Very Suitable
	16. Savana River	Maros	3.81	Suitable
	17. Takapala Waterfall	Gowa	4.29	Very Suitable
	18. Lakkang Island	Makassar	4.16	Suitable
	19. Bili-Bili Reservoir	Gowa	5.21	Very Suitable
	20. Kampili Dam	Gowa	4.70	Very Suitable
	21. Lantebung Mangrove Ecotourism	Makassar	5.05	Very Suitable
	22. Samalona Island	Makassar	2.40	Moderately Suitable
	23. Lae-Lae Island	Makassar	5.00	Very Suitable
	24. Sanrobengi Island	Takalar	3.29	Moderately Suitable
	25. Kuri Beach (Caddi)	Maros	3.65	Suitable
	26. Topejawa Beach	Takalar	3.65	Suitable
Man-Made Tourism	27. Pucak Teaching Farm	Maros	4.00	Suitable
	28. Dairyland Farm Theme Park	Gowa	4.70	Very Suitable
	29. Bugis Waterpark Adventure	Makassar	5.05	Very Suitable
	30. Dewi Sri Waterpark	Gowa	5.05	Very Suitable
	31. Pakui Sayang Park	Makassar	4.00	Suitable
	32. Grandmall Waterboom	Maros	4.00	Suitable
Special-Interest Tourism	33. PTB Maros Culinary Area	Maros	4.00	Suitable
	34. Beba Takalar Fish Auction Site	Takalar	3.46	Suitable
	35. Lego-Lego CPI Waterfront	Makassar	4.35	Very Suitable
	36. Denassa Garden	Gowa	5.00	Very Suitable

The class distribution also differs by attraction type. Cultural tourism shows the strongest overall performance, with 8 of 10 sites in the very suitable class and the remaining 2 in the suitable class, reflecting its concentration in accessible urban and heritage areas. Natural tourism is more heterogeneous, with 8 very suitable, 6 suitable, and 2 moderately suitable sites, which is consistent with its broader spread across coastal, island, karst, and upland settings.

A similar territorial contrast appears across jurisdictions. All 10 inventoried attractions in Gowa fall in

the very suitable class, while Makassar records 8 very suitable, 3 suitable, and 1 moderately suitable site. Maros is more mixed, with 3 very suitable and 7 suitable attractions, whereas Takalar contains 3 suitable and 1 moderately suitable site and no very suitable site in the current inventory. These differences suggest that the strongest immediate planning leverage lies in Makassar-Gowa urban and peri-urban corridors, while Takalar and parts of Maros may require stronger accessibility, environmental management, or destination-integration strategies.

The findings indicate that educational tourism in MAMMINASATA is territorially diverse, but this diversity is not translated into spatial equivalence across attraction categories or administrative jurisdictions. Although the metropolitan area contains a broad portfolio of cultural, natural, man-made, and special-interest destinations, the spatial performance of these attractions is clearly uneven. Sites located in Makassar and Gowa—particularly cultural and mixed-use attractions—tend to combine high attraction value with favorable territorial support, including stronger road accessibility, gentler terrain, and closer functional relationships with metropolitan services. By contrast, several coastal, island, and more peripheral natural attractions display more variable suitability because their educational potential is mediated by weaker accessibility and less advantageous territorial context. In this sense, the first research question is best understood not merely through the presence of attractions, but through the internal differentiation of the metropolitan Edu-tourism system according to both attraction type and locational conditions [43].

The weighted-overlay results further show that MAMMINASATA is, in general, territorially supportive of educational tourism development. The predominance of S1 and S2 classes suggests that large parts of the metropolitan area combine relatively favorable terrain, vegetation conditions, road access, and proximity to service concentrations. However, the site-based extraction also demonstrates that favorable areal suitability does not automatically produce uniform site-level readiness. Attractions embedded in the urban core and well-connected peri-urban corridors tend to perform more strongly than destinations in coastal and island settings, where accessibility constraints and service distance remain more pronounced. Accordingly, the third research question is answered through a logic of differentiated prioritization: the key planning issue is no longer whether educational tourism can be developed in MAMMINASATA, but which areas are immediately ready for integration, which require targeted accessibility and service improvements, and which should remain subject to more selective or cautious development.

Taken together, these results suggest that educational tourism suitability in MAMMINASATA should be interpreted as a gradient of metropolitan readiness rather than a binary distinction between suitable and unsuitable areas. This is an important conceptual point because it shifts the discussion from simple resource inventory toward spatial capability: attractions become educationally valuable not only because of their thematic or scenic content, but because they are embedded within territorial conditions that enable interpretation, movement, supervision, and repeated educational use. In practical terms, the results show that metropolitan structure matters as much as attraction content in shaping edu-tourism potential [12], [44], [45].

The MAMMINASATA findings are broadly consistent with GIS-MCDA tourism studies that identify accessibility, terrain feasibility, environmental quality, and proximity to settlement or service concentrations as recurrent determinants of tourism suitability. Earlier ecotourism suitability studies using GIS-AHP and related MCDA approaches likewise show that road proximity, slope, land cover or vegetation, and supporting settlement characteristics strongly influence where tourism development is most feasible [18], [43]. The predominance of S1 and S2 classes in MAMMINASATA follows this general pattern, reflecting the fact that large portions of the metropolitan area possess relatively manageable topography and broad accessibility advantages.

At the same time, this study extends previous GIS-MCDA work in two important ways. First, it shows that high educational-tourism suitability is not limited to remote or purely natural landscapes. Several of the strongest-performing sites in MAMMINASATA are cultural, urban, or mixed-use attractions located in or near the metropolitan core. This finding departs from a substantial portion of ecotourism suitability literature, which tends to privilege relatively pristine or mountainous environments. Instead, it supports more recent arguments that tourism spaces can function as learning resources across natural, cultural, and community settings [12], [46]. In other words, educational value is not monopolized by “naturalness”; it can also emerge from heritage concentration, interpretive opportunity, and the density of supporting urban infrastructure.

Second, the site-level results demonstrate that natural attractions are not automatically the most suitable for educational tourism simply because they possess ecological or scenic value. Natural destinations located in steeper, more peripheral, coastal, or island environments perform more unevenly when assessed against territorial support variables. This resonates with tourism-suitability studies showing that the developmental potential of high-value sites may be constrained by physical inaccessibility or infrastructural weakness, even where scenic or ecological assets are substantial [18], [43]. The MAMMINASATA case therefore refines the common assumption that natural attractions should necessarily be prioritized in Edu-tourism planning; in practice, suitability depends on how environmental qualities interact with accessibility, service reach, and metropolitan connectivity.

The findings also resonate strongly with tourism-learning literature, which argues that educational potential cannot be explained by attraction content alone. Travel learning has long been understood as a process shaped by engagement, reflection, interpretation, and context rather than by passive exposure to places [8], [9]. More recent work further emphasizes that tourism learning outcomes depend on how experiences are intentionally designed and facilitated, including the role

of guided interpretation, activity structure, and interaction scenarios [5], [46], [47]. The strong performance of well-connected cultural sites in Makassar and Gowa is therefore significant: their planning advantage lies not only in thematic or heritage value, but also in the metropolitan conditions that make interpretation, group mobility, supervision, and repeated educational programming easier to organize and sustain.

This interpretation is also supported by recent educational-tourism studies showing that learning outcomes are multidimensional and often depend on structured encounters that connect mobility with reflection, cultural exposure, and guided experience. Contemporary research has shown that educational tourism can generate cognitive, affective, and behavioral gains, while study-tour formats can improve practical knowledge application, critical thinking, self-awareness, teamwork, and social responsibility [48]–[50]. Related work on educational travelers' cross-cultural experiences also suggests that learning through travel can be transformative when visitors are exposed to new settings through meaningful interaction and reflection [51]. Within this broader literature, the MAMMINASATA findings suggest that the most suitable sites are those where territorial conditions make such structured and sustained learning encounters more feasible.

3.5. Implications of Theoretical and Practical

The findings theoretically support the view that educational tourism constitutes a spatially embedded learning resource system rather than merely a form of student mobility, organized educational travel, or university-based activity [1], [2], [6]. The MAMMINASATA case demonstrates that attractions acquire educational significance not only through their content, but also through the territorial conditions that facilitate access, movement, interpretation, and visitor engagement. This pattern is particularly evident in the strong performance of urban cultural and mixed-use sites, whose educational potential is amplified by metropolitan connectivity.

The results also accord with tourism-learning studies that conceptualize learning as an experiential process shaped by place and contextual support [5], [8], [9]. Although spatial suitability does not directly measure learning outcomes, it identifies the territorial conditions that make learning-oriented tourism more accessible, practicable, and repeatable. In this respect, the study distinguishes educational value from educational effectiveness.

From a practical perspective, the findings indicate the need for differentiated planning priorities across subregions. Makassar and Gowa exhibit strong potential for short educational routes connecting museums, heritage sites, religious landmarks, parks, and waterfront spaces. In these areas, planning should prioritize interpretation, route integration, and institutional coordination. By contrast, natural, coastal, and island-

based attractions require more selective forms of upgrading. In Maros, development should balance improvements in accessibility with environmental protection, consistent with sustainable tourism suitability studies in environmentally sensitive landscapes [15], [25]. In Takalar and the island destinations surrounding Makassar, lower suitability is more closely associated with weaker access and service connectivity. This suggests a need for transport integration, safer access infrastructure, interpretation, signage, and basic visitor facilities before broader promotional efforts are undertaken.

3.6. Limitations and Future Research

Several limitations should be acknowledged. First, the model incorporates only four spatial criteria and therefore captures enabling territorial conditions rather than the full educational performance of a destination. Important variables, including interpretive quality, management capacity, safety services, institutional partnerships, programming intensity, and actual learning outcomes, were not directly measured. Second, the weighting scheme was implemented as a planning-oriented weighted overlay rather than through formal AHP pairwise comparison or extensive expert elicitation. Third, the attraction inventory was treated as a point-based dataset. Although this approach is appropriate for metropolitan-scale screening, it may oversimplify the internal spatial complexity of large sites such as national parks, waterfronts, and cultural landscapes.

Future research should extend the framework both methodologically and substantively. Methodological refinements could include alternative weighting scenarios, travel-time measures, and network-based accessibility analysis in place of reliance on Euclidean distance alone. Substantive extensions could incorporate interpretive infrastructure, conservation sensitivity, hazard exposure, public transport access, and service capacity. Further research should also examine the relationship between spatial suitability and visitor learning outcomes, satisfaction, and behavioral change through survey-based or mixed-method designs, in line with tourism-learning research [52]–[54]. Comparative applications in other metropolitan or peri-urban regions of Indonesia would also help determine whether the MAMMINASATA pattern reflects a broader model of Edu-tourism development in emerging urban regions.

4. CONCLUSION

This study shows that educational tourism in the MAMMINASATA Metropolitan Area should be understood as a spatially embedded learning resource system rather than merely as a set of attractions. By integrating attraction inventory, typological classification, and GIS-based weighted overlay analysis, the study finds that edu-

tourism resources are widely distributed across Makassar, Gowa, Maros, and Takalar, but their spatial readiness is uneven. Most of the study area falls within the very suitable and suitable classes, and most inventoried attractions are already located in supportive territorial settings. Makassar and Gowa show the strongest immediate potential, while parts of Maros and Takalar remain more conditional due to weaker accessibility and service connectivity.

These findings contribute by linking educational tourism more explicitly with metropolitan spatial planning. The results suggest that attraction value should be assessed not only by thematic content, but also by the territorial conditions that support access, interpretation, and repeated learning use. In practical terms, Makassar and Gowa should be prioritized for route integration and interpretive development, whereas Maros and Takalar require more selective improvements in accessibility, visitor support, and environmentally sensitive planning. Overall, the study confirms that the future of edu-tourism in MAMMINASATA depends on how effectively attractions are organized into an integrated and sustainable metropolitan learning network.

ACKNOWLEDGMENTS

The authors would like to express their deepest gratitude to the Directorate of Research and Community Service, Ministry of Higher Education, Science, and Technology (KEMDIKTISAINTEK) Republic of Indonesia, Universitas Negeri Makassar, Department of Culture and Tourism Provincial Government and our colleagues for their exceptional support and resources, which were critical in facilitating this research.

CONFLICTS OF INTEREST

The authors declare that no conflicts of interest are associated with this study. All aspects of the research were conducted with the utmost integrity and transparency.

DATA AVAILABILITY

The datasets utilized and analyzed during this research are available from the corresponding author upon reasonable request.

ETHICAL STATEMENTS

Not applicable. This study did not involve any human participants or animals, and no personal or sensitive data were collected, used, or analyzed at any stage of the research.

FUNDING

This study was funded by Directorate of Research and Community Service (DPPM) KEMDIKTISAINTEK (Directorate of Research and Community Service, Ministry of Higher Education, Science, and Technology) under Grant No. 084/C3/DT.05.00/PL/2025.

REFERENCES

- [1] S. Tomasi, G. Paviotti, and A. Cavicchi, "Educational tourism and local development: The role of universities," *Sustain.*, vol. 12, no. 17, p. 6766, 2020, <https://doi.org/10.3390/SU12176766>
- [2] B. W. Ritchie, *Managing Educational Tourism*, vol. 10. Channel View Publications, 2004.
- [3] S. Zhang, J. Liu, and Y. Li, "Tourism Learning Resources and Development Strategies in China: A Review and Conceptual Framework," *Land*, vol. 14, no. 7, p. 1421, 2025, <https://doi.org/10.3390/land14071421>
- [4] Y. Chai, B. Dai, Y. Zhang, and Y. Wang, "Partnerships in educational tourism in China: a power perspective," *J. Sustain. Tour.*, vol. 33, no. 7, pp. 1330-1347, 2025, <https://doi.org/10.1080/09669582.2024.2346789>
- [5] J. Bueddefeld and M. D. Duerden, "The transformative tourism learning model," *Ann. Tour. Res.*, vol. 94, p. 103405, 2022, <https://doi.org/10.1016/j.annals.2022.103405>
- [6] C. A. McGladdery and B. A. Lubbe, "Rethinking educational tourism: proposing a new model and future directions," *Tour. Rev.*, vol. 72, no. 3, pp. 319-329, 2017, <https://doi.org/10.1108/TR-03-2017-0055>
- [7] M. D. Kurniawan and H. Haryanto, "GOMS-based User Experience for Cultural Tourism Application in Indonesia," *Adv. Sustain. Sci. Eng. Technol.*, vol. 6, no. 1, 2024, <https://doi.org/10.26877/asset.v6i1.17862>
- [8] J. H. Falk, R. Ballantyne, J. Packer, and P. Benckendorff, "Travel and Learning: A Neglected Tourism Research Area," *Ann. Tour. Res.*, vol. 39, no. 2, pp. 908-927, 2012, <https://doi.org/10.1016/j.annals.2011.11.016>
- [9] C. M. van Winkle and K. Lagay, "Learning during tourism: the experience of learning from the tourist's perspective," *Stud. Contin. Educ.*, vol. 34, no. 3, pp. 339-355, 2012, <https://doi.org/10.1080/0158037X.2011.646981>
- [10] R. P. Sari and S. R. Henim, "Measurement and Analysis of Tourism Website User Experience Using Usability Techniques," *J. Appl. Eng. Technol. Sci.*, vol. 4, no. 1, pp. 539-546, 2022, <https://doi.org/10.37385/jaets.v4i1.1343>
- [11] R. Ballantyne, J. Packer, and J. Falk, "Visitors' learning for environmental sustainability: Testing short- and long-term impacts of wildlife tourism experiences using structural equation modelling," *Tour. Manag.*, vol. 32, no. 6, pp. 1243-1252, 2011, <https://doi.org/10.1016/j.tourman.2010.11.003>
- [12] M. A. M. Mir, B. Shelley, and C. S. Ooi, "Uses of tourism resources for educational and community development: A systematic literature review and lessons," *Tour. Manag. Perspect.*, vol. 53, p. 101278, 2024, <https://doi.org/10.1016/j.tmp.2024.101278>
- [13] L. Safriana, Nurhayati, Widiyani, and D. Suharjito, "Narrative-Driven Optimization for Sustainable Museum Networks: Integrating Freytag's Pyramid and Hybrid PSO-Machine Learning Framework," *Adv. Sustain. Sci. Eng. Technol.*, vol. 7, no. 4, 2025, <https://doi.org/10.26877/asset.v7i4.1954>
- [14] M. K. Sari, R. P. Lita, S. Lenggogeni, and M. Ma'ruf, "The Paradox of Smart Tourism: Does Technology Empower or Discourage Experience Sharing," *J. Appl. Eng. Technol. Sci.*, vol. 7, no. 1, pp. 519-538, 2025, <https://doi.org/10.37385/jaets.v7i1.7353>
- [15] N. C. Withanage, D. Chanuwan Wijesinghe, P. K. Mishra, K. Abdelrahman, V. Mishra, and M. S. Fnais, "An ecotourism suitability index for a world heritage city using GIS-multi criteria decision analysis techniques," *Heliyon*, vol. 10, no. 11, 2024, <https://doi.org/10.1016/j.heliyon.2024.e31585>
- [16] D. Omarzadeh, S. Pourmoradian, B. Feizizadeh, H. Khallaghi, A. Sharifi, and K. V. Kamran, "A GIS-based multiple ecotourism sustainability assessment of West

- Azerbaijan province, Iran,” *J. Environ. Plan. Manag.*, vol. 65, no. 3, pp. 490–513, 2022, <https://doi.org/10.1080/09640568.2021.1887827>
- [17] E. Aksoy and B. T. San, “Geographical information systems (GIS) and Multi-Criteria Decision Analysis (MCDA) integration for sustainable landfill site selection considering dynamic data source,” *Bull. Eng. Geol. Environ.*, vol. 78, no. 2, pp. 779–791, 2019, <https://doi.org/10.1007/s10064-017-1135-z>
- [18] K. Bunruamkaew and Y. Murayama, “Site suitability evaluation for ecotourism using GIS & AHP: A case study of surat Thani Province, Thailand,” *Procedia - Soc. Behav. Sci.*, vol. 21, pp. 269–278, 2011, <https://doi.org/10.1016/j.sbspro.2011.07.024>
- [19] K. M. Ullah and R. Hafiz, “Finding suitable locations for ecotourism development in Cox’s Bazar using Geographical Information System and Analytical Hierarchy Process,” *Geocarto Int.*, vol. 29, no. 3, pp. 256–267, 2014, <https://doi.org/10.1080/10106049.2012.760005>
- [20] G. Hassanshahi, A. Soltani, M. Roosta, and S. Askari, “Walking as soft mobility: A multi-criteria GIS-based approach for prioritizing tourist routes,” *Front. Archit. Res.*, vol. 12, no. 6, pp. 1080–1096, 2023, <https://doi.org/10.1016/j.foar.2023.09.001>
- [21] C. Çetinkaya, M. Kabak, M. Erbaş, and E. Özceylan, “Evaluation of ecotourism sites: a GIS-based multi-criteria decision analysis,” *Kybernetes*, vol. 47, no. 8, pp. 1664–1686, 2018, <https://doi.org/10.1108/K-10-2017-0392>
- [22] M. Salehipour, N. Kazemi, J. Jokar Arsanjani, and M. Karimi Firozjaei, “Developing a Multi-Criteria Decision Model to Unlock Sustainable Heritage Tourism Potential,” *Sustain.*, vol. 17, no. 8, p. 3703, 2025, <https://doi.org/10.3390/su17083703>
- [23] A. Acharya et al., “Geospatial Analysis of Geo-Ecotourism Site Suitability Using AHP and GIS for Sustainable and Resilient Tourism Planning in West Bengal, India,” *Sustain.*, vol. 14, no. 4, p. 2422, 2022, <https://doi.org/10.3390/su14042422>
- [24] Q. Quan and Y. Wu, “Integrating Entropy Weight and MaxEnt Models for Ecotourism Suitability Assessment in Northeast China Tiger and Leopard National Park,” *Land*, vol. 13, no. 8, p. 1269, 2024, <https://doi.org/10.3390/land13081269>
- [25] F. Khazaee Fadafan, A. Soffianian, S. Pourmanafi, and M. Morgan, “Assessing ecotourism in a mountainous landscape using GIS – MCDA approaches,” *Appl. Geogr.*, vol. 147, p. 102743, 2022, <https://doi.org/10.1016/j.apgeog.2022.102743>
- [26] M. C. M. Parlato and A. Pezzuolo, “Rural–Urban Linkages and Development: A GIS-MCDA Approach to Sustainable Cyclo-Tourism and Rural Land Protection,” *L. Degrad. Dev.*, vol. 36, no. 14, pp. 4809–4826, 2025, <https://doi.org/10.1002/ldr.5669>
- [27] R. R. Putra, I. D. Perwitasari, D. M. Rangkutiy, V. Tasril, S. Handayani, and A. S. Dewi, “From Virtual To Reality: How Metaverse and VR Technologies Influence Travel Decisions,” *J. Appl. Eng. Technol. Sci.*, vol. 6, no. 2, pp. 862–873, 2025, <https://doi.org/10.37385/jaets.v6i2.6314>
- [28] J. Malczewski, “GIS-based multicriteria decision analysis: A survey of the literature,” *Int. J. Geogr. Inf. Sci.*, vol. 20, no. 7, pp. 703–726, 2006, <https://doi.org/10.1080/13658810600661508>
- [29] C. Leake and J. Malczewski, *GIS and Multicriteria Decision Analysis*, vol. 51, no. 2. John Wiley & Sons, 2000. <https://doi.org/10.2307/254268>
- [30] J. Malczewski, “GIS-based land-use suitability analysis: a critical overview,” *Prog. Plann.*, vol. 62, no. 1, pp. 3–65, 2004.
- [31] C. Antweiler, “Towards a cosmopolitan Indonesia: Makassar as a paradigm for organising cultural diversity?,” *Asian J. Soc. Sci.*, vol. 47, no. 3, pp. 340–363, 2019, <https://doi.org/10.1163/15685314-04703004>
- [32] A. M. Y. Hakim, S. Baja, D. A. Rampisela, S. Arif, M. Matsuoka, and I. Ridwansyah, “Assessment of future environmental carrying capacity in the Mamminasata area, Indonesia, derived from regional census and land cover,” *Int. J. Environ. Stud.*, vol. 80, no. 5, pp. 1417–1434, 2023, <https://doi.org/10.1080/00207233.2023.2204001>
- [33] F. Pucha-Cofrep and A. Fries, *ArcGIS Pro Manual*. Franz Pucha Cofrep, 2025.
- [34] M. Drusch et al., “Sentinel-2: ESA’s optical high-resolution mission for GMES operational services,” *Remote Sens. Environ.*, vol. 120, pp. 25–36, 2012, <https://doi.org/10.1016/j.rse.2011.11.026>
- [35] C. J. Tucker, “Red and photographic infrared linear combinations for monitoring vegetation,” *Remote Sens. Environ.*, vol. 8, no. 2, pp. 127–150, 1979, [https://doi.org/10.1016/0034-4257\(79\)90013-0](https://doi.org/10.1016/0034-4257(79)90013-0)
- [36] F. Joerin, M. Thériault, and A. Musy, “Using GIS and outranking multicriteria analysis for land-use suitability assessment,” *Int. J. Geogr. Inf. Sci.*, vol. 15, no. 2, pp. 153–174, 2001, <https://doi.org/10.1080/13658810051030487>
- [37] J. Ommer et al., “The Impact of Spatial Resolutions on Nature-Based Solution Suitability Mapping for Europe,” *Appl. Sci.*, vol. 14, no. 11, p. 4608, 2024, <https://doi.org/10.3390/app14114608>
- [38] J. Malczewski, “Ordered weighted averaging with fuzzy quantifiers: GIS-based multicriteria evaluation for land-use suitability analysis,” *Int. J. Appl. Earth Obs. Geoinf.*, vol. 8, no. 4, pp. 270–277, 2006, <https://doi.org/10.1016/j.jag.2006.01.003>
- [39] A. Stein, W. Shi, and M. R. Delavar, “Preface-ISPRS international symposium on spatial data quality (ISSDQ 2019),” in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, 2019, vol. 42, no. 2/W13, pp. 1191–1192. <https://doi.org/10.5194/isprs-archives-XLII-2-W13-1191-2019>
- [40] F. Zabel, B. Putzenlechner, and W. Mauser, “Correction: Global agricultural land resources - A high resolution suitability evaluation and its perspectives until 2100 under climate change conditions,” *PLoS One*, vol. 9, no. 12, p. e107522, 2014, <https://doi.org/10.1371/journal.pone.0114980>
- [41] T. Orusa, A. Viani, D. Cammareri, and E. Borgogno Mondino, “A Google Earth Engine Algorithm to Map Phenological Metrics in Mountain Areas Worldwide with Landsat Collection and Sentinel-2,” *Geomatics*, vol. 3, no. 1, pp. 221–238, 2023, <https://doi.org/10.3390/geomatics3010012>
- [42] L. Caiza-Morales, C. Gómez, R. Torres, A. P. Nicolau, and J. M. Olano, “MANGLEE: A Tool for Mapping and Monitoring MANgrove Ecosystem on Google Earth Engine—A Case Study in Ecuador,” *J. Geovisualization Spat. Anal.*, vol. 8, no. 1, p. 17, 2024, <https://doi.org/10.1007/s41651-024-00175-3>

- [43] N. Sahani, "Application of analytical hierarchy process and GIS for ecotourism potentiality mapping in Kullu District, Himachal Pradesh, India," *Environ. Dev. Sustain.*, vol. 22, no. 7, pp. 6187–6211, 2020, <https://doi.org/10.1007/s10668-019-00470-w>
- [44] A. Iranmanesh and S. Abokhamis Mousavi, "Insights from the relationship between urban form, social media, and edu-tourism," *Curr. Issues Tour.*, vol. 26, no. 15, pp. 2559–2574, 2023, <https://doi.org/10.1080/13683500.2022.2090908>
- [45] H. Alipour, H. Fatemi, and N. Malazizi, "Is edu-tourism a sustainable option? A case study of residents' perceptions," *Sustainability*, vol. 12, no. 15, p. 5937, 2020, <https://doi.org/10.3390/su12155937>
- [46] J. Wang and J. Dolah, "A Framework for Facilitating Experiential Learning in Cultural Tourism," *Int. J. Virtual Pers. Learn. Environ.*, vol. 14, no. 1, pp. 1–24, 2024, <https://doi.org/10.4018/IJVPLE.360381>
- [47] A. Durko and H. Martens, "Fostering higher level cultural learning among tourism students through virtual interaction," *J. Teach. Travel Tour.*, vol. 21, no. 3, pp. 235–247, 2021, <https://doi.org/10.1080/15313220.2021.1880350>
- [48] M. Tong and T. Gao, "Beyond the classroom: Evaluating study tours' impact on adolescents' learning outcomes, psychological growth, and social responsibility," *Acta Psychol. (Amst.)*, vol. 261, p. 105740, 2025, <https://doi.org/10.1016/j.actpsy.2025.105740>
- [49] S. X. Chen, L. Yu, S. W. T. Tse, and Y. Zhang, "When travel teaches: Unpacking student outcomes in educational tourism," *Tour. Manag. Perspect.*, vol. 58, p. 101385, 2025, <https://doi.org/10.1016/j.tmp.2025.101385>
- [50] D. C. Moos and B. Honkomp, "Adventure learning: Motivating students in a Minnesota middle school," *J. Res. Technol. Educ.*, vol. 43, no. 3, pp. 231–252, 2011, <https://doi.org/10.1080/15391523.2011.10782571>
- [51] M. W. Teoh, Y. Wang, and A. Kwek, "Deconstructing transformations: educational travellers' cross-cultural transformative experiences," *J. Hosp. Tour. Manag.*, vol. 58, pp. 506–515, 2024, <https://doi.org/10.1016/j.jhtm.2023.02.012>
- [52] W. H. Lee and G. Moscardo, "Understanding the impact of ecotourism resort experiences on tourists' environmental attitudes and behavioural intentions," *J. Sustain. Tour.*, vol. 13, no. 6, pp. 546–565, 2005, <https://doi.org/10.1080/09669580508668581>
- [53] K. Hughes, J. Packer, and R. Ballantyne, "Using post-visit action resources to support family conservation learning following a wildlife tourism experience," *Environ. Educ. Res.*, vol. 17, no. 3, pp. 307–328, 2011, <https://doi.org/10.1080/13504622.2010.540644>
- [54] C. Tisdell and C. Wilson, "Perceived impacts of ecotourism on environmental learning and conservation: Turtle watching as a case study," *Environ. Dev. Sustain.*, vol. 7, no. 3, pp. 291–302, 2005, <https://doi.org/10.1007/s10668-004-7619-6>