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RESEARCH ARTICLE

Analysis of Carrying Capacity for Tourism Destination in Tabanan Regency, Bali Province

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ABSTRACT

This study evaluates the tourism carrying capacity of Tabanan Regency using the Cifuentes model, which includes physical, real, and effective carrying capacity (PCC, RCC, and ECC). Data on visitor numbers, site areas, facility capacities, and ecological management parameters were analyzed across natural, cultural, and beach tourism sites. The results reveal that several destinations exhibit latent overtourism, indicated by RCC values falling below ECC, which signals ecological and management pressures. To address this, k-means clustering was applied to classify tourism sites into three area units with distinct characteristics and activity patterns. K-means cluster analysis was used to group tourist attractions into three tourism area units (SKW) in Tabanan Regency with different characteristics. SKW 1: High PCC and ECC carrying capacity, a significant number of tourists, but far from the district capital. SKW 2: Low PCC, RCC, and ECC, a small number of tourists, and a moderate distance from the district capital. SKW 3: Highest PCC, RCC, and RCC, located closest to the district capital. Based on these findings, management actions such as visitor limits and infrastructure improvements are recommended for sites with RCC below ECC. These measures can guide policymakers toward sustainable tourism planning, minimizing environmental impacts while enhancing visitor experiences.

Introduction

Tourism serves as the primary economic sector in Tabanan Regency, Bali, renowned for its natural and cultural attractions [1]. Between 2021 and 2022, the number of tourists surged dramatically, reaching 1,380,480 visitors [2]. However, the main challenge concerning tourism in Tabanan Regency is the high concentration of tourists at several popular sites, leading to potential overtourism. This phenomenon poses a threat to environmental sustainability and could diminish the overall quality of the tourist experience [3].

The rapid growth of tourism raises concerns about carrying capacity, as excessive visitor influx can lead to overtourism, straining infrastructure and harming the environment. Vourdoubas [4] found that overtourism in Crete, Greece, caused environmental degradation and disrupted the local social structure, posing a threat to the sustainability and stability of the tourism industry. These findings highlight the urgent need for effective mitigation policies.

Evaluating a tourism destination’s carrying capacity assists in keeping it sustainable. The carrying capacity index facilitates managing tourist numbers, balancing tourism development with the environment, and ensuring the destination remains sustainable. It determines the maximum number of tourists a destination can handle without harming the environment or reducing the quality of the tourist experience [5].

Strategic approaches to sustainable tourism can mitigate the negative impacts of over-tourism [6]. Sustainable tourism is crucial in regional planning and destination management due to the challenges of balancing economic, social, and environmental interests. Pantic et al. [7] state that sustainable tourism aims

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to meet current needs without compromising future resource capabilities. It emphasizes natural resource conservation, maintaining local culture and customs, and transitioning from mass tourism to ensure authenticity and sustainability in tourism development.

This research will focus on developing tourism in Tabanan Regency, Bali, with three types: beach, nature, and cultural tourism. It will use carrying capacity to determine how many tourists each area can handle and then make policy recommendations for developing these tourism destinations using Tourism Area Units (TAU). TAU are effective strategies for responsibly managing tourism visits, balancing economic benefits, environmental sustainability, and local community welfare. TAU is a spatial approach that determines land use and group tourism activities within an area to achieve measurable sustainability goals. TAU directs tourism activities to areas aligned with the area's potential and characteristics, allowing for structured, efficient, and sustainable management. Additionally, TAU supports implementation policy considering environmental carrying capacity, resource limitations, and local cultural values.

This research combines different approaches and focuses on a specific area. It uses carrying capacity principles by evaluating physical, real, and effective carrying capacities to assess how well the environment can support tourism. The carrying capacity indices were also utilized to develop a typology of tourist destinations named the TAU to construct policy recommendations for sustainable tourism development. The research aims to provide new insights and essential contributions to sustainable tourism in Tabanan Regency, Bali.

Materials and Methods

Study Area

This research was conducted at 30 tourism sites (nine natural, fourteen beaches, and seven cultural), which were selected based on their official designation as tourism destinations by the Tabanan Regency Government and their visitor significance. These sites represent the majority of formally recognized tourist attractions in Tabanan, making them a representative sample of the regency's tourism profile rather than a random selection. They reflect Tabanan's natural wealth and cultural heritage and offer diverse experiences [8]. According to Tabanan Regency Regulation [9], tourism sites are categorized into beach, natural, and cultural types. The study area of the beach site category includes Bebali, Bulungdayu, Soka, and Bonian Beaches in Selemadeg; Kelating and Pasut Beaches in Kerambitan; Nyanyi and Kedungu Beaches in Kediri; Yeh Gangga Beach in Tabanan; Batulumbang, Suwan Ngaluh, and Lalanglinggah Beaches in West Selemadeg; and Beraban and Kelacung Beaches in East Selemadeg. Figure 1 presents the spatial distribution of beach tourism sites in Tabanan Regency.

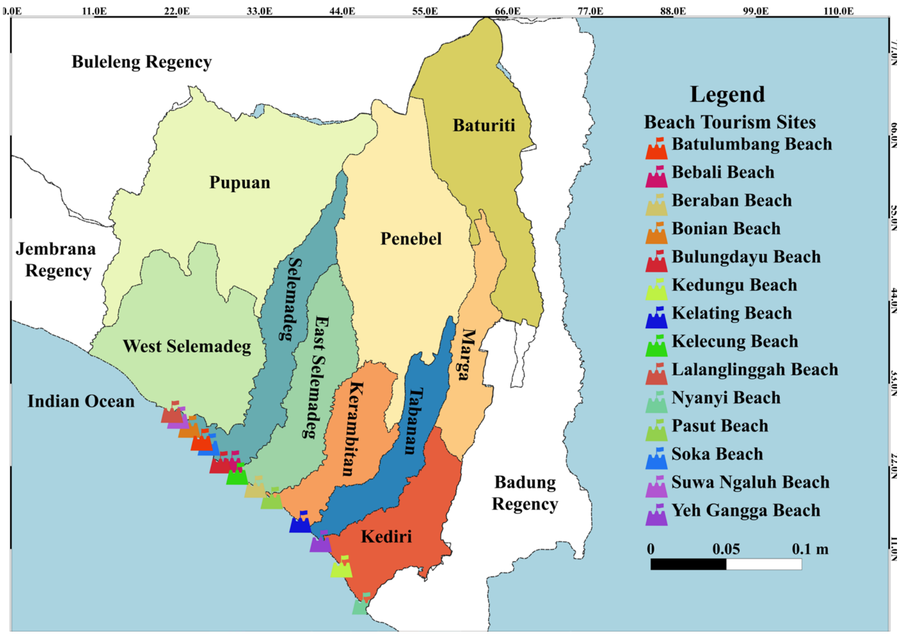

Figure 1. The map illustrates the spatial distribution of beach tourism sites in the study area, highlighting their geographic locations and clustering patterns.

Natural tourism sites in Tabanan Regency include Sarinbuana in Selemadeg; Eka Raya Botanical Garden, Yeh Panes, and Angseri Bamboo Forest in Baturiti; Jatiluwih Area, Yeh Panes Penatahan, and Yeh Panes Belulang in Penebel; Alas Kedaton in Marga; and Mekori Forest Area, Waterfall, and Pujungan Plantation in Pupuan. These sites are located within a predominantly mountainous area characterized by volcanic soils, terraced rice fields, tropical forests, and numerous natural springs. The region's cool climate and high biodiversity support activities such as trekking, agroforestry, and ecotourism. Socio-culturally, the area is strongly influenced by Balinese Hindu traditions, evident in temple sites, community-based management of tourism, and the subak irrigation system recognized by UNESCO. Figure 2 presents the spatial distribution of these natural tourism sites. Cultural tourism sites include Puri Anyar and Puri Gede Kerambitan in Kerambitan; Tanah Lot and Subak Museums in Kediri; Ulun Danu Beratan in Baturiti; Taman Pujaan Bangsa Margarana in Marga; and Areal Batukaru in Penebel. Figure 3 presents the distribution of these cultural tourism sites.

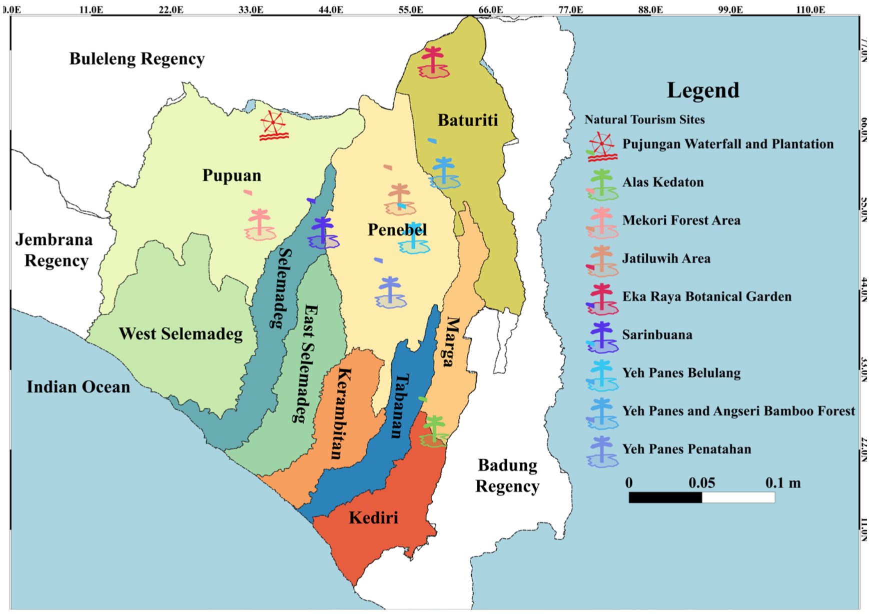

Figure 2. The map illustrates the spatial distribution of natural tourism sites in the study area, highlighting their geographic locations and clustering patterns.

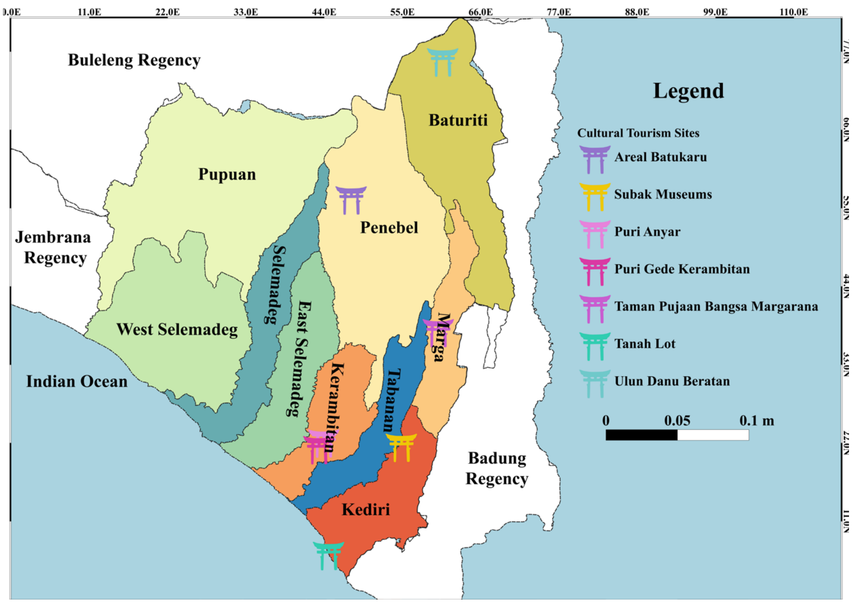

Figure 3. The map illustrates the spatial distribution of cultural tourism sites in the study area, highlighting their geographic locations and clustering patterns.

Data Collection

This research used primary data from surveys and questionnaires and secondary data from literature and agency documents. The tourism carrying capacity index of the destinations was calculated using data on rainfall, wind speed, slope, number of religious ceremonies, and employee numbers. The TAU method and secondary data from the Tourism Master Plan were used to generate recommendations for development policies.

Data Analysis

This research stage involved multiple analyses to achieve the objectives. First, the tourism carrying capacity index (TCCI) of tourism sites in Tabanan Regency was determined using physical carrying capacity (PCC), real carrying capacity (RCC), and effective carrying capacity (ECC) methods. These methods are superior as they consider physical, environmental, and operational factors affecting tourism capacity, providing a comprehensive analysis for sustainability and quality of tourism experience [10]. According to Prokopiou et al. [11] PCC, RCC, and ECC effectively identify the maximum number of tourists to minimize ecological impact and support sustainable tourism.

To calculate the TCCI, primary data such as the number of tourists, site area, slope, rainfall, wind speed, availability of facilities, and employee capacity were collected through surveys and field observations. Secondary data, including historical tourism trends, religious ceremony schedules, and planning documents from relevant agencies, were used to complement and validate the primary data. These combined datasets allowed for an accurate estimation of physical limits, operational constraints, and socio-cultural factors affecting each tourism site.

Additionally, recommendations for sustainable tourism development in Tabanan Regency were made using k-means clustering to classify sites based on their carrying capacity characteristics. The analysis techniques used in this research are as follows.

Tourism Carrying Capacity Index

Tourism carrying capacity index aids in planning tourism destinations by setting optimal tourist limits and minimizing environmental impacts [12]. Cifuentes [13] explained the formula for calculating carrying capacity into three components: PCC, RCC, and ECC. Physical carrying capacity calculates the maximum of tourists accommodated daily, which is expressed in Equation (1), when limiting or correction factors (Cf) are considered, real carrying capacity is the maximum of tourists (Equation 2), and real carrying capacity (RCC) (Equation 3).

$$PCC = A \times \frac{1}{B} \times Rf \quad (1)$$

Where:

A = Area used for tourism (m^2).
B = Area a tourist needs to travel while still getting satisfaction (m^2).
Rf = Rotation factor (operational hours of tourist attractions at average length of visit).

A tourist requires 15 m^2 to travel and move freely with satisfaction [14].

$$RCC = PCC \times Cf_1 \times Cf_2 \times \ldots\ldots \times Cf_n \quad (2)$$

The correction factor (Cf) is derived from biophysical, environmental, and ecological variables. The formula for (Cf) is (3):

$$Cfn = 1 - \left(\frac{Mn}{Mt}\right) \quad (3)$$

Where:

Mn = Real condition on the calculated fn variable.

Mt = Maximum limit on the fn variable.

The research calculates the tourism carrying capacity index for nature, beach, and cultural tourism sites. Correction factors (Cf) for beach tourism sites include rainfall estimated based on the Schmidt & Ferguson index and wind speed [15]. For nature tourism sites, correction factors are rainfall and slope (Decree of the Minister of Agriculture No. 837/KPTS/UM/11/1980 on Criteria and Procedures for Designating Protected Forests). For cultural tourism sites, correction factors include rainfall and the number of temple ceremonies (Balinese calendar), as ceremonies often increase tourist visits, risking over-tourism. Effective carrying capacity is the maximum of tourists that can be optimally served at a tourism site, considering human resource capacities is calculate using Equation 4. Management capacity (MC) is calculated based on the number of human resources at tourist sites (management officers) using the following formula (5).

$$ECC = RCC \times MC \quad (4)$$

Where:

MC = Management capacity.

$$MC = \frac{Rn}{Rt} \times 100\% \quad (5)$$

Where:
Rn = Number of officers actively working/day.
Rt = Number of available management officers.

Tourism carrying capacity index is crucial for planning sustainable tourism development [16]. It determines how many tourists a destination can accommodate without reducing experience quality and maintaining sustainability. According to Mapalad [17], tourism carrying capacity index defines the maximum number of tourists an area can support without environmental degradation or reduced visitor satisfaction. This concept helps identify optimal tourist numbers, minimizing negative environmental and social impacts [18]. Based on PCC, RCC, and ECC formulas, PCC is always greater than RCC, and RCC is greater than or equal to ECC (PCC > RCC and RCC ≥ ECC). This equation is the standard for determining the index carrying capacity of tourist attractions [13]. Over-tourism occurs when tourists exceed the site's effective management capacity regarding environmental, social, and management aspects. Scientifically, this is explained by the relationship between RCC and ECC. If RCC is smaller than ECC, the RCC limit is lower than what can be effectively managed. This RCC serves as a threshold in carrying capacity, reflecting environmental susceptibility. Low RCC indicates vulnerability to ecological damage such as erosion, pollution, and habitat degradation [19].

Recommendations for Sustainable Tourism Destination Development

Recommendations for developing sustainable tourism destinations in Tabanan Regency use k-means clustering methods. This method considers the distance of tourist attractions to the capital city, the number of tourists in April 2024, physical carrying capacity, real carrying capacity, and effective carrying capacity. The distance to the capital city is crucial for identifying infrastructure and facility needs based on accessibility. The number of tourists indicates popularity and pressure on sites; those with high tourist numbers need stricter management to ensure sustainability. Physical carrying capacity shows the physical limitations of attractions. Real carrying capacity reflects the environmental capacity to accommodate tourists sustainably. Effective carrying capacity provides insight into how management readiness affects visitor numbers.

The output of this analysis is a policy recommendation for developing sustainable tourism destinations in Tabanan Regency through the formation of Tourism Area Units (SKW). The k-means cluster method effectively recommends sustainable tourism development zoning by grouping similar tourist preferences and behaviors. This method categorizes tourist attractions based on characteristics like gender, age, and occupation [20]. It leads to targeted marketing strategies and improved tourism experiences, essential for sustainable tourism management. Previous research by Jauhari et al. [21] used K-means clustering to analyze tourist attractions based on visitor characteristics, enhancing the understanding of tourism zoning in Bangkalan. The tourism area unit created using this method helps in governance that aligns the interests of tourism stakeholders with environmental conservation and local community welfare [22].

Results

Tourism Carrying Capacity Index of Tourism Destinations in Tabanan Regency

A comprehensive evaluation of a destination's carrying capacity is conducted using the tourism carrying capacity, which covers physical, ecological, and managerial dimensions. This index quantitatively shows how well the destination can accommodate tourists without compromising sustainability. The calculation involves key variables such as area, duration of visit, number of supporting facilities, and management capacity, with the detailed data for each variable attached to ensure the accuracy of the calculation results. This approach allows for detailed identification of carrying capacity limits and provides a basis for necessary management actions. Table 1 presents the results of the tourism carrying capacity compared to the tourists visiting in April 2024.

Table 1. Comparison of tourists visiting with tourism carrying capacity index.

Tourism Destination	Tourism Sites	Tourists Visiting (Person/Day)	PCC (Person/Day)	RCC (Person/Day)	ECC (Person/Day)
Tourism Destination Selemadeg	Bebali Beach	4	234	200	77
	Bulungdayu Beach	15	3,197	2,726	1,055
	Soka Beach	50	234	200	140
	Bonian Beach	16	6,126	5,224	3,063
	Sarinbuana	22	445	165	146
Tourism Destination Kerambitan	Kelating Beach	45	7,734	6,596	3,310
	Pasut Beach	29	3,459	2,950	2,552
	Puri Anyar	10	2,400	1,917	792
	Puri Gede Kerambitan	10	4,800	3,211	2,400
Tourism Destination Kediri	Nyanyi Beach	26	5,794	4,941	3,476
	Kedungu Beach	39	2,789	2,379	1,673
	Subak Museum**	0	859	456*	537
	Tanah Lot	3,006	79,103	63,199*	75,939
Tourism Destination Baturiti	Eka Raya Botanical Garden	771	388,455	144,350*	369,032
	Ulun Danu Beratan	962	162,000	129.428	64,800
	Yeh Panes dan Bambo Forest Angseri	24	5,946	2,210*	3,924
Tourism Destination Penebel	Jatiluwih Area	725	69,174	12,853*	61,564
	Yeh Panes Penatahan	38	29,970	16,705	14,985
	Yeh Panes Belulang	19	999	557	330
	Areal Batukaru	50	4,905	683*	4,610
Tourism Destination Tabanan	Yeh Gangga Beach	100	18,392	15,685	6,069
Tourism Destination Marga	Alas Kedaton	72	600,000	334,440*	375,000
	Taman Pujaan Bangsa Margarana	21	22,661	18,105*	20,621
Tourism Destination Pupuan	Mekori Forest Area	80	42,000	15,607*	21,840
	Pujungan Waterfall and Plantation	10	10,264	1,907*	10,264
Tourism Destination West Selemadeg	Batulumbang Beach	35	1,515	1,292	500
	Suwan Ngaluh Beach	27	1,229	1,048	811
	Lalalinggah Beach	28	4,069	3,470	1,742
Tourism Destination East Selemadeg	Beraban Beach	36	13,065	11,142	6,532
	Kelecung Beach	19	5,455	4,652	3,600

Information: *Tourism sites experience latent overtourism, ** Temporarily closed due to renovations.

Table 1 shows that natural tourism sites such as Eka Raya Botanical Garden, Yeh Panes and Angseri Bamboo Forest, Jatiluwih Area, Alas Kedaton, Mekori Forest Area, and Pujungan Waterfall and Plantation have a lower real carrying capacity (RCC) compared to the effective carrying capacity (ECC). The same results are seen in cultural tourism sites like Subak Museum, Tanah Lot, Taman Pujaan Bangsa Margarana, and Batukaru Area. This indicates that ten out of thirty tourist attractions in Tabanan Regency are experiencing latent overtourism.

Recommendations for Sustainable Tourism Destination Development

Recommendations for developing tourism destinations in Tabanan Regency are organized as Tourism Area Units (SKW), identified through k-means cluster. The Tourism Area Unit in Tabanan Regency was created by combining tourist attractions, considering factors such as distance to the center of Tabanan Regency, tourists in April 2024, PCC, RCC, and ECC. This unit aims to reduce disparities in tourism benefits, promote sustainable growth, and positively impact the economy and community welfare. The results of the k-means cluster were used to form Tourism Area Units (SKW) in Tabanan Regency, which serve as the basis for recommending sustainable tourism development, are shown in Figure 4.

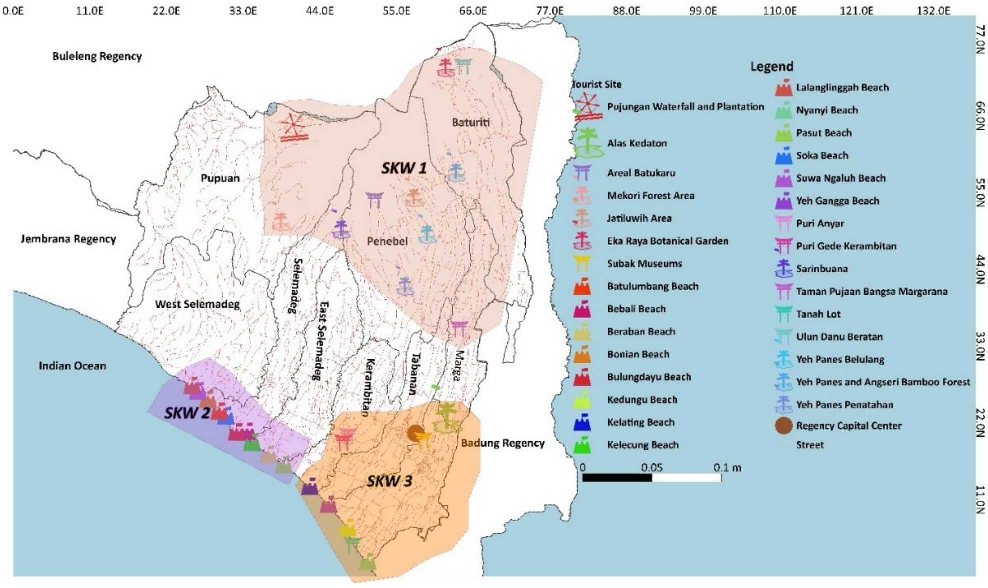

Figure 4. The map of Tourism Area Units in Tabanan Regency, created using k-means cluster, divides the region into three units: SKW 1, SKW 2, and SKW 3. Each unit reflects tourism potential based on location and tourism site type. This analysis offers insights into targeted and sustainable tourism management.

Figure 4 shows that the Tourism Area Unit in Tabanan Regency forms three clusters. These clusters are determined through a hierarchical analysis, starting with variable weights using auto-weighting. These weights group areas identify clusters with similar characteristics. Hierarchical analysis helps find the optimal number of clusters for tourism development [23]. The clustering results are then validated using the k-means clustering approach to ensure accuracy.

Each of the three tourism area units has distinct characteristics. These characteristics are formed using k-means clustering with GeoDa software. Unlike previous studies, this research applies the k-means clustering method specifically to assess the tourism carrying capacity and socio-environmental attributes of sites in Tabanan Regency. This original application enables a more evidence-based identification of tourism development priorities and supports the formulation of sustainable tourism strategies in the region. According to Azrahwati et al. [24], the k-means method groups data based on the average value of each variable in its group; however, in this study, the approach is adapted to cluster tourism area units, making it directly relevant to sustainable tourism planning in Tabanan Regency. Table 2 shows the characteristics of tourism area units in Tabanan Regency for sustainable tourism development.

Table 2. Shows the k-means cluster calculation results for forming tourism area units in Tabanan Regency. The cluster centers are based on several variables: PCC, RCC, ECC, number of tourists, and distance to the district center. Each cluster (SKW 1, SKW 2, SKW 3) represents areas with distinct characteristic patterns, providing a basis for strategic tourism planning and management.

Cluster	PCC (people)	RCC (people)	ECC (people)	Total Visitors	Distance to P
C1	66,983.5	31,142.7	52,010.5	247,455	26.27
C2	3,858.3	3,290.4	2,007.2	25.9	21.8
C3	80,207.9	48,091.6	52,132.9	367,556	9.3

Table 2 shows the k-means clustering results for forming tourism area units in Tabanan Regency based on five key variables: physical carrying capacity (PCC), real carrying capacity (RCC), effective carrying capacity (ECC), number of tourists, and distance to the district center. Cluster 1 is characterized by relatively high PCC, RCC, and ECC values (66,983.5; 31,142.7; and 52,010.5 people, respectively) with a moderate number of tourists (247,455 visitors) at an average distance of 26.27 km from the district center. This suggests that Cluster 1 comprises large-capacity tourism sites with strong infrastructure but located farther from the district center, which may affect accessibility. Cluster 2 shows very low PCC, RCC, and ECC values (3,858.3; 3,290.4; and 2,007.2 people, respectively) with the smallest number of tourists (25.9 visitors) at a moderate distance of 21.8 km. This indicates that Cluster 2 contains small-scale tourism sites with limited physical and operational capacity, requiring infrastructure and management support to increase competitiveness and sustainability. In contrast, Cluster 3 has the highest PCC, RCC, and ECC values (80,207.9; 48,091.6; and 52,132.9 people, respectively) and the largest number of tourists (367,556 visitors) at the closest distance to the district center (9.3 km), reflecting areas with the most intensive tourism activity, high accessibility, and potential pressure on natural and socio-cultural resources.

Each variable strongly influences the findings: PCC reflects the maximum physical capacity of the site based on available space; RCC adjusts this by considering environmental and regulatory constraints such as religious ceremonies or climate; ECC incorporates management capacity, including employees and facilities [25]. The number of tourists shows actual demand and pressure on the destination, while distance to the district center influences accessibility, transportation costs, and the potential spillover of tourism benefits [26]. By integrating these indicators, the k-means clustering produces tourism area units (SKW 1, SKW 2, SKW 3) with distinct characteristics, offering evidence-based insights for strategic tourism planning and sustainable resource management in Tabanan Regency.

Discussion

Tourism Carrying Capacity Index of Tourism Destinations in Tabanan Regency

The tourism carrying capacity index is crucial for managing tourist attractions, as it determines the maximum number of tourists that support sustainable tourism. Evaluating this index helps identify over-tourism and latent over-tourism [11], making it a strategic tool for balancing tourism sustainability, tourist needs, industry players, and the environment. According to Yusoh et al. [25], knowing the maximum number of tourists allows destinations to gain economic benefits while sustaining natural and cultural resources. According to Candia et al. [26], the tourism carrying capacity index can identify both over-tourism and latent over-tourism in tourism site development.

Over-tourism occurs when the number of tourists significantly exceeds the carrying capacity of a site, resulting in observable and often irreversible negative impacts on the environment, local culture, and infrastructure. This situation typically manifests as overcrowding, heavy pressure on natural resources, increased waste, traffic congestion, and disruption to local communities and traditional practices [14]. For example, a high tourist density can damage sensitive ecosystems, degrade heritage sites, and increase infrastructure maintenance costs.

In contrast, latent over-tourism represents an earlier stage, where tourism numbers approach or slightly exceed the real carrying capacity. However, the negative impacts are still emerging and may not yet be visible to the public. This stage is often indicated by environmental stress markers such as soil erosion, minor waste accumulation, or reduced water quality, as well as social tensions like disruption during religious ceremonies. Identifying latent over-tourism allows local authorities and site managers to intervene early before damage becomes severe [27].

The analysis of the tourism carrying capacity index for destinations in Tabanan Regency illustrates these concepts. Ten out of thirty tourism sites are at risk of latent over-tourism, as indicated by lower RCC values compared to ECC. This reflects the impact of limiting factors included in RCC calculations, such as rainfall and slope for natural attractions, and religious ceremonies for cultural attractions. Sites such as Eka Raya Botanical Garden, Yeh Panes, Angseri Bamboo Forest, Jatiluwih Area, Alas Kedaton, Mekori Forest Area, Waterfall, and Pujungan Plantation have slopes between 15–40%, which increases the risks of landslides, soil erosion, and other environmental damage. By setting maximum tourist limits to ensure visitor safety and ecological stability, RCC values are intentionally kept lower than ECC [28]. According to Skiniti et al. [14], this approach allows tourism activities to remain safe and sustainable while preventing long-term damage to infrastructure and natural landscapes [29].

Cultural tourism sites like Tanah Lot, Taman Pujaan Bangsa Margarana, the Subak Museum, and the Batukaru Area also show lower RCC than ECC. This difference results from correction factors including rainfall and the frequency of religious ceremonies at temple sites. According to Munshi et al. [30] and Iftikhar et al. [31], religious ceremonies can attract more tourists, necessitating effective visitor management to avoid cultural disruption. Hindu ceremonies often require significant time and space, and uncontrolled tourist presence during these ceremonies can interfere with sacred processions and diminish the quality of worship. Therefore, tourist limits are imposed to keep RCC values below ECC. According to Yusoh et al. [25] and Joseph et al. [32], applying the RCC concept in the tourism carrying capacity index helps prevent overcrowding during religious ceremonies, preserve cultural values, and ensure sustainable tourism.

By clearly distinguishing over-tourism from latent over-tourism and understanding their respective impacts on the environment, culture, and infrastructure, local governments and tourism managers in Tabanan Regency can implement proactive strategies. These include early-warning systems, visitor quotas, and infrastructure upgrades tailored to each tourism site's carrying capacity profile, thereby maintaining both sustainability and community well-being.

Recommendations for Sustainable Tourism Destination Development

Tourists in Tabanan Regency tend to visit popular attractions. At the same time, lesser-known sites with beautiful panoramas and rich cultural and historical stories remain under-visited despite their proximity to well-known spots. Observations indicate that local government promotion focuses mainly on already popular attractions, neglecting those with potential for development.

Based on this analysis, recommendations for developing tourism destinations in Tabanan Regency were made in the form of Tourism Area Units (SKW) using the k-means clustering method. These recommendations aim to advance the regional tourism sector by combining various existing potentials to increase tourist visits [33]. According to Liu et al. [34], understanding tourism's potential to increase visits is essential for sustainable and beneficial development. Tourism development should not only focus on the outcomes but also consider the process for long-term sustainability.

The k-means cluster analysis identified three main clusters (Figure 4), reflecting the unique characteristics of each tourism area unit in Tabanan Regency (Table 2), SKW 1: High physical and effective carrying capacity, significant tourist numbers, but far from the capital. It requires a strategy for sustainable carrying capacity management. SKW 2: Low physical, real, and effective carrying capacity, few tourists, and a medium distance from the capital. New tourism products need to be developed because existing ones have low potential. SKW 3: The highest physical, real, and effective carrying capacity is closest to the capital. Strict carrying capacity management is needed to prevent environmental degradation.

Jauhari et al. [21] demonstrated that the k-means cluster method can group tourist attractions into high, medium, and low categories for sustainable tourism development. This classification facilitates targeted marketing strategies, optimizes tourism resource allocation, and aids in planning infrastructure development, ultimately enhancing the tourist experience. Table 3 presents recommendations for developing sustainable tourism destinations based on the characteristics of tourism area units.

Table 3. Recommendations for sustainable tourism destination development in Tabanan Regency, Bali Province.

Tourism Area Unit (TAU)	Variables	Analysis	Recommendations for Tourism Destination Development
Tourism Area Unit (TAU) 1	Location of Distribution of Tourism Destinations	Sarinbuana, Eka Raya Botanical Garden, Ulun Danu Beratan, Yeh Panes and Angseri Bamboo Forest, Jatiluwih Area, Yeh Panes Penatahan, Yeh Panes Belulang, Batukaru Area, Taman Pujaan Margarana, Mekori Forest Area, and Pujungan Waterfall and Plantation.	The distance between tourist sites the center of the capital is 26.27 km. These sites include natural and cultural attractions. Creating integrated tourist routes can facilitate movement between sites without adding environmental burdens. Educating tourists on environmental preservation through information boards and guides is crucial. Simkova et al. [35] highlights that tourist education is vital for sustainable tourism as it raises awareness about their responsibility to protect the environment at tourist sites. Using GIS (Geographic Information System) technology to monitor tourist visit patterns and real-time density at attractions can aid sustainable tourism development [33].
	Total Physical Carrying Capacity	736,819 Person/Day	
	Total Real Carrying Capacity	342,570 Person/Day	
	Total Effective Carrying Capacity	572,116 Person/Day	
	Tourists Visiting	2,722 Person/Day	
	Distance to Tabanan Regency Center	26.27 KM	
Tourism Area Unit	Location of Distribution of	Bebali Beach, Bulundayu Beach, Soka Beach, Bonian Beach, Pasut Beach,	SKW 2 consists of beach tourism sites. Therefore, waste management is crucial. For

Tourism Area Unit (TAU)	Variables	Analysis	Recommendations for Tourism Destination Development
(TAU) 2	Tourism Destinations	Batulumbang Beach, Suwa Ngaluh Beach, Lalalinggah Beach, Beraban Beach, and Kelecung Beach.	example, providing organic and non-organic waste bins and building liquid waste processing infrastructure to prevent seawater pollution will ensure the sustainability of beach tourism sites in Tabanan Regency. Tourist visits to beach sites in Tabanan Regency remain low. To increase visits, managers and stakeholders diversify tourism products, such as organizing local festivals and promoting eco-friendly water sports, such as paddleboarding, beach yoga, and landscape photography competitions. Set indicators like coastal erosion levels, water quality, and waste amount to evaluate sustainable beach tourism sites. Lopez-Arquillo et al. [36] suggest that a data-based approach supports effective management strategies to sustain beach tourism sites.
	Total Physical Carrying Capacity	38,583 Person/Day	
	Total Real Carrying Capacity	32,904 Person/Day	
	Total Effective Carrying Capacity	20,072 Person/Day	
	Tourists Visiting	259 Person/Day	
	Distance to Tabanan Regency Center	21.8 KM	
Tourism Area Unit (TAU) 3	Location of Distribution of Tourism Destinations	Kelating Beach, Puri Anyar, Puri Gede Kerambitan, Nyanyi Beach, Kedungu Beach, Subak Museum, Tanah Lot, Yeh Gangga Beach, and Alas Kedaton.	SKW 3 has a lower RCC than ECC, indicating the area is nearing or has exceeded its environmental carrying capacity. Despite theoretical capacity (ECC) suggesting room for more tourists, this highlights challenges in balancing tourism growth and environmental sustainability. Implementing a restoration program can address this issue. Implement a reservation system to manage tourist visiting hours and prevent overcrowding at peak times. SKW 3 includes Alas Kedaton, a natural tourism site with a unique population of monkeys. Preserving flora and fauna is crucial to protect their habitat.
	Total Physical Carrying Capacity	721,871 Person/Day	
	Total Real Carrying Capacity	432,825 Person/Day	
	Total Effective Carrying Capacity	469,196 Person/Day	
	Tourists Visiting	3,308 Person/Day	
	Distance to Tabanan Regency Center	9.3 KM	

Conclusions

Index carrying capacity using Physical Carrying Capacity (PCC), Real Carrying Capacity (RCC), and Effective Carrying Capacity (ECC) identified ten tourism sites experiencing latent overtourism, where the RCC value was lower than the ECC. Furthermore, k-means cluster analysis was used to group tourist attractions into three tourism area units (SKW) in Tabanan Regency with different characteristics. SKW 1: High PCC and ECC carrying capacity, a significant number of tourists, but far from the district capital. SKW 2: Low PCC, RCC, and ECC, a small number of tourists, and a moderate distance from the district capital. SKW 3: Highest PCC, RCC and RCC, located closest to the district capital. These results form the basis for recommendations on managing and developing tourism sites sustainably.

Author Contributions

FSP: Conceptualization, Methodology, Writing-Editing; **WDA**: Writing-Review & Editing, Supervision; **DRP**: Writing-Review & Editing, Supervision.

AI Writing Statement

During the preparation of this work, the author used ChatGPT and Grammarly to translate, correct grammar, and clarify narratives. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the publication’s content.

Conflicts of Interest

There are no conflicts to declare

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